# Adapting to the Future Storm and Ice Regime in the Great Lakes

# Stream 2 Report

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*Great Lakes Ice Cover March 25, 2019 from the MODIS Satellite*

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# 1.0 INTRODUCTION

This report summarizes the Stream 2 activities and outcomes from the study entitled "Adapting to the Future Storm and Ice Regime in the Great Lakes", including the results from four case studies focused on climate change adaptation planning. As background, the Stream 1 report (Zuzek Inc., 2019) presented the findings on the projected impacts of climate change on future air and lake temperatures, ice cover trends and future conditions, synoptic-scale storms patterns, and storm frequency and storm intensity. The investigation focused on Lake Ontario and Lake Erie, and the findings are not necessarily represented of future trends or outcomes for the upper lakes (Superior, Michigan-Huron, and St. Clair). Refer to Figure 1.1 for a map of the Great Lakes watershed.

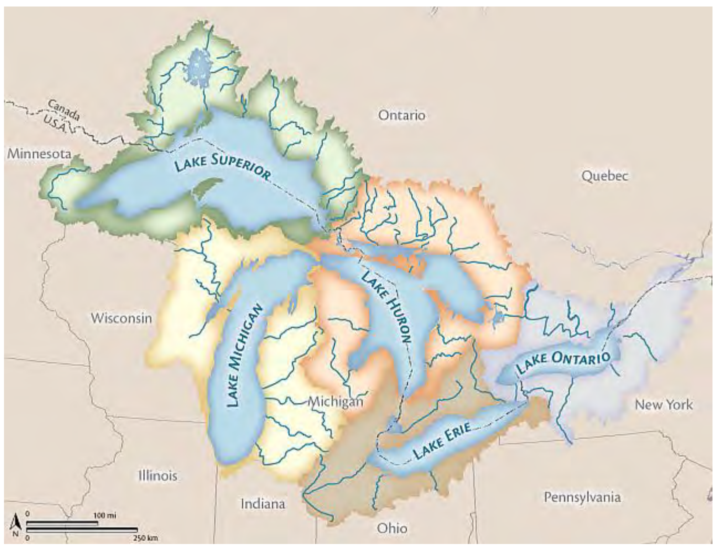


**Figure 1.1 Map of the Great Lakes Watershed**

## 1.1 Overview of the Stream 1 Findings

The key findings from Stream 1 were presented in Zuzek Inc. (2019) and the technical appendices. They are summarized below for reference:

- Winter temperatures are projected to be 5 to 7 degrees warmer in Southern Ontario by late century for RCP8.5 (Bush and Lemmen, 2019).
- Based on output from five global climate models, no change in synoptic-scale weather patterns (storm type, region of origin, or storm track) are expected for the Great Lakes (RWDI. 2020).
- No statistically significant changes in sea-level pressure gradients were observed for synoptic-scale storms in the future climate model output, suggesting future storms will not be more intense (RWDI, 2020).
- Average lake levels are projected to be higher for Lakes Superior, Michigan-Huron, St. Clair, and Erie in the future (note: modelling not completed for Lake Ontario) for RCP4.5

and RCP8.5 and wet periods due to above average precipitation may result in lake levels higher than the records recently established in 2019 and 2020 (ECCC Open File, 2020).

- On average, wave heights and storm surges are not projected to be higher in the future based on the climate model outputs for the RCP8.5 emission scenario (Baird, 2019).

- Air and water temperature increases will result in reductions in ice cover, potentially leading to ice-free conditions on Lake Erie and Lake Ontario by late century for RCP8.5 (RWDI, 2020; ECCC Open File, 2020).

- Ice-free lakes in the winter will increase the amount of wave energy reaching the shorelines of Lake Ontario and Lake Erie by up to 100% in some regions (Baird, 2019).

- The exposure and frequency of damaging storm events, especially in the winter, will increase leading to more flooding events, higher erosion rates, increased damage to coastal infrastructure, and negative impacts to coastal ecosystems such as barrier beach wetlands (Zuzek Inc., 2020a; Zuzek Inc., 2020b).

## 1.2 Introduction of Stream 2 Case Studies

The Stream 2 scope of work included two case studies on Lake Ontario, one of Lake Erie, and one with relevance to the entire Canadian basin of the Great Lakes, as follows:

- Case Study #1: White Paper on Coastal Hazard Management in the Great Lakes (Canadian shoreline).

- Case Study #2: Chatham-Kent Lake Erie Shoreline Study.

- Case Study #3: Credit Valley Conservation Authority Watershed and Nearshore Water Quality Modelling.

- Case Study #4: Screening Level Assessment of Climate Change Impacts on the Burlington Beach Master Plan.

# 2.0 CASE STUDY OUTCOMES

A brief overview of the four case studies and key findings is provided. The full technical reports are provided in Appendix A to D.

## 2.1 White Paper: Coastal Hazard Management in the Great Lakes

The Stream 1 findings were shared with the members of the Conservation Authority (CA) Coastal Working Group and used to inform an on-line survey for the regulatory staff of the CAs. In-person interviews were also used to identify current challenges with enforcing shoreline regulations and coastal management. Insights into the potential impacts of climate change on coastal hazard management was also provided by the CAs. Finally, barriers and opportunities for the integration of climate change adaptation strategies into CA hazard management was documented. Information on the use of climate change adaptation strategies by the individual CAs was also gathered and at present there has been very little work on coastal adaptation.

The findings of the engagement with CAs informed the development of a White Paper on coastal hazard management and preparing for a changing climate. The White Paper will be broadly circulated, including provincial ministries with responsibility for coastal development and hazard management (Ontario Ministry of Municipal Affairs and Housing, and the Ministry of Natural Resources and Forestry). The full White Paper is provided in Appendix A.

## 2.2 Chatham-Kent Lake Erie Shoreline Study

A comprehensive coastal vulnerability and risk assessment was completed the for the Chatham-Kent's Lake Erie shoreline with significant contributions from Municipal staff and the Lower Thames Valley Conservation Authority. Extensive public engagement was completed (9 meetings with over 1,000 attendees) to share the technical findings of projected climate change impacts on future lake levels and coastal hazards, plus co-develop community-scale adaptation concepts. Recommendations were provided for 10 shoreline reaches, including concepts that embrace the principals of avoid, accommodate, retreat, and protect. The case study findings were summarized in a detailed technical report, which is provided in Appendix B, and is now informing future steps to implements the adaptation strategies.

## 2.3 Credit Valley Conservation Authority Watershed and Nearshore Water Quality Modelling

Staff from the Credit Valley Conservation Authority participated in the background research for the White Paper and leveraged the Stream 1 technical findings for an ongoing watershed and nearshore water quality modelling study. The investigation is using a 3D hydrodynamic and water quality model to simulate climate change impacts on nearshore water quality. The findings will inform future management decisions on drinking water intakes and source water protection.

## 2.4 Screening Level Assessment of Climate Change Impacts on the Burlington Beach Master Plan Implementation

The Burlington Beach Master Plan was prepared with little consideration of coastal hazards and no integration of the projected impacts of climate change on important physical processes. A screening level assessment of climate change impacts on future lake levels, ice cover, flood risk and wave exposure was completed and shared with Halton Region, the City of Burlington, and the Halton Region Conservation Authority.  Zuzek Inc. was subsequently retained by Halton Region to complete a beach and dune restoration plan, building off the findings from the initial report completed for this study (provided in Appendix C of Zuzek Inc, 2020).

# 3.0 OVERALL STUDY FINDINGS

Section 3.0 summarizes the overall findings from the study Adapting to the Future Storm and Ice Regime in the Great Lakes.

## 3.1 Implications of the Projected Climate Change Impacts on Future Storms and Ice Cover

The implications of the projected climate change impacts from this study on future storms and ice cover in the Great Lakes Basin are summarized.

- Managing coastal hazards, protecting coastal infrastructure, and preserving coastal ecosystems is already incredibly challenging in the Great Lakes Basins, as the recent record high lake levels of 2017 and 2019 have shown. Climate change will make all of these challenges even harder.

- Mean lake levels are projected to increase and higher high levels are anticipated during periods of above average rainfall. Lake ice cover will continue to decrease, possibly leading to ice-free conditions on Lake Erie and Lake Ontario later this century. Less ice cover will result in more storms impacting our shoreline communities at higher lake levels. Erosion rates will accelerate, and the frequency and magnitude of coastal flooding will increase. The existence of barrier beach ecosystems and coastal wetlands will be threatened in some areas.

- The conditions in 2017 and 2019 were a prelude to even greater challenges in the future.

Further research on this topic, including the investigation of additional GCM and RCM outputs for difference emission scenarios is recommended.

## 3.2 Climate Change Adaptation Planning

The study findings related to climate change adaptation planning in the Great Lakes include:

- Prior to this study and recent technical studies by ECCC (Open File, 2020), there was very little information on climate change impacts for future storms, ice cover, and lake levels which resulted in an information deficit for climate change adaptation planning.

- Consequently, little adaptation planning has been occurring along Ontario's coastal regions of the Great Lakes. In short, government and practitioners didn't know what they are adapting to, given the implications of a non-stationary climate had yet to be investigated? And in some cases, dealing with historical extremes was already challenging institutional capacity to mitigate coastal risks.

- When projected future climate change extremes were considered in the studies, in some cases the cost to implement long-term adaptation strategies at the community scale was significantly higher than the value of the assets we were trying to protect. As a result, it will not be financially viable to protect all communities in the future.

- This economic reality, namely we can't afford climate change, raises serious questions about aspects of our policy and regulatory regime in Ontario for new and existing development. For example, our regulatory approach of allowing new homes on eroding bluff shorelines is planning to fail and creating problems no-one can afford to fix.

- Coastal planning practitioners must expand their toolbox, which historically defaulted to the construction of shoreline armouring to protect against coastal hazards. The case studies have shown the importance of embracing a wide spectrum of adaptation approaches, including avoid, accommodate, retreat, and protect. In locations where the exposure to coastal hazards is extremely high, such as Chatham-Kent, in some locations managed retreat or managed re-alignment are the only viable planning approaches for hazard mitigation and increasing resilience.

- As our climate continues to change and coastal hazard extremes increase, more emphasis on transformative adaptation approaches and nature-based solutions will be required. These are relatively new concepts in the Great Lakes Basin and the region would benefit greatly from the successful implementation of adaptation projects which embrace these principals.

## 3.3 Next Steps for Mainstreaming Climate Change Adaptation in the Great Lakes

The following next steps are recommended, based on the study findings and overall state of the coastal regions of the Great Lakes:

- As our climate continues to change, so to must our legislation, policies, and regulations. Climate stationarity is over and significant effort from all levels of government is needed to mainstream climate change science and adaptation planning into our coastal management activities.

- No single level of government can implement climate change adaptation strategies alone. Strong partnerships are required across government, as is dedicated funding to implement successful adaptation projects.

- Climate modeling is constantly evolving and the technical findings from this investigation should be followed by additional investigations using more emission scenarios, updated technical approaches, and expanded analysis to all of the Great Lakes.

- The most cost-effective adaptation strategy is 'avoid'. Unfortunately, our legislative policies over the last 30-years have focused on permitting new development as close to the waters edge as safely possible, assuming a stationary climate. We must now spend the next 30-years locating development, existing and new, as far back from the waters edge as possible.

- Moving forward, coastal communities must focus on building resilience to coastal hazards with proactive planning and zoning, recognizing some locations are simply not suitable for coastal development.  Embracing nature-based solutions is the road to a more resilience coastal future.

# REFERENCES


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Zuzek Inc. (2020b). Screening Level Assessment of Climate Change Impacts on the Burlington Beach Master Plan. Prepared for Halton Region.

# APPENDIX A

## WHITE PAPER

## Coastal Hazard Management in the Great Lakes

## A Call to Action to Prepare for a Changing Climate

# WHITE PAPER

## Coastal Hazard Management in the Great Lakes

## A Call to Action to Prepare for a Changing Climate

**April 28, 2020**

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## EXECUTIVE SUMMARY

An assumption fundamental to coastal management and land use planning in Ontario – the past is a reliable guide to the future – is being challenged due to human-caused climate change. The climate risk profile is evolving (e.g., greater fluctuations in lake levels, less ice cover, higher erosion rates); the projections are for more extremes, future increases in hazards, and expansion of the coastal hazard zone. This information has significant implications and needs to be effectively integrated or "mainstreamed" into planning, management and regulation of the coastal zone in the Great Lakes.

"Coastal Hazard Management in the Great Lakes Preparing for a Changing Climate: A Call to Action" is a White Paper that explores the challenge of climate change from the perspective of Conservation Authorities (CAs). Representatives from 21 CAs on the Coastal Working Group (CWG) provided their expertise and insights through an online survey, facilitated meetings, and review of the White Paper. This report is relevant to those with a role in coastal hazard regulation and management. The call to action identifies gaps and needs to address hazards associated with climate change in the Great Lakes coastal zone with an emphasis for alignment across all levels of government.

CWG members identified current shoreline regulation challenges such as outdated guidance, policies, regulations, legislation; gaps in data and knowledge; ongoing coastal development pressures; agency and community capacity; and limited multi-jurisdictional alignment and collaboration. Moreover, current shoreline regulation focuses almost exclusively on preventing new development in hazard-prone areas, and decisions, traditionally, have been made on a lot by-lot-basis resulting in fragmented development of the coast. As a result, many communities have lost the coastal zone buffer as well as their resilience. In a changing climate when the risk profile increases options become constrained. While guidance on how to address legacy development exposed to recurring flooding and erosion is limited, how to address evolving hazards due to climate change is an important gap.

The 2020 Provincial Policy Statement (PPS) increases the urgency and necessity of addressing climate change by rewording section 3.1.3 to, "*Planning authorities* ***<u>shall prepare for the impacts of a changing climate</u> that may increase the risk associated with natural hazards.***" This alters the Ontario planning context from being aware of and considering climate change impacts and natural hazard risks to incorporating climate change information into updating (and perhaps changing) the shoreline hazard regulation process and addressing the evolving risks through adaptation. This context supports setting the lot-by-lot approach within a broader, integrated coastal management perspective that considers proactive planning, management by littoral cells, nature-based solutions, and safeguarding heritage and ecosystem services.

Historically, climate change assessments of the coastal zone in Ontario have focused on projected changes in water levels of the Great Lakes. Water level variability will continue in the future and projected levels will extend beyond the historical range with new high and low extremes. However, new research identifies additional considerations - a projected reduction in winter ice cover leading to increased wave energy, higher erosion rates, and more winter flooding. This amplifies the erosion hazard with repercussions for projecting long-term recession rates and future erosion setbacks. Impacts to other key physical processes are unknown, including rates of longshore sediment transport, net transport direction, and evolution of depositional environments such as beaches. CA-CWG members identified these physical risks from climate change. Their greatest concerns were the potential for reactive responses (e.g., coastal hardening) to extreme hazard events and enhanced damages along the coast because of limited coordination and collaboration on adaptation between private landowners, CAs, municipalities and provincial and federal government agencies.

There is a “deficit” related to adaptation strategy development and implementation due limited guidance to support its development. CAs are at an early stage in implementing adaptation response strategies. Many have not undertaken coastal vulnerability and risk assessments or developed formal climate change adaptation strategies. The most common barriers to the capacity to act were resources - financial, staff and technical guidance. Collaboration was the greatest opportunity to advance climate change adaptation and reduce coastal hazard risk.

***Implementing shoreline regulation is already challenging; climate change will make it more difficult because of changes in coastal processes, the evolving risk profile and likely expansion of hazard lands***. ***This call to action highlights the need to manage the coastal zone, not just the shoreline, in light of a changing climate***. To protect Ontario’s residents and communities as well as economic activity, infrastructure, and the natural and cultural heritage from unacceptable coastal hazard risk, it is no longer sufficient to focus exclusively on regulating so new development is not located on hazard lands. Addressing climate change requires situating development regulation within ***a broader, proactive approach to natural resources and infrastructure management along the coast that considers social, economic, and ecological systems and has a more integrated, holistic, systems approach.*** Strategic actions that support addressing climate change include:

- ***Multi-agency collaboration to address climate change and coastal management challenges***
- ***Ongoing updates to guidelines and technical documents, including hazard extremes***
- ***Research and data collection on climate change relevant for coastal management***
- ***Updated hazard information, assessments, tools and guidance for coastal management practitioners in a changing climate***
- ***Engagement, collaboration, education, and outreach with the public and landowners***

While Conservation Authorities can and do efficiently regulate development on hazardous lands, proactive measures are needed now to ensure effective integrated coastal management in a changing climate. Immediate action to engage agencies and stakeholders in collaborative management, undertake research on climate change impacts, update technical guidelines to integrate climate change impacts, assess risks, and map updated hazards is critical to ensuring CA’s continue to make informed and valuable decisions on development in coastal areas. The future ecological health and resilience of coastal communities and ecosystems to climate change will depend on the path senior levels of government choose to follow. Our vision is all levels of government, ENGOs, and stakeholders working together to deal with this climate change challenge and enhance coastal resilience.

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# Coastal Hazard Management in the Great Lakes
# Preparing for a Changing Climate: A Call to Action

## 1.0 Introduction and Purpose

An assumption fundamental to coastal management and land use planning in Ontario – the past is a reliable guide to the future – is being challenged due to human-caused climate change. With a changing climate, it is anticipated that the climate risk profile will evolve. There will be more extremes and likely future increases in hazards related to increased water level variability, loss of ice cover, more winter storms impacting the coast, more intense precipitation events, higher erosion rates, and more frequent coastal and riverine flooding. This changing climate context has significant implications for planning, management and regulation of the coastal zone in the Great Lakes. It exacerbates existing coastal hazards and creates new hazards for consideration. This White Paper, utilizing Conservation Authority (CA) expert input, explores the challenge of climate change and how it can be mainstreamed into managing coastal hazards in the Great Lakes. Scale matters when dealing with a complex issue such as climate change and coastal management. It reveals the nature of impacts, the range of appropriate planning responses and level of action or implementation. Moreover, scale links to jurisdiction, mandate, and responsibilities and the capacity to respond. This White Paper is directed at informing those who have a role in coastal zone regulation and management by identifying the gaps in data, knowledge and capacity as well as articulating how activities, integrated and aligned across all levels of government, could address the call to action on climate change.

### 1.1 Coastal Management and Climate Change

Section 28(1) of the Conservation Authorities Act gives Conservation Authorities (authority) the power to make regulations to prohibit, regulate, or require permission for development if in their opinion the control of flooding, erosion, dynamic beaches or pollution or the conservation of land may be affected by the development. Ontario Regulation 97/04 (2011) was issued under the Conservation Authorities Act and describes the requirements and content for a regulation pertaining to hazardous lands. The limit of hazardous lands is defined as the furthest landward extent of the aggregate of:

1. The 100-year flood level, plus an allowance in metres, determined by the authority, for wave uprush and, if necessary, an allowance in metres, determined by the authority, for other water-related hazards, including ship-generated waves, ice piling and ice jamming,
2. The predicted long-term stable slope projected from the existing stable toe of the slope or from the predicted location of the toe of the slope as that location may have shifted as a result of shoreline erosion over a 100-year period,
3. Where a dynamic beach is associated with the waterfront lands, an allowance in metres inland, determined by the authority, to accommodate dynamic beach movement, and
4. An allowance in metres inland, determined by the authority, not to exceed 15 metres.

Currently, there is no mention of climate change or inclusion of the effects in the mapping of hazardous lands.

The Provincial Policy Statement (PPS) also provides guidance for shoreline planning in Ontario. A review of the 2005, 2014 and 2020 PPS, shows the evolution of climate change as an issue for planning in Ontario and frames the challenge ahead for all levels of government as they develop their adaptation responses to climate change.

In the 2005 PPS, climate was mentioned once in Section 1.1.3.2 related to,

> "[l]*and use patterns within settlement areas shall be based on: … 3. minimize negative impacts to air quality and climate change and promote energy efficiency in accordance with policy 1.8.*"

Treatment of climate change expanded significantly in the 2014 PPS which recognized adaptation and that efficient development and land use patterns promote,

> "*[s]trong, liveable and healthy communities, promote and enhance human health and social well-being, are economically and environmentally sound…*" but additionally, "… *are resilient to climate change*". Climate change is introduced in Protecting Public Health and Safety with a new Section 3.1.3 where, "*Planning authorities* ***shall consider the potential impacts of climate change*** ***that may increase the risk associated with natural hazards***" and throughout in other sections (e.g., infrastructure, stormwater management, watershed water resources).

The 2020 PPS increases the urgency and necessity of addressing climate change by rewording section 3.1.3 to,

> "*Planning authorities* ***shall prepare for the impacts of a changing climate*** ***that may increase the risk associated with natural hazards.***" It defines the impacts of a changing climate as "…*the potential for present and future consequences and opportunities from changes in weather patterns at local and regional levels including extreme weather events and increased climate variability*." The intent in the PPS is that, "[d]*evelopment shall be directed away from areas of natural or human-made hazards where there is an unacceptable risk to public health or safety or of property damage…,"* and in light of climate change more attention needs to be devoted to *"… and* ***not create new or aggravate existing hazards***" (PPS, 2014; 2020).

The wording "***shall prepare for the impacts of a changing climate***" in the 2020 PPS alters the Ontario planning context. It evolves from being aware of and considering climate change impacts and natural hazards risks to a directive to incorporate or "mainstream" climate change information into the shoreline hazard regulation process and prepare for emerging risks through adaptation. The report produced by Ontario's Special Advisor on Flooding also recommended addressing climate change by developing technical guides and assessing hazards (McNeil, 2020). There is uncertainty as to what to do; there are gaps in technical direction and limited resources to incorporate climate change into the planning/decision making context. Important documents for shoreline hazard regulation, including the Conservation Authorities Act, Guidelines for Developing Schedules in Regulated Areas (2005), and the Provincial Technical Guide for Great Lakes-St. Lawrence River Shorelines (MNR, 2001) do not mention climate change nor do they set out the context for how to consider the issue. There is limited technical guidance for the professional community on how to integrate climate change information into hazard assessment, regulation and mitigation processes. Foundational information such as time horizons for climate change scenario development, impact assessment methods, risk assessment approaches, data sources, and case studies for adaptation strategy development are needed. Elected officials, the public, property owners and developers need to be alerted to the evolving hazard risk due to a changing climate and the need for collaborating on adaptation strategy development and implementation.

### 1.2 Process for Developing the White Paper

The Coastal Working Group (CWG) with representatives from 21 Conservation Authorities provides a forum for discussing Great Lakes basin-wide coastal management issues. The members of the CWG provided their expertise and insights in the development of the White Paper content. The goal of the White Paper is:

- highlight the need for coastal management policy development in-light-of a changing climate system and evolving hazard risk, and
- illustrate the need for climate change guidance to determine coastal hazards and development of adaptation approaches coastal management in Ontario.

CWG members were engaged in the following manner to provide their input to the content presented here:

- An online survey of Climate Change Information Needs (November 2018). CA respondents provided an assessment of current regulatory and coastal management issues as well as future challenges related to climate change; state of climate change risk assessment; barriers to and opportunities for climate change adaptation; and information needs. The response was excellent (17 of 21 CAs).
- A facilitated Group Discussion (November 28, 2018) explored what the White Paper should address.
- An Interview Matrix (October 18, 2019) used four questions to elicit insights from participants (n=12) on climate change research and guidance needs; barriers and opportunities for integrating climate change impacts into regulatory work; gaps in CA mandates and how to enhance CA authority in light of climate change; and short-term and long-term adaptations for coastal flooding and erosion.
- Review of draft White Paper and facilitated discussion (February to March 2020) to finalize the document.

### 1.3 Outline of White Paper

The White Paper is organized in three main themes:

- the current context with respect to shoreline regulation and coastal management;
- the future implications of climate change for shoreline management and the need for adaptation; and
- a way forward for addressing climate change and adaptation in the coastal zone of the Great Lakes.

## 2.0 The Current Context: Shoreline Regulation and Management

In the mid-1980s, an extended period of high-water levels with widespread property and infrastructure damage in the Great Lakes resulted in improved shoreline planning and management in Ontario. What emerged were development policies and plans that focused on the assessment and mitigation of flood and erosion hazards directly along the Great Lakes shoreline (Lawrence, 1995, 1998).

CAs are authorized to regulate and manage development in hazard-prone areas along the shoreline incorporating knowledge of the built environment as well as the physical environment including coastline geomorphology, flooding, erosion (bluffs and beaches), and longshore drift. The Conservation Authorities Act (1946 OR RSO, 1990), Section 20(1) gives CAs the authority to develop programs to conserve, restore, develop, and manage natural resources. This gives them the mandate to develop Shoreline Management Plans (SMPs) and hazard mapping for erosion, flooding, and dynamic beaches. Municipalities also play an important role with shoreline development, since they are responsible for municipal zoning, by-laws, and Official Plans.

Current shoreline regulation focuses almost exclusively on preventing new development in hazard-prone areas since this is the emphasis of the Provincial Technical Guidelines. There is little guidance on how to deal with legacy development exposed to recurring flooding and erosion or evolving hazards due to climate change. Instead of a broad integrated coastal management perspective that considers proactive planning, management by littoral cells; nature-based solutions or safeguarding of heritage and environmental benefits, the focus is local and on individual development applications. Decisions are made on a lot by lot basis resulting in fragmented development of the shoreline and often reactive, engineered solutions to deal with hazards (e.g., shoreline armouring).

The cumulative effect of the Provincial Technical Guidelines, the PPS, Conservation Authorities Act, and other technical guidance has been a legacy of development along our coastlines that is as close as possible to the edge of the Great Lakes shoreline while theoretically mitigating flooding for the 100-year lake level and erosion hazards for the 100-year planning horizon. However, climate change has resulted in evolving and increasing hazard exposure, which reveals numerous limitations with this approach. For example, communities relinquish the coastal zone buffer and their resilience when development encroaches as close to the shoreline as possible. As the risk profile changes (e.g., rising lake levels, less ice cover, higher erosion rates) response options become constrained. CWG members identified current challenges related to management and regulation of the Great Lake shoreline in the online survey. They included: gaps in and limitations to policy, regulations and legislation; ongoing coastal development pressures; agency and community capacity; and limited multi-jurisdictional alignment and collaboration. See Box 1 for the detailed CA-identified list.

**Box 1 - Current issues and challenges for shoreline regulation and management**
(Source: CA CWG Climate Change Information Needs Survey 2018)

- The foundational shoreline management guidance document, "The Provincial Technical Guide," is outdated and needs updating
- Old and outdated data on coastal hazards (erosion rates, flood levels) and mapping of flood, erosion and dynamic beach setbacks
- Outdated shoreline management plans and limited funds to update
- Poor and outdated Municipal zoning
- A lack of qualified experts to prepare technical assessments for development applications
- Much existing (legacy) shoreline development is located on hazardous lands. Pressure continues for more development in these areas (e.g., rebuilds, infill, intensification processes)
- Negative impacts of shoreline armouring on coastal processes, ecosystems, and habitat
- Nature-based solutions cannot be considered when the majority of the shoreline is armoured/hardened
- Typical development relies on a lot-by-lot approach, rather than a broad regional, littoral cell- or physically-based integrated coastal plan for development
- CAs do not have authority to regulate unless there is a development application. CAs are reacting to Municipal zoning.

## 3.0 The Future: Climate Change Projections, Impacts, and Initiation of Adaptation

The climate system is transforming. Observed changes or trends in climate include an increase in air and water temperatures; greater lake level extremes; a reduction in lake ice cover extent, thickness and duration with an associated longer erosion season; and more intense precipitation events and a greater proportion of precipitation falling as rain instead of snow (Bush and Lemmen, 2019). With an evolving climate system there is recognition that action must be taken to address emerging impacts and risks through proactive adaptation needs assessment, strategy design, planning and implementation.

### 3.1 Historical and Future Projected Climate Drivers of Shoreline Hazards

Traditionally, most climate change assessments in Ontario have focused on projecting changes in water levels of the Great Lakes. The most recent research indicates that water level variability will continue in the future (F. Seglenieks, 2020 pers. com.) and projected high lake levels will extend beyond the historical range. This research by Environment and Climate Change Canada (ECCC) was based on Representative Concentration Pathway 4.5 and 8.5 (RCP4.5 and RCP8.5) with projections for mid and late century (i.e., 2050s and 2080s). It supports the results of earlier research on future Great Lakes water levels (IUGLS, 2012) which projected increased variability in water level extremes.

In 2019 new record all-time high static water levels were established on Lake Ontario, Lake Erie, and Lake St. Clair, which is consistent with the projected trends for the future. The impacts of the 2019 high water levels on Lake Ontario were recently evaluated for a Shoreline Management Plan (Zuzek Inc., 2020). The 100-year static water level on Lake Ontario (non-storm) increased by 0.18 m (to 75.84 m International Great Lakes Datum of 1985 (IGLD85)) when compared to the historical data published by the Ministry of Natural Resources and Forestry (MNR, 1989). It should be noted this analysis also factored in the role of the International Joint Commission (IJC) Lake Ontario – St. Lawrence River Plan 2014.

When this new 100-year static Lake Ontario water level was integrated into a joint probability analysis with measured storm surges (Zuzek Inc., 2020), the new 100-year flood hazard level for the Toronto gauge increased by 0.27 m to 76.01 m (IGLD85) when compared to the old published MNR (1989) level of 75.74 m IGLD85. Integrating this evolving (non-stationary) information into hazard management approaches in Ontario is a critical requirement.

There have been fewer assessments of the projected effects of climate change on winds, waves, storm surge. However, they are important drivers that alter coastal processes and affect flooding and erosion hazard risk which influence coastal planning, development, and regulation (Mortsch, 2016). A recent assessment for the Great Lakes explored the influence of climate change on storm tracks, storm frequency, wind speed, and pressure gradients to model wave and storm surge response (RWDI, 2020; Baird, 2020). A limited number of global climate model (GCM) outputs forced by RCP8.5 were used. A commonly cited impact of climate change is the projected increase in intensity and duration of storms. However, no discernable difference in historical and future storm tracks and storm intensity emerged from the analysis by RWDI (2020) for the large-scale, synoptic cyclones evaluated (not the heavy precipitation-generating convective storms).

The results from this pioneering work should be verified with further technical studies. This includes storm assessment methodology and more storm analyses using additional GCM and regional climate model (RCM) output forced with a range of RCPs. Another noteworthy finding is the projected reduction in winter ice cover and associated increase in wave energy reaching the shoreline. This could lead to higher erosion rates and more frequent winter flooding events. For example, winter wave energy in the western basin of Lake Erie was projected to increase by 120% by late century (RCP8.5 scenario) by Baird (2020) if the lake becomes ice-free. This represents a projected amplification of erosion hazard with significant implications for the adoption of long-term recession rates for the Erosion Hazard Setback. Implications for other key physical processes, including rates of longshore sediment transport, net transport direction, and the evolution of sandy depositional environments (e.g., barrier beaches) are unknown.

These findings point to the critical importance of "mainstreaming" climate change into shoreline regulation and management. Incorporating information on the evolving climate system will ensure the recession rate used for the 100-year erosion hazard setback is reflective of future recession and the adopted 100-year flood level captures future extremes. There are also critical research needs to support this process and provide guidance to practitioners. Future climate change impacts of greatest concern for the CA-CWG in the online survey were related to the physical environment and human responses (see Box 2). The increasing physical risks included more extreme events, loss of ice cover enhancing erosion potential, expanded area of hazard lands, and more infrastructure, residences and people exposed to hazard risk. The greatest concern was the reactive human responses to future extreme hazard events such as hardening of the shoreline. Coordination and collaboration between landowners and hazards practitioners can decrease damages to neighboring properties and downdrift along the shoreline.

**Box 2. Future impacts of climate change relevant to CAs**
(Source: CA CWG Climate Change Information Needs Survey 2018)

- Extreme events and hazard risk increase:
    - Changes in ice cover, wind direction and speed, coastal processes, rain intensity, floods
    - Water level changes
    - Potential increase in frequency and intensity of future storm events
    - Heavy rain events that exceed the regional flood standard
- Shoreline hazard lands expand:
    - More existing development located in the hazard zone
    - Potential increase in property damage
    - Need to relocate buildings, infrastructure and associated costs
    - Failure of shoreline infrastructure and/or higher maintenance costs
- Erosion frequency, intensity, rates increase:
    - Accelerated loss of natural areas and features (e.g., bluff erosion, loss of shoreline riparian vegetation)
    - Increased demand for structural responses and expanded armoring of the shoreline
- Hazard maps and other coastal information for planning and regulation become obsolete
- Shoreline protection and hardening increases
- No guidance on how to assess climate change impacts on shorelines and modify shoreline protection construction

### 3.2 Initiating Adaptation to Climate Change Hazard Risks

CAs are at an early stage of developing climate change adaptation response strategies to address coastal issues. In designing adaptation strategies, the process consists of acquiring an understanding of the system vulnerabilities, the projected impacts, and the risks of greatest concern. In the 2018 CA CWG Climate Change Information Needs Survey, more than half of the respondents (8 of 15) indicated that their CA had not identified climate change risks while two respondents indicated other risks were identified but not those specific to coastal areas. For the remaining CAs, climate change risks were identified and incorporated to some degree in either flood and erosion risk assessments, flood control infrastructure and capacity, and shoreline hazard management plans.

There is a "deficit" related to adaptation strategy development and implementation. More than half of the respondents (10 of 16) to the 2018 Survey indicated their CA had not developed formal climate change adaptation strategies – the high-level strategic goals from which to develop detailed adaptation measures and planned implementation actions. For two CAs, an adaptation strategy was in development while one respondent indicated that a Climate Change Strategy had been developed but its implementation was opportunistic. Adaptations that were identified were directed at water control structures in wetlands, a project updating hazard lines for development decision making, stormwater management, and species-at-risk.

CWG members were asked to identify barriers to and opportunities for initiating adaptation (see Box 3). The most common barrier to act was resources - financial, staff and technical guidance. Collaboration was the greatest opportunity to use for addressing climate change and reducing shoreline hazard risk.

**Box 3 Barriers to and opportunities for adaptation identified by CWG members**
(Source: CA CWG Climate Change Information Needs Survey 2018)

**Barriers (n= 41):**

- Limited, incomplete technical resources:
    - Require studies, data development and mapping to inform adaptation policy development or to implement adaptation
    - Uncertainty in climate change projections and approaches to undertake assessments and design adaptation
- Limited financial resources
- Staff capacity and workload constraints
- Ongoing development pressures in hazardous areas
- Misinformation
- Difficult to gain "buy-in" from public, landowners, municipal staff, politicians for changes
- Private ownership of large portions of land/shoreline constrains agency-led integrated shoreline hazard planning and implementation
- Unclear or gaps in lines of authority or responsibility

**Opportunities (n= 37):**

- Studies, assessments (hazard, risk) and adaptation strategy development to advance knowledge and capacity. Chatham-Kent Lake Erie Shoreline Study (Zuzek Inc.) is a case study
- Collaboration between Municipalities, other CAs, Ministry of Natural Resources and Forestry (MNRF), other Provincial Ministries and Federal Departments with mandates for the coastal zones of the Great Lakes, CA CWG, user groups, consultants, business
    - Shared understanding of risk assessment and adaptation strategy development, lessons learned
    - Build support for implementation
- Shoreline management plans are a means of mainstreaming climate change information
- Implementation of the Lake Ontario Shoreline Management Plan (CLOCA, GRCA, LTCA) with a coastal reach perspective can be a case study
- Funding
- Education
- Emergency response plans can integrate climate change risk information and are a means to initiate adaptation
- Monitoring can be used to detect changes, assess performance of adaptations

## 4.0 A Call to Action: Coastal Management in the Great Lakes in a Changing Climate

In response to the record high lake levels in 1986, the Province of Ontario commenced development of the Great Lakes Technical Guide (MNR, 2001), which introduced the concept of hazardous lands to

Ontario and development setback regulations related to flooding, erosion, and dynamic beaches. The primary focus of regulations was to ensure new development was located landward of coastal hazards, such as flooding and erosion, and beaches were sufficiently protected from development to respond dynamically to rising and falling lake levels. The Technical Guide was first released in the early 1990s when shoreline regulations were the responsibility of the Ontario Ministry of Natural Resources. By the mid-1990s the Province had signed a Memorandum of Understanding (MOU) with Conservation Ontario to delegate the responsibility of implementing the natural hazards section of the PPS (Section 3.1) to local Conservation Authorities (TRCA, 2007).

By the mid-2000's updates to the Conservation Authorities Act, Section 28, were implemented to give Conservation Authorities the legislative authority to develop their own Generic Regulations for the 'Development, Interference with Wetlands, and Alterations to Shorelines and Watercourses'. A new document, Guidelines for Development Schedules in Regulated Areas (2005), was developed to provide technical guidance on how to map hazardous lands and regulate development.

Since the early 1990s, the planning and regulatory philosophy in the Great Lakes has been "direct new development away from hazardous lands" to protect buildings and infrastructure from flooding and erosion damages. Development setbacks were calculated and mapped for erosion, flooding and dynamic beaches and often summarized in Shoreline Management Plans. The 100-year planning horizon was the standard, but this could be reduced if shoreline protection structures were constructed at the water's edge. One of the earliest plans, the Report on Erosion, Fill, and Flood Line (Dillion, 1976) was prepared for the Essex Region Conservation Authority. Many of the original SMPs were developed around 1990 corresponding to the first release of the Technical Guide (Philpott, 1989; SSW, 1990; Sandwell, 1993).

Thirty years ago, the overall approach to hazard mitigation was innovative and the 100-year planning horizon for erosion hazards is still longer than the other jurisdictions in the Great Lakes (e.g., the US States). However, over time this management approach has facilitated development as close as possible to the lake, within the regulatory limits, and ultimately decreased the resilience of coastal communities since it failed to recognize the integrated nature of our Great Lakes shorelines. The shoreline protection that inevitably followed the coastal development disrupted natural physical processes such as the supply of new beach building material through natural background erosion rates and the movement of this sediment within littoral cells. In many locations, the dunes, beaches and barrier beaches were starved of sediment and stable shorelines switched to eroding systems (Baird, 2007; 2008; Zuzek Inc., 2018; 2020). In some locations erosion was exacerbated while in other areas deposition increased but the coastal system did not function as a balanced, integrated system. Decisions were made lot-by-lot, and 30-years later coastal resilience has decreased.

***Implementing shoreline regulation is already challenging. Climate change will make it more difficult because of the evolving risk profile and likely expansion of hazard lands***. Strategic actions that can address climate change include:

- ***A new, proactive approach to coastal zone regulation, planning and management is needed due to changing climate***. Climate change results in an evolving coastal hazard risk regime that broadens exposure and expands hazard lands. To protect Ontario's residents and communities from unacceptable coastal hazard risk, it is no longer sufficient to regulate so new development is not located on hazard lands. Addressing climate change requires situating development regulation within ***a broader approach to natural resources planning and management along the coast that considers social, economic, and ecological systems, natural and cultural heritage, and has a more integrated, holistic, systems approach.***

- ***Multi-agency collaboration to address climate change and coastal regulation and management challenges.*** No one agency can tackle the issue of climate change adaptation. Agencies have different mandates, roles and expertise to bring to bear on addressing coastal regulation and management issues. The CA mandate is primarily regulating hazards but that is only one aspect of coastal management; this presents a challenge. Additionally, CAs only regulate the front-end of development proposals (or re-development). There is limited regulatory authority when the erosion buffer is gone and homes become flood prone (i.e., located on hazardous lands). The Province plays an important role in governance of coastal management. It supports development of legislation and regulations, delegates authority, enhances guidance and technical support for implementation, and engages in co-management with CAs. Municipalities can develop strong by-lays and Official Plans (with links to SMPs). Federal agencies can provide research support and guidance to build capacity to integrate climate change into coastal regulation and management as well as stable ongoing funding to support climate change adaptation. Land use deliberations by municipal planning authorities and local councils need to equality consider technical advice on coastal hazards and risks to property owners as well as political input. There is limited guidance for Emergency managers that need to consider climate change.

- ***Ongoing updates to guidelines and technical documents and hazard information.*** Provincial shoreline planning and hazard guidelines, and supporting resources need to be living documents (e.g., Technical Guide, water level extremes, SMPs, Hazard Maps etc.). Many are currently out of date and do not reflect new science, the advances in coastal management principles, or the new requirement to incorporate climate change into hazard regulation outlined in the 2020 PPS. Gaps in the regulation process include limited ecological tests since the conservation of land has never been clearly defined or operationalized. Plus, incremental and cumulative loss is not considered when making decisions on shoreline hardening impacts to the conservation of land, as outlined in the Mining and Lands Commission decision on Russell versus TRCA (MLC, 2009). Consequently, there is a need for a process that regularly updates documents which reflect advances in knowledge and on the ground learning and experience. A permanent committee could bring different levels of government together could collaborate in updating guidelines.

- ***Research and data collection directed at shoreline management related to climate change.*** The knowledge transfer from the climate change research community to the practitioner community needs ongoing support and enhancement. New, evolving results with respect to impacts of climate change on water levels, storm surges, increased exposure to winter storms, erosion rates, flooding and potential impacts to shoreline ecosystems needs to be integrated into the planning, management and regulation process. Additional information such as the assessment of societal impacts of changes in coastal processes, risk to properties and estimated costs of projected impacts and adaptation responses could inform the decision-making process as would an assessment of a "do nothing" approach to adaptation. This would establish the economic, social and environmental costs of impacts that could be aligned with the costs of coastal adaptation action. Projected coastal hazards need to be presented so there is a line of sight for development of adaptation strategies, adaptive measures, and implementation actions including communication with and solicitation of feedback from stakeholders based on updated hazard risk science. This will build understanding of the issues and need for adaptation.

- ***Assessments, updated hazard information, tools and guidance for coastal management practitioners.*** Coastal management practitioners (e.g., CAs, other government agencies, ENGOs, and consultants) need data, tools and guidance to address climate change. They have many questions with respect to assessment of climate change impacts and risks, and development of adaptations: How do we determine the nature and extent of the climate change influenced hazards? How much more area is affected? What are the rates of change (ice cover, erosion)? How severe will impacts and damages be over time? How much risk amelioration (i.e., adaptation) is needed? What is acceptable risk? These questions reflect the need for support for the practitioner community. There is uncertainty in how to apply the climate change science and a need for capacity building through guidance and training. Practitioners bring their expertise and understanding of the current context - needs and challenges - but it must be integrated with the evolving climate change science and implications for Great Lakes coastlines. The highest priority is delineating the hazards under climate change and understanding impacts to ecosystems. Moreover, support and guidance for adaption is required such as designing adaptation strategies, tools for assessing adaptation measures, and case studies examples of successfully completed projects.

- ***Engagement, collaboration, education, and outreach with the public and landowners.*** An important component of addressing coastal hazard risk is engagement with the public, landowners and other stakeholders. They need to be aware of the projected impacts of climate change on the shoreline and the implications for safety, property damage and costs. Riparian landowners are typically responsible for the costs to floodproof their buildings and protect their land from erosion, not government. Additionally, they need to understand the necessity for adaptation and engage in dialogue for developing potential adaptation responses and appreciating the transformation that may be required to achieve outcomes. The greatest challenge is that as a society we have encouraged stationarity in behavior and development practices but because of the evolving risks due to climate change there is a need to become more adaptive.

## 5.0 Conclusions

While Conservation Authorities can and do efficiently regulate new development on hazardous lands, proactive measures are needed now to ensure effective integrated coastal management in a changing climate. Immediate action to engage agencies and stakeholders in collaborative management, undertake research on climate change impacts, update technical guidelines to integrate climate change impacts, assess risks, and map updated hazards is critical to ensuring CAs continue to make informed and valuable decisions on development in coastal areas. The future ecological health and resilience of coastal communities and ecosystems to climate change will depend on the path senior levels of government choose to follow. Our vision is all levels of government, ENGOs, and stakeholders working together to deal with this climate change challenge and enhance coastal resilience.

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# APPENDIX B

## Chatham-Kent Lake Erie Shoreline Study

# Chatham-Kent Lake Erie Shoreline Study

Prepared for:

The Municipality of Chatham-Kent

May 25, 2020

Prepared by:


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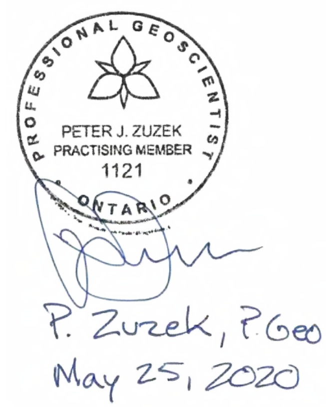
ONE WORLD

*Municipality of Chatham-Kent Lake Erie Shoreline from Space (April-May, 2008)*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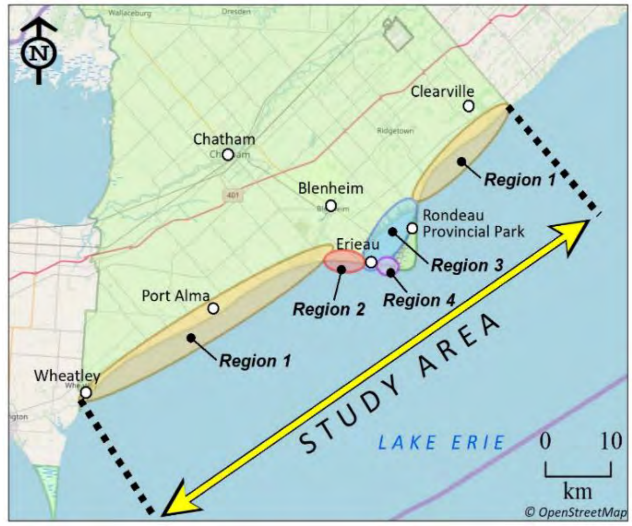
# EXECUTIVE SUMMARY

The Chatham-Kent Lake Erie Shoreline Study integrated the latest information on historical and anticipated future coastal hazards due to climate change into a comprehensive vulnerability and risk assessment. The study was led by the Municipality of Chatham-Kent, with support from the Lower Thames Valley Conservation Authority. The technical work was completed by Zuzek Inc. in partnership with Linda Mortsch from the University of Waterloo.




Climate change has increased historical air temperatures in Southwestern Ontario. By late century (i.e., 2080), they are projected to be 5 to 7 degrees Celsius warmer in the winter for emission scenario RCP-8.5. The seasonal extent of ice cover on Lake Erie has already been declining for several decades and by late century, the lake could be ice free in the winter. An ice-free winter will increase the amount of wave energy reaching the shoreline by 70 to 80%, resulting in higher erosion rates and more frequent winter flooding. The ice-free winter of 2019/2020, when storms impacted the coastal zone all winter, is a prelude to the future.

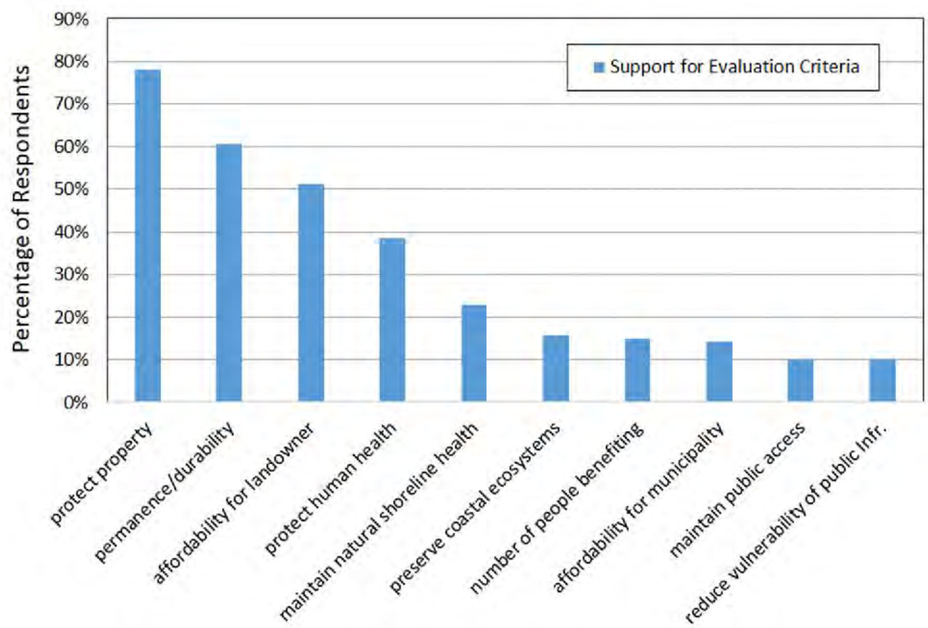
In June 2019 Lake Erie established a record high monthly level of 175.14 m and the climate change research suggest future highs could be on the order of 0.5 m higher. This study used a 100-year lake level of 175.3 m International Great Lakes Datum, 1985 (IGLD'85) based on historical data and a 100-year climate change lake level of 175.8 m IGLD'85.

A coastal vulnerability assessment was completed for the 120 km coastal zone of Chatham-Kent from Wheatley to the municipal boundary in the east near Clearville, including Rondeau Bay. The highlights of the assessment based on 2019 Municipal Property Assessment Corporation (MPAC) values for buildings, infrastructure, and the coastal ecosystem include:

- The assessed value of land and buildings (538) vulnerable to flooding for the 100-year lake level along the Lake Erie coastline in Chatham-Kent is $41.6 million.
- The assessed value of buildings (1,153) vulnerable to flooding for the 100-year climate change lake level in Chatham-Kent increases to $101.7 million.
- A total of 478 primary and secondary buildings along the bluffs will be impacted by coastal erosion in 50 years or less, with an assessed value of $66.2 million.
- A section of Erie Shore Drive was closed for traffic on March 9, 2020 to implement emergency repairs to the dike, based on the recommendations from Golder (2020a), that indicated a slope failure during a wave overtopping event could lead to a dike breach.
- The only ingress and egress route for Erieau is Erieau Road and it would be inundated by 1.5 m of water if the Erie Shore Drive dike breaches during the 100-year storm event.

- In 50 years or less, 5.9 km of the Talbot Trail will be threatened by erosion. A section of the road is already closed at Coatsworth Cut, resulting in significant traffic disruptions.
- A section of Rose Beach Line is closed between Antrim Road and Hill Street.
- The Rondeau Bay barrier beach east of the navigation channel has receded 650 m since 1868 and featured a wide breach in the fall of 2019.
- More than 160 hectares of coastal wetlands have disappeared in Rondeau Bay since 1955 due to the eroding barrier beach.
- Without remedial measures, the barrier beach will continue to erode, and the stability of the navigation channel is threatened. The 100-year wave height in the bay increases from 1.0 m with a barrier beach, to 2.7 m with no barrier beach.
- In many cases, the 2019 MPAC property assessment values are less than the capital costs to protect the property and buildings from coastal hazards (e.g., erosion and flooding threats). Plus, all the engineered shoreline protection concepts presented in this report will require on-going future maintenance which increases the cost of the solutions.

Extensive community engagement was completed for the study with nine public meetings attended by close to 1,000 people. The community co-developed and ranked the evaluation criteria for the adaptation concepts, as summarized in the adjacent bar chart.




Climate Change adaptation concepts that follow the four general principals of avoid, accommodate, retreat, and protect were explored during the community meetings. The coastal zone was sub-divided into four regions with similar physical conditions and exposure to hazards. The range of adaptation concepts are presented in Section 6.0, with the recommendations outlined in Section 7.0. They are briefly summarized along with concept-level costing information.

Once the most vulnerable areas are prioritized, planning and engineering studies are required to implement the climate change adaptation approaches. Government and stakeholders must continue to work together to pursue viable funding models and implement solutions.

**Table I Summary of recommendations and opinion of costs by Region**

| Region | Adaptation Concept | Recommendation | Time Horizon | Threatened Buildings and Infrastructure | Opinion of Cost (Low to High Range) |
|---|---|---|---|---|---|
| **1A – Wheatley, Detroit Line, and Pier Road** | Accommodate<br>and<br>Avoid | • Maintain existing shore protection. Replace vertical walls with sloping armour stone revetments<br>• Complete a long-term planning study for the Wheatly Provincial Park area, since the current "do nothing" strategy will have significant negative impacts for the local area | • As required for shore protection maintenance<br>• Medium-term for the Wheatley PP study | • Currently low vulnerability. With continued erosion, vulnerability will increase | • No costs generated |
| **1B – High Bluffs East of Wheatley PP to Erie Beach** | Option 1-3: Retreat | • Re-align approximately 30 km of the Talbot Trail inland<br>• Re-locate buildings as required when threatened by erosion<br>• Re-evaluate existing land-use policies, zoning regulations, and building standards along the eroding bluffs to avoid future challenges with development and erosion hazards | • Short-term | • 439 primary and secondary buildings, with an assessed value of $59.7 million are threatened<br>• 5.9 km of Talbot Trail | • Total: $68 to $96.6 million<br>• Re-align Road: $34.7 million<br>• Re-locate Buildings: $33.3 to $61.9 million |
| **1C – Bates Line Drive and Rose Beach Line to Mckinlay Road** | Accommodate | • Maintain existing shore protection<br>• At risk buildings should be flood proofed | • As required | • Low vulnerability | • No costs generated |
| **1D – Mckinlay Road to Hill Road** | Option 1-5: Retreat | • Decommission a section of Rose Beach Line between Mckinlay Road and Hill Road (including utility relocates), and upgrade New Scotland Line | • Short-term | • 2 km of Rose Beach Line<br>• 9 primary buildings | • $12.1 to $14.6 million |
| **1E –Hill Road to the East Study Boundary** | Avoid and Accommodate | • Review existing land-use policies and zoning to avoid the types of challenges that currently exist along the Talbot Trail to the west of Erie Beach | • Short-term | • Low vulnerability | • No costs generated |
| **2A – Erie Beach** | Accommodate | • Maintain existing shore protection<br>• Construct new shore protection when required | • As required | • Low vulnerability | • No costs generated |
| **2B – Erie Shore Drive** | Option 2-1a to 2-1c: Protect<br>or<br>Option 2-2 plus Option 2-3: Retreat & Protect Dike for Agriculture<br>or<br>Option 2-2 plus Option 2-4: Retreat and Naturalize the Interior | • Implement community-scale shore protection and dike upgrades. Use the Drainage Act to allocate costs<br>• If the Protect options are not affordable, pursue a retreat program (Option 2-2) and implement Option 2-3 (protect dike for agriculture and emergency access of Erieau Road)<br>• If the Protect options are not affordable, pursue a retreat program (Option 2-2) and naturalize the shoreline/interior (Option 2-4) | • Immediate action | • 123 primary and secondary buildings impacted by the 100-year flood. Increases to 141 buildings impacted for the 100-year climate change flood level<br>• Agricultural flooding<br>• Loss of emergency access to the Village of Erieau | • Option 2-1a: $59.2 to $84.4 million<br>• Option 2-1b: $45.7 to $64.3 million<br>• Option 2-1c: $36.8 to $50.7 million<br>• Option 2-2 plus Option 2-3: $42.5 to $51.7 million<br>• Option 2-2 plus Option 2-4: $53.1 to $67.4 million |

| Region | Adaptation Recommendation | Recommendation | Time Horizon | Threatened Buildings and Infrastructure | Opinion of Cost (Low to High Range) |
|---|---|---|---|---|---|
| **3A – Village of Erieau** | Option 3-2: Protect<br><br>Avoid, Protect, and Accommodate | • Construction of an armour stone revetment for the dike protecting Erieau Road opposite St. Anne's Church<br><br>• Depending on the selected approach for Erie Shore Drive, the elevation of Erieau Road near McGeachy Pond may need to be raised by more than 1 m to ensure emergency access<br><br>• In the medium-term, develop a community-scale flood mitigation plan for the flood prone development in Erieau | • Option 3-2: Short-term<br><br>• Medium-term for a community-scale flood mitigation plan | • Emergency ingress and egress is threatened for the Village of Erieau<br><br>• 101 buildings with an assessed value of $13.3 million vulnerable to the 100-year flood level<br><br>• 357 primary and secondary buildings with an assessed value of $45.6 million vulnerable to the 100-year climate change flood level | • $4.6 to $6.4 million<br><br>• No costs generated for the flood mitigation study and capital improvements in Erieau |
| **3B – Communities of Rondeau Bay** | Avoid, Accommodate, Retreat, Protect | • The full spectrum of adaptation options is applicable for the communities of Rondeau Bay<br><br>• In the medium-term, develop a flood mitigation plan for Shrewsbury | • As required for the general options<br><br>• Medium-term for the community-scale flood mitigation plan for Shrewsbury | • In Shrewsbury, 184 primary and secondary buildings impacted by the 100-year flood ($9.4 million). Increases to 413 buildings for the 100-year climate change flood level ($22 million) | No costs generated |
| **4 – Federal Navigation Channel and Barrier Beach** | Option 4-3: Protect | • Create a collaborative of local stakeholders and all levels of government to advance the nature-based adaptation option for the Federal navigation channel, pursue funding opportunities to implement the project, and establish maintenance protocols | • Immediate action | • The functionality of the navigation channel is threatened, wave exposure has increased for the marina basin, commercial fishing fleet, and the communities of Rondeau Bay | $10.2 to $15.2 million |
| **Total Costs (*for recommendations with capital costs*)** | | | | | **$131.7 to $217.2 million** |

Notes:

**1) Time Horizon Definitions**: Immediate action: commence as soon as possible; Short-term: 1 to 5 years; Medium-term: 5 to 10 years

**2) Maintenance of Shore Protection**: All shoreline protection requires maintenance. The costs reported in Table I are for initial capital costs only. Future maintenance is not included in the Opinion of Cost

## Next Steps

The combined cost of the preferred adaptation options detailed and costed in this report ranges from $131.7 to $217.2 million. In some cases, the adaptation options exceed the value of the assets they are attempting to protect. For Regions 1A, 1C, 1E, 2A, 3B coastal vulnerability is generally low and community-scale adaptation concepts have not been developed. Alternatively, a series of generic adaptation options were developed that could be implemented on a lot-by-lot basis. It is beyond the scope of this investigation to generate lot-by-lot cost estimates for these specific adaption approaches. Finally, in three locations (the Wheatley Provincial Park Area, the Village of Erieau, and Shrewsbury) further planning studies are recommended in the medium-term to address coastal risks and increase community resilience to coastal hazards.

The path forward is unknown and complex, but priorities must be established, and solutions implemented. Also, the community must learn from the long history of inaction along Erie Shore Drive. Coastal hazards do not go away, they just get more severe over time and more expensive to mitigate. And climate change is making everything more complicated and more expensive.

The following steps are recommended:

1. Prioritize the most vulnerable areas and proceed with planning and engineering studies to implement the selected adaptation option(s), including nature-based solutions. The top priority areas include:
    a. Region 2B: develop and implement a long-term plan for Erie Shore Drive.
    b. Region 3A: protect the dike along Erieau Road opposite St. Anne's Church.
    c. Region 1B: complete the Environmental Assessment for the Talbot Trail realignment and implement a solution.
    d. Region 1D: complete the Environmental Assessment for Rose Beach Line and implement a solution.
    e. Protect the navigation channel, commercial fishing fleet, fuel dock, and marina by restoring the Rondeau barrier beach.
2. Reach consensus on the approaches for the remaining Regions and Sub-regions.
3. Modify the Lower Thames Valley Conservation Authority board-approved policies as required based on the study findings.
4. Update Lower Thames Valley Conservation Authority hazard mapping (erosion and flooding) based on the study findings.
5. Update the Municipal Official Plan, Zoning By-laws, and Development and Building Standards based on the technical findings and recommendations from this study

A CV for P. Zuzek is provided in Appendix D.

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## EXECUTIVE SUMMARY

## 1.0 INTRODUCTION

The Chatham-Kent Lake Erie shoreline extends for 120 km from Wheatley Harbour in the west to McPherson Road east of Clearville, including Rondeau Bay. Refer to Figure 1.1 for a map of the study area. Zuzek Inc. and Linda Mortsch, University of Waterloo, were retained by the Municipality of Chatham-Kent to assess the vulnerability of the shoreline to coastal hazards, including the projected impacts of climate change on future lake levels, ice cover, storm surge, and the nearshore wave climate. Potential economic damages to coastal development from flooding and erosion, threatened road infrastructure, and the coastal ecosystem were quantified. The community was engaged to co-develop the evaluation criteria, identify the most vulnerable areas, and provide feedback on the climate change adaptation options. The technical studies and recommendations will be used by the Municipality of Chatham-Kent and the Lower Thames Valley Conservation Authority to increase community resilience to coastal hazards.

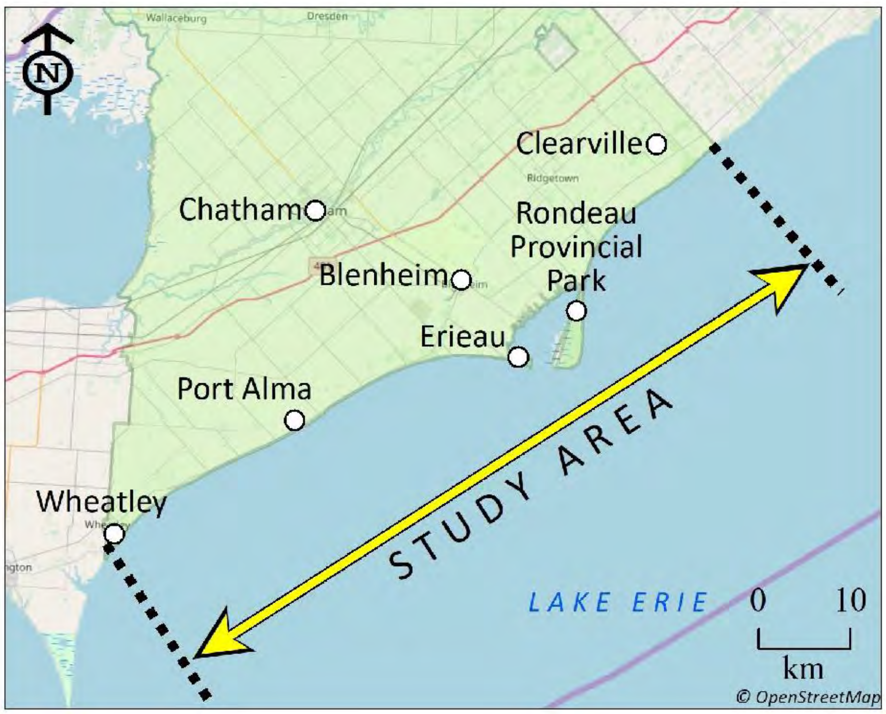



**Figure 1.1 Study Area**

### 1.1 Mandates for Shoreline Management

The mandate for shoreline management in Ontario is multi-jurisdictional, with responsibilties spread between local Municipalities, Conservation Authorities, Provincial Ministries, and Federal Departments. The local mandates for the Municipality of Chatham-Kent and the Lower Thames Valley Conservation Authority are highlighted to provide context for this investigation.

#### 1.1.1 Municipality of Chatham-Kent

The Municipal Act outlines the responsibilities for local municipal governments in Ontario. Chatham-Kent was the lead agency for this study and is responsible for land use planning, provision and maintenance of infrastructure such as roads and bridges, and the supply of public drinking water. Building permits are reviewed and issued for new development.

The Provincial Policy Statement (PPS, 2020) is prepared in accordance with the Planning Act, and provides guidance for Municipalities on land use, housing, natural heritage, and protection of public health from natural and man-made hazards.

### 1.1.2 Lower Thames Valley Conservation Authority (LTVCA)

The LTVCA's responsibilities and mandate for coastal management are outlined in the Conservation Authorities Act, which is currently under review. Ontario Regulation 97/04, which was developed under the Conservation Authorities Act, pertains to the regulation of development on hazardous lands. For the Great Lakes, this includes lands subject to flooding for the 100-year lake level, a stable slope and recession setback for a 100-year planning horizon, setbacks for dynamic beaches, and other allowances determined by the Conservation Authority.

On October 17, 2019 the LTVCA Board of Directors approved the updated Lake Erie Shoreline Development Policy within the Municipality of Chatham-Kent. The document outlines the general policies for the areas regulated by the LTVCA, such as site grading, new building setbacks, and building standards. Refer to the LTVCA website (https://www.lowerthames-conservation.on.ca/) to obtain a copy of the policy.

### 1.1.3 Other Relevant Acts

Although the Province of Ontario and the Federal Government were not active participants in the study, they are responsible for numerous Acts that contribute to shoreline management, including:

- Ontario Public Lands Act: outlines the requirements for work permits on public lands to protect Crown interests, such as dredging, filling, and construction.
- Ontario Lakes and Rivers Improvement Act: ensure the management and protection of the waters in the lakes and rivers in Ontario, plus the species that rely on the water.
- Ontario Endangered Species Act: provides protection to more than 200 species of plants and animals in Ontario.
- Federal Fisheries Act: protects fish and fish habitat, and outlines management approaches for fish.
- Federal Species at Risk Act: focused on preventing wildlife species loss and recovery of endangered or threatened species.

The following report sections will review data collected for the study, summarize the technical analysis, highlight the findings of the vulnerability assessment, review key findings from the community engagement, present the climate change adaptation options, and overall conclusions.

# 2.0 DATA COLLECTION AND SITE OBSERVATIONS

Key data sources and information collected for the study will be summarized, along with shoreline observations and the field surveying.

## 2.1 Historical Maps of the Study Area

One of the oldest maps of Lake Erie was prepared in 1859 by the Bureau of Topographic Engineers, War Department, in the United States. The portion of the map that covers the Rondeau Bay area is presented in Figure 2.1. While the cartographic detail is not consistent with a modern map, it is clear the entire shoreline in the Rondeau area is natural and the amount of fringing coastal wetlands in the bay is extensive.

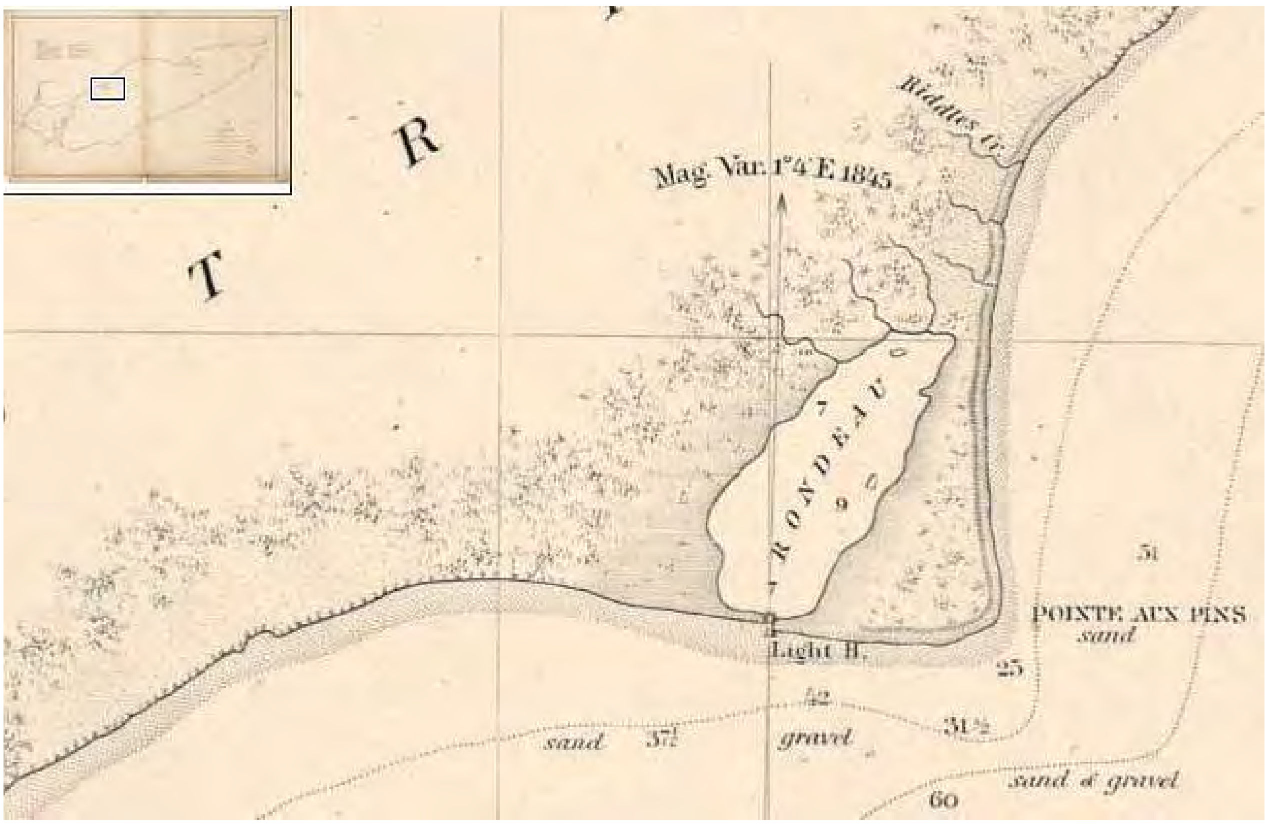



**Figure 2.1 1849 Map of the Rondeau Peninsula (Bureau of Topographic Engineers, USA)**

A second map from the mid-1800s is presented in Figure 2.2 and appears to be augmented with additional information from the 1900s. Key information and observations from the map include:

- There was an original navigation channel stabilized with two short jetties. Then the east structure was expanded, and a larger west jetty was constructed.

- West of the existing navigation channel, the shoreline consisted of a series of wayward islands and there were multiple shallow entrances to Rondeau Bay.

- A breakwall was constructed from the west jetty to a large island around 1868. This breakwater likely played a significant role in the formation of the Village of Erieau. The location of the 1938 shoreline west of the jetties documents a significant amount of deposition over a 70-year period.

- The barrier beach east of the jetties was originally connected to the east jetty.

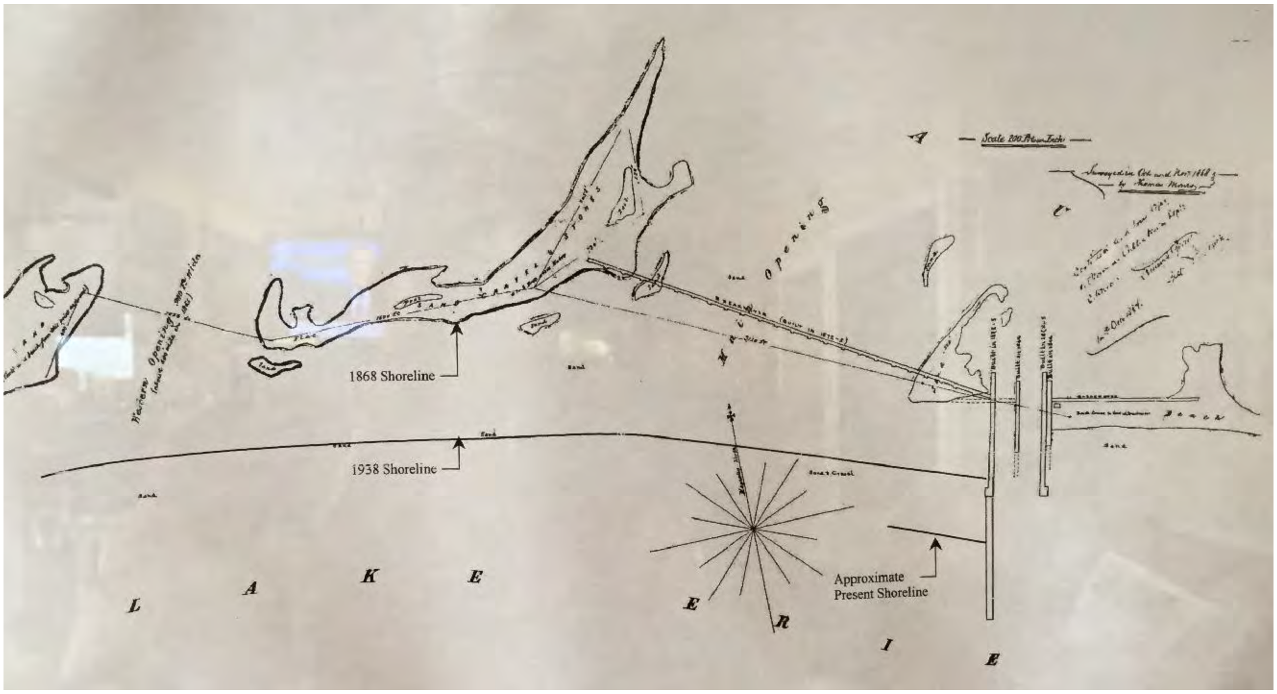



**Figure 2.2 Mid- to Late-1800's Map (date unknown)**

The 1910 map of Rondeau from the Canadian Department of Militia and Defence (Figure 2.3) highlights an interesting junction in the history of Rondeau Bay. Key observations include:

- Development in Shrewsbury had begun and there was a pier or boardwalk to the lake around the foot of Brook Street. The development in 1910 was separated from the lake by a large marsh.

- The Pere Marquette Railway connected the coal port in Erieau to the communities of Southwestern Ontario.

- The western limit of the Rondeau Bay marsh extended to Bisnett Line. A peat factory operated in the current Burk Drain.

- The Village of Erieau featured several buildings and an extensive rail yard to support the coal port.

- The beaches on the east and west side of the navigation channel have a similar proximity to Lake Erie (southern limit).


**Figure 2.3 1910 Map of Rondeau Harbour (Canadian Department of Militia and Defence)**

With the information on the 1941 map from the Department of National Defence (Figure 2.4), we know the Burk Drainage Scheme was constructed and Erie Shore Drive connected Erie Beach to Erieau. Some initial development south of Erie Shore Drive had occurred. The current jetty configuration for the navigation channel was in place, with the shorter east jetty. However, it was still connected to the Rondeau Barrier Beach. Significant growth of the west fillet beach had occurred by 1941 and the rail infrastructure was significant. This is also the first map on which the Provincial Park was officially recognized.

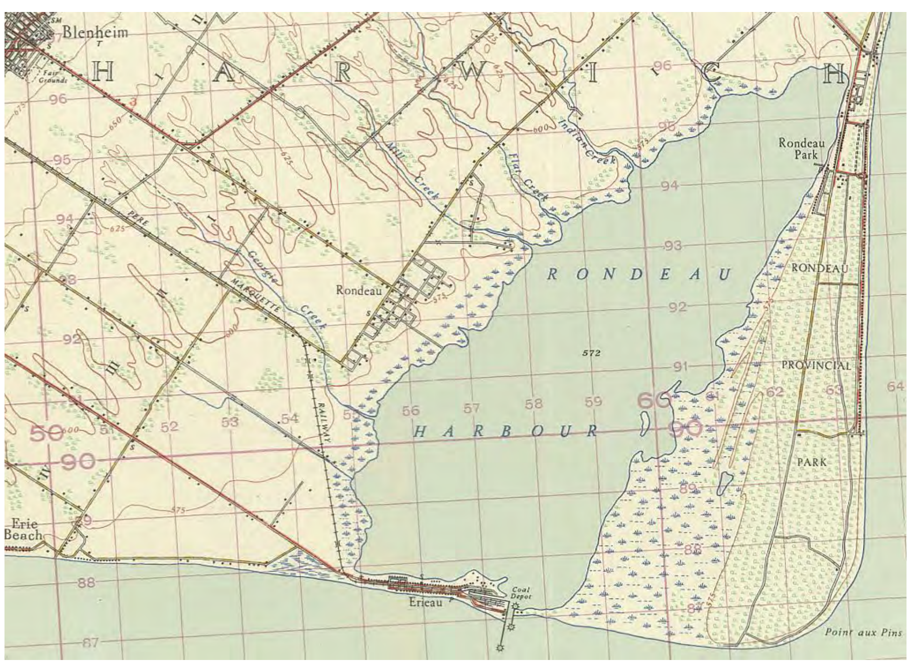



**Figure 2.4 1941 Map of Rondeau Harbour (Department of National Defence)**

## 2.2 Historical Photographs of Coastal Hazards

A series of historical images were obtained from the Chatham-Kent Museum that document the long history of problems with coastal hazards in Erieau. In Figures 2.5 and 2.6, images of sandbagging from 1937 suggest the challenges with coastal erosion started more than 80 years ago. There appear to be agricultural fields in the background of Figure 2.6, suggesting the images were taken near Erie Shore Drive or McGeachy Pond.


**Figure 2.5 1937 Sandbagging in Erieau (image courtesy of the Chatham-Kent Museum)**


**Figure 2.6 1937 Sandbagging in Erieau (image courtesy of the Chatham-Kent Museum)**

Flooding of agricultural crops in the Erieau Marsh is depicted in Figure 2.7 (1946) and Figure 2.8 (1948). The current challenges faced with the dike infrastructure and flood risk are not new.


**Figure 2.7 1946 Flooded Crops (image courtesy of the Chatham-Kent Museum)**


**Figure 2.8 1948 Flooded Crops (image courtesy of the Chatham-Kent Museum)**

The impacts of a 1955 winter ice-storm on the coastal development in Erieau is depicted in Figures 2.9 and 2.10. The threat of coastal hazards on buildings also has a long history.


**Figure 2.9 1955 Ice Storm in Erieau (Chatham-Kent Museum)**

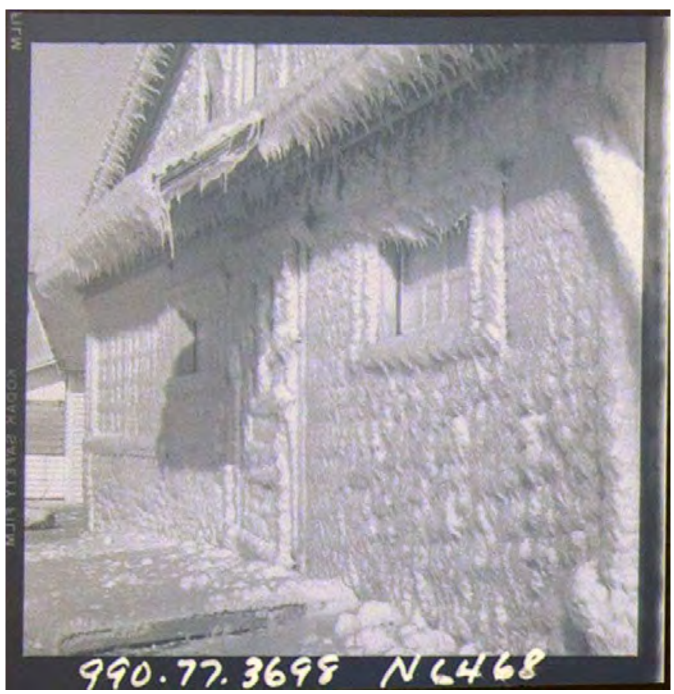



**Figure 2.10 1955 Ice Storm in Erieau (Chatham-Kent Museum)**

In summary, coastal hazards due to erosion and flooding and winter storms are not new to the Village of Erieau. They have been impacting the community for more than 80 years.

## 2.3 Coastal Observations

The study area was traversed by the project team for the first time in August 2018, from west to east, with staff from the Conservation Authority, Municipality, Ontario Parks, and Rondeau Provincial Park. Many additional field visits were completed in 2018 and 2019. Observations for the four regions and sub-regions are summarized in the following report sections. Refer to Figure 2.11 for a map of the regions.

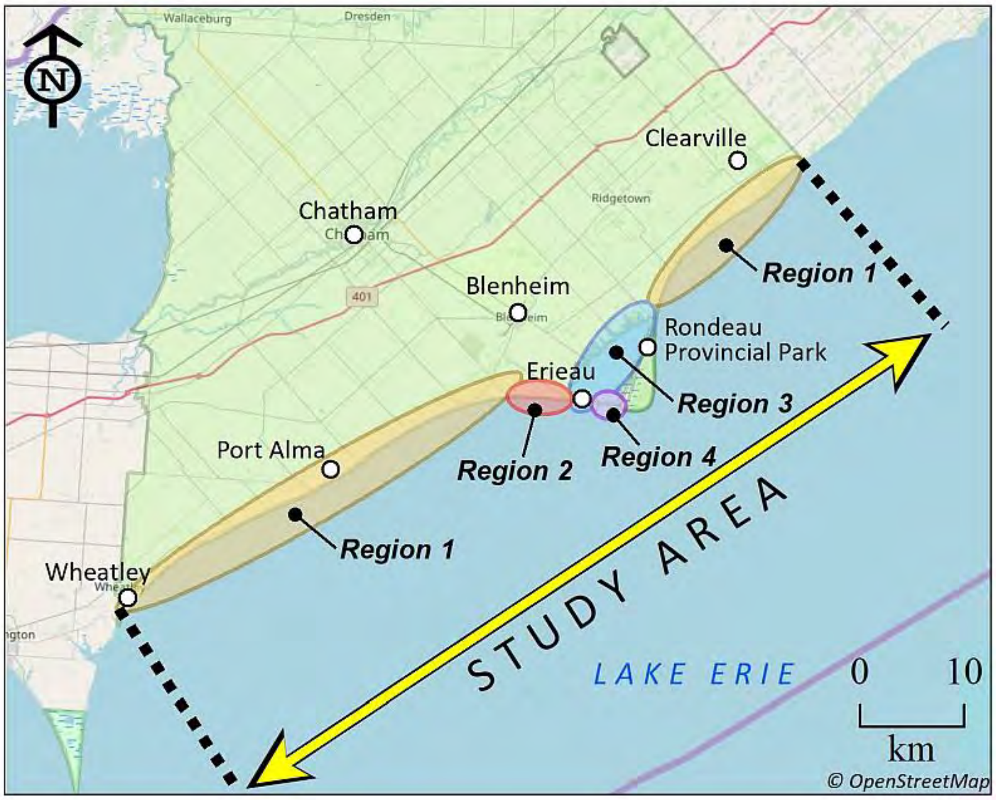



Figure 2.11 Study Area and Regions 1 to 4

### 2.3.1 Region 1 – High Bluffs

Region 1 covers the high bluff environments along the western and eastern portions of the study area. A total of five sub-regions were identified based on unique site conditions and exposure to coastal hazards.

#### *2.3.1.1 Region 1A – Wheatley, Detroit Line, and Holiday Harbour*

Region 1A includes the north side of Wheatley Harbour, Detroit Line and the Holiday Harbour area around Pier Road. This is a low plain shoreline that is heavily developed and protected with various types of shoreline structures, including seawalls and groynes. The entrance to Wheatley Harbour is shown in Figure 2.12. A typical armoured shoreline is presented in Figure 2.13. The eroding bluffs of Wheatley Provincial Park are seen in Figure 2.14.

**Figure 2.12 Entrance to Wheatley Harbour (Sept. 2019)**

**Figure 2.13 Typical Shoreline in Reach 1A (Sept. 2019)**

**Figure 2.14 Eroding Bluffs in Wheatley Provincial Park**

### 2.3.1.2 *Region 1B – Bluffs East of Wheatley Provincial Park to Erie Beach*

The shoreline in Region 1B is dominated by eroding bluffs that exceed 20 m in elevation in most locations. The steep bluff face along Bluff Line in August 2018 is presented in Figure 2.15. Two images of the eroding bluffs in the Port Alma area are presented in Figure 2.16 and 2.17. Waves continually undercut the toe or base of the bluffs, leading to upper slope failures.


**Figure 2.15 Bluff Line August 2018**

**Figure 2.16 Port Alma Bluffs in 2005**

**Figure 2.17 Port Alma Bluffs on August 22, 2018 (same location as Figure 2.16)**

The impacts of storms and wave attack on the bluff toe are obvious signs of the severity of the long-term erosion rate in Region 1B. However, erosion is not limited to the bluff face. It happens on the lake bottom and is known as lakebed downcutting. It also happens on the bluff slope and on the table lands in response to the toe erosion. Refer to Figure 2.18, where the signs of a deep-seated rotational failure are evident in the mowed yard (i.e., the 1 ft offset where the gentleman is standing is the start of a large block failure). These deep-seated failures are first observed on the tablelands but can extend all the way to the lake level and below. As these failures progress downslope, they form tension cracks as the block of soil separates from the inland. Eventually large pieces of the bluff fall into the lake (see tension cracks in Figure 2.19 and 2.20).

**Figure 2.18 Offset in the Tablelands Due to a Deep-seated Rotational Failure**

**Figure 2.19 Formation of Tension Crack Along Bluff Crest**

**Figure 2.20 Port Alma Bluffs Tension Crack, November 2019**

### *2.3.1.3 Region 1C – Bates Line/Drive and Rose Beach Line to Mckinlay Road*


Region 1C is in the transition zone from the high bluffs to the east and the sandy depositional environment along the shoreline of Rondeau Provincial Park. The area is densely developed and features shoreline protection at the back of the beach (e.g., walls). A photograph of a typical sandy shoreline and a vertical seawall is presented in Figure 2.21.

**Figure 2.21 Typical View of the Shoreline in Reach 1C (August 2018)**

### *2.3.1.4 Region 1D – Mckinley Road to Hill Road*


Region 1D marks the beginning of the bluff shoreline northeast of Rondeau Bay. A picture of the eroding bluffs and road closure along Rose Beach Line is provided in Figure 2.22. At the base of the eroding clay bluffs, dumped concrete rubble was observed, as seen in Figure 2.23.

**Figure 2.22 Road Closure on Rose Beach Line**

**Figure 2.23  Dumped Concrete Rubble at the Base of Rose Beach Line**

#### *2.3.1.5 Region 1E – Hill Road to East Study Boundary*


The eastern third of the study area consists of the eroding bluffs in Region 1E. A typical image of the bluff toe is seen in Figure 2.24. Near the eastern boundary, a small boat launch provides access to Lake Erie at the base of Clearville Road (Figure 2.25).

**Figure 2.24  Eroding Bluffs in Region 1E**

**Figure 2.25  Boat Launch near Clearville**

## 2.3.2 Region 2 – Erie Beach and Erie Shore Drive

Erie Beach and Erie Shore Drive are in Region 2, located between the high bluff shoreline along Talbot Trail and Rondeau Bay.

### *2.3.2.1 Region 2A – Erie Beach*


The Erie Beach community is approximately 1.5 km in length and is protected with near continuous steel sheet pile groynes and seawalls at the back of the beach. Refer to Figure 2.26 for a picture of the typical shoreline conditions. Figure 2.27 highlights the potential for erosion between the groynes if the low bank is not protected.


**Figure 2.26 Steel Sheet Pile Groynes at Erie Beach**


**Figure 2.27 Erosion of the Backshore between the Groynes at Erie Beach**

#### *2.3.2.2 Region 2B – Erie Shore Drive*


A brief history on the development of Erie Shore Drive is provided to put the current challenges with coastal hazards in perspective. In approximately 1913, work began on the Burk Drainage Scheme to convert the edge of the Rondeau Bay swamp into 1,600 acres of productive muck agricultural land. This work included the construction of a dike along the lake and interior ditches to convey water back to the lake (Uhlik, 1971). Following a storm in the 1940s that flooded the farm fields located below lake level, a new dike system was constructed around the McGeachy property between Erie Shore Drive and the Erieau. The dike was re-enforced with armour stone in 1973 under the Agricultural and Rural Development Act (ARDA) program (Todgham and Case, 1998).

A wooden retaining wall was constructed parallel to Erie Shore Drive and then re-enforced with a series of wooden groynes approximately 25 feet in length in 1930 (Todgham and Case, 1998) and expanded/repaired numerous times between 1943 and 1968. Remnants of the old wooden retaining wall and groyne are visible in select locations along Erie Shore Drive.

By the late 1930s, there were approximately 50 cottages and cabins located at the back of the sand beach (Public Works Canada Map, 1938). A dirt road was constructed on top of the dike and was eventually renamed Erie Shore Drive.

In the early 1970s, the deterioration of the shoreline was noted in the Dike Road Report (Uhlik, 1971). The former sand beach had eroded and in locations glacial sediment (e.g., clay) was exposed. Given the reduced lot depths, the functionality of the private septic systems and weeping beds was identified as a serious pollution problem and health concern.

In 1998, a preliminary report was prepared under the Drainage Act by Todgham & Case Associates to investigate options for flood protection along Erie Shore Drive. Coastal engineering aspects of the project were investigated by Baird & Associates (1998). Several key findings from the engineering study remain relevant today. First, the shoreline is eroding, and the process is irreversible without significant investment in coastal engineering structures. Lot-by-lot shore protection can only provide limited localized flood and erosion relief and it can also result in negative impacts to adjacent properties. Finally, with the passing of time, the design and construction of a regional shoreline protection scheme for Erie Shore Drive will become more difficult and expensive to implement. The recommended approach was a regional solution that included a revetment at the western end of the site and large armour stone headlands with beach nourishment for the central and eastern portion of Erie Shore Drive, for a total cost of approximately $11 million in 1998 dollars ($16.5 million in 2020 dollars).

Recommendations were provided for all stakeholders to continue collaborating in the pursuit of a regional solution to Erie Shore Drive. Unfortunately, there was no action by the Council of the day to take further steps towards a long-term solution following the report and Region 2B continued to deteriorate.

Pictures of Erie Shore Drive during non-storm conditions are provided in Figure 2.28 (old timber groynes) and Figure 2.29 (concrete rubble shore protection). Images from the August 27, 2019 flooding event at Erie Shore Drive are presented in Figures 2.30 to 2.32. Extensive flooding occurred around home foundations, structural damage occurred in some locations due to wave forces, and septic tile beds were in failure due to the yard flooding. In locations where Erie Shore Drive is low, sheet flow conveyed water over the road and into the Lakeshore Drain. Erosion of the north dike slope occurred in several locations, threatening the stability of the road and dike crest.


**Figure 2.28 Old Timber Groynes and New Steel Sheet Pile Wall (2018.08.22)**


**Figure 2.29 Dumped Concrete Rubble Shore Protection (2018.08.22)**

**Figure 2.30 Flooding of Building Foundations, August 27, 2019 Storm**

**Figure 2.31 Direct Wave Attack on Buildings, August 27, 2019 Storm**

**Figure 2.32 Erosion of Road Base, North Dike Slope and Flooding of Agricultural Fields, August 27, 2019 Storm**

### 2.3.3 Region 3 – Rondeau Bay

The communities of the Rondeau Bay in Region 3 are described in Section 2.3.3.

#### *2.3.3.1 Region 3A – Village of Erieau*


The Village of Erieau features a variety of shoreline conditions and different exposures to coastal hazards. A picture of the dike fronting Erieau Road at St. Anne's Church is provided in Figure 2.33. The wide sand beach west of the navigation channel is seen in Figure 2.34. The sheltered shoreline on the north side of Erieau is seen in Figure 2.35. The community is vulnerable to lake flooding, especially along Rondeau Bay (see Figure 2.36).

**Figure 2.33 Armour Stone and Concrete Rubble in front of Dike, St. Anne's Church**

**Figure 2.34 Erieau West Beach**

**Figure 2.35 Typical Rondeau Bay Shoreline in Erieau**

**Figure 2.36 Erieau Flooding along Rondeau Bay Shoreline in Erieau**

### *2.3.3.2 Region 3B – Shrewsbury and Rondeau Bay Estates*


The two largest developments in Rondeau Bay other than Erieau are Shrewsbury and Rondeau Bay Estates. Photographs of typical shoreline conditions in these two communities are provided in Figures 2.37 and 2.38 respectively. A picture of the flooded boat launch in Shrewsbury is provided in Figure 2.39.

**Figure 2.37 Shrewsbury Drain Along Brock Street**


**Figure 2.38 Private Canal in Rondeau Bay Estates**

**Figure 2.39  Flooded Boat Launch in Shrewsbury**

### 2.3.4 Region 4 – Federal Navigation Channel and Barrier Beach

Figure 2.40 provides a view of the Federal Navigation Channel looking into Rondeau Bay, from the west jetty. A view of the channel looking east into Lake Erie is provided in Figure 2.41. A picture of the eroded barrier beach looking east on August 20, 2019 is presented in Figure 2.42.

**Figure 2.40  Navigation Channel Looking into Rondeau Bay**

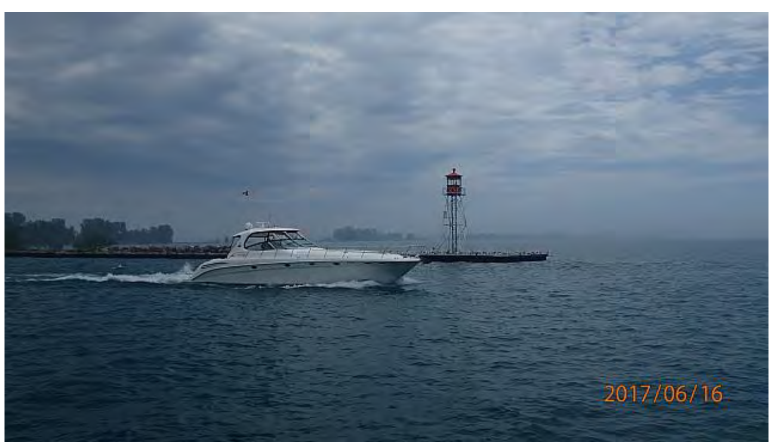



**Figure 2.41  Navigation Channel to Lake Erie (east jetty in background)**

**Figure 2.42 Remnants of the Rondeau Barrier Beach, August 20, 2019**

### 2.3.5 Rondeau Provincial Park

Although Rondeau Provincial Park does not fall within the jurisdiction of the Municipality of Chatham-Kent or the Conservation Authority, it is a popular recreational destination and the park is ecologically significant for its coastal wetland habitat and beaches. The wetlands in the bay, most of which are within the boundary of the Provincial Park, represent 8.3% of the coastal wetlands along the Canadian shores of Lake Erie and support endangered species such as the Fowlers Toad and Spotted Gar. It is the third largest wetland complex on the Canadian shores of Lake Erie, behind only Long Point and Point Pelee (Zuzek Inc., 2018). A map of the existing land cover for Rondeau Bay, including the wetland categories (swamp, shrub swamp, marsh, and shallow water marshes) is presented in Figure 2.43.

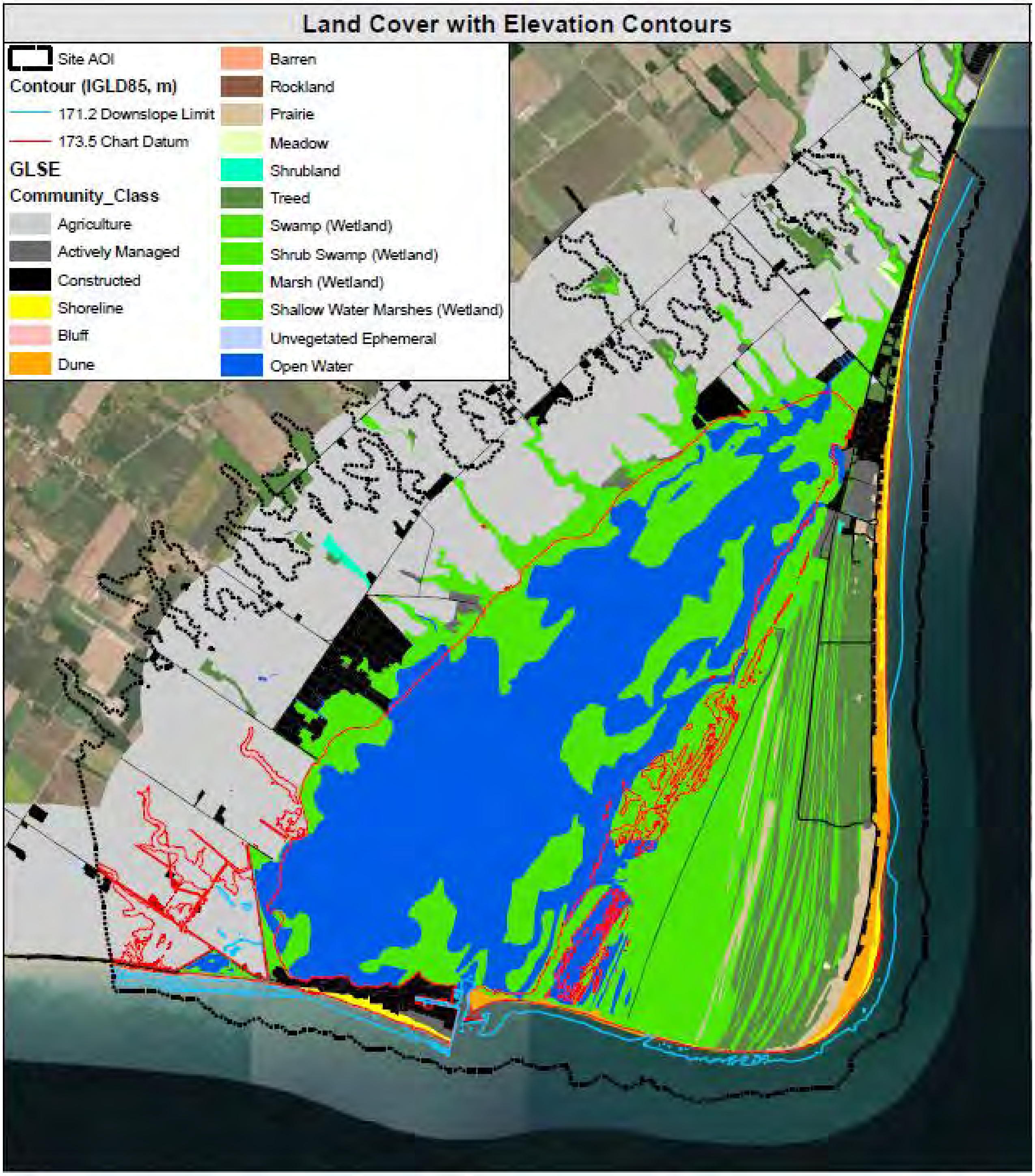



**Figure 2.43 Land Cover Classification for Rondeau Bay (source: Ministry of Natural Resources and Forestry Great Lakes Shoreline Ecosystem Mapping)**

## 2.4 Coastal Survey

In addition to the shoreline observations made between 2018 and 2019, two coastal surveys were completed, as outlined below.

### 2.4.1 October 2018 Survey of the Rondeau Barrier Beach

The exact date of the breach in the Rondeau Barrier Beach is unknown, but one possible event was the April 2018 ice storm that featured strong winds over several days from the east. The barrier beach and navigation channel were surveyed on October 25, 2018 in partnership with the Lower Thames Valley Conservation Authority, who also collected a waterline for the barrier and cross-sections, to record the elevation of the beach.

The SOLIX is a single-beam bathymetric and sonar system with built-in recording and navigation tools. The transducer was mounted at the back of an aluminum boat with a dedicated GPS antenna located directly above the unit. Refer to Figure 2.44. The unit auto-corrects for the depth of the transducer below the lake surface and the depths were recorded every second. The depth readings were corrected to the IGLD'85 datum using real-time hydrometric data acquired from the Government of Canada water level website.


**Figure 2.44 SOLIX Navigation Monitor (black, right) and GPS Antenna (back of boat)**

Figure 2.45 provides a summary of the tracks collected on October 25, 2018 (left side of image). The sonar capabilities of the SOLIX allow collection of digital images of the lake bottom simultaneously while the instrument is also collecting depth data. The right side of the image in Figure 2.45 provides a sample of the sonar collected while traveling on the lake side of the breach. The scale on the bottom of the image records distance to the left of the boat (0 to 100 m) and the left scale is the distance along the shore (0 to 100 m). Individual sand ripples are captured with the high-resolution image. Exposures of peat were also captured, as noted in Figure 2.45. When the barrier was lakeward of its present location, these peat exposures formed in the marsh. As the barrier migrates north into the marsh, the peat is exposed and eroded by lake waves.

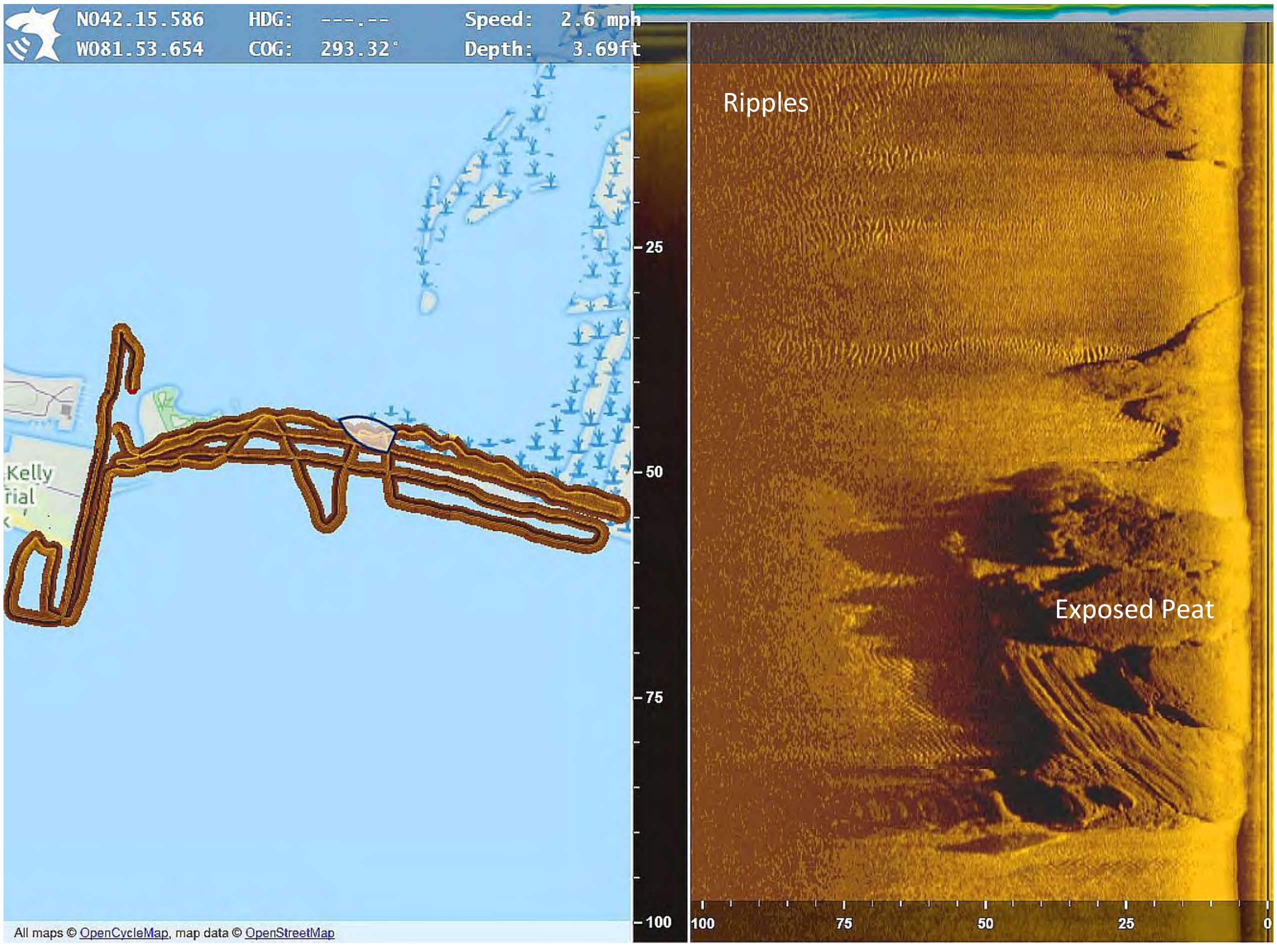



**Figure 2.45 SOLIX Output (left track lines; right sonar imagery)**

### 2.4.2 August 2019 Survey of Rondeau Barrier, Erie Shore Drive, and Erie Beach

The Rondeau Barrier beach was re-surveyed on August 20, 2019 with the SOLIX to collect updated information on the growth of the breach and the onshore migration of the sand ridge. A picture of the treeless barrier beach, which has transformed into a washover terrace, is provided in Figure 2.46. The breach is seen in Figure 2.47.

**Figure 2.46 Rondeau Barrier Beach**

**Figure 2.47 Breach in Rondeau Barrier Beach (looking west)**

A total of 15 profiles were collected from the fillet beach adjacent to the west jetty in Erieau, across the Erie Shore Drive shoreline, and on Erie Beach. Refer to Figure 2.48. The water depths below the lake surface were recorded from the shoreline to approximately 500 m offshore. Sonar imaging of the lake bottom was also collected along the 15 profiles.

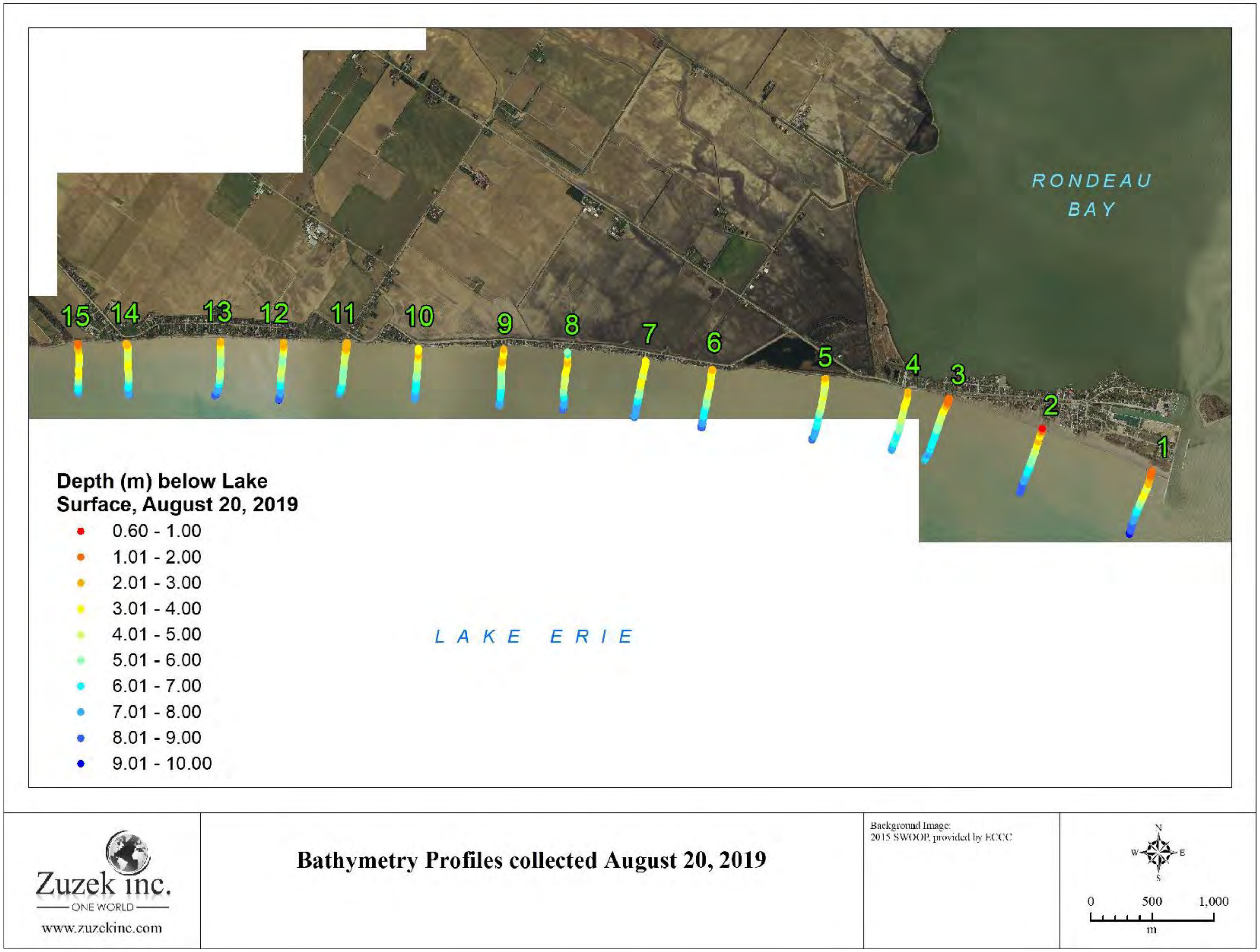



Figure 2.48 Lake Bottom Profiles Collected on August 20, 2019

# 3.0 TECHNICAL ANALYSIS

The key findings from the technical analysis are summarized in Section 3.0.

## 3.1 NRCan Supported Study on Coastal Storms

A recent technical study supported by Natural Resources Canada (Zuzek Inc., 2019) investigated the impacts of climate change on future storms and ice cover in the Great Lakes Basin. This investigation was the first of its kind to focus solely on storm impacts to wave heights and storm surges in the basin. The key findings are summarized in the following report sections.

### 3.1.1 Warming Due to Climate Change

The projected winter warming in Canada for RCP2.6 and RCP8.5 were recently summarized by Bush and Lemmen (2019). Refer to information for 2031-2050 and 2081-2100 in Figure 3.1. Significant winter warming is projected, especially for RCP8.5. By late century, winter temperatures for this scenario are projected to be 5 to 7 degrees Celsius warmer.

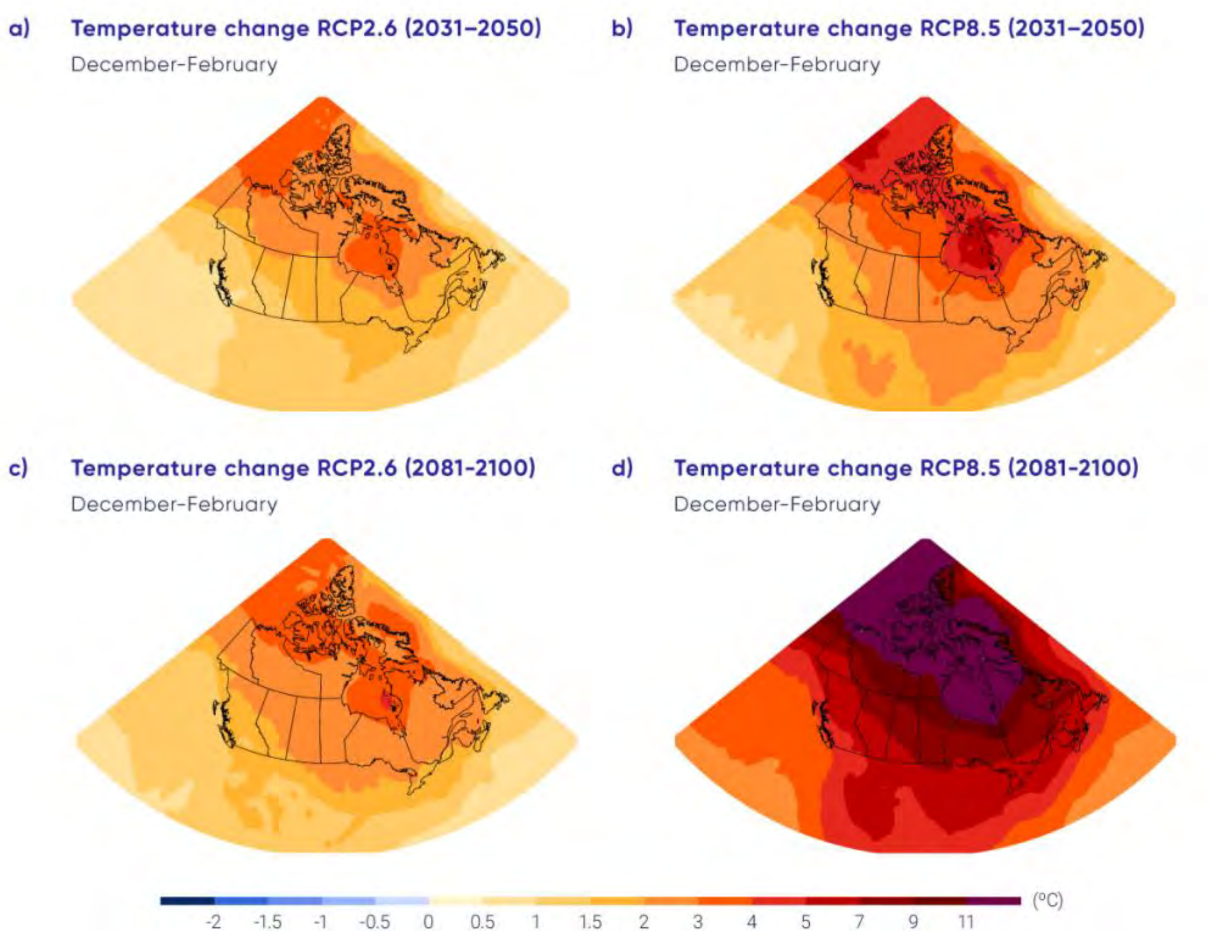



**Figure 3.1 Winter Warming for Mid- and Late-Century (from Bush and Lemmen, 2019)**

### 3.1.2 Ice Cover Projections Due to Warming

Ice cover in the Great Lakes has been decreasing since 1973 (Wang et al, 2012) and across the northern hemisphere (Sharma et al, 2019). The projected winter warming will continue to increase air and lake water temperatures, resulting in further reductions in ice cover in the future. Figure 3.2 provides a conceptual diagram of these changes on ice cover, with near full lake ice coverage in the left-hand panel, partial coverage in the middle satellite image, and limited coverage in the right-hand panel. As the winter temperatures continue to warm in Southern Ontario, the duration of lake ice coverage is projected to continue to decrease and could approach zero coverage by late century (e.g., 2080s).


**Figure 3.2 Schematic Diagram of Reduced Lake Erie Ice Coverage**

Based on future air and lake water temperatures extracted from the Weather Research and Forecasting (WRF) model for a late century RCP8.5 scenario, RWDI (2020) reached similar conclusions. Lakes Erie and Ontario could be ice free in the future. This conclusion was recently validated by an ongoing ECCC study for the Great Lakes (ECCC, Internal File 2020).

### 3.1.3 Changes in Wave Climate and Storm Surge

The impacts of climate change on future coastal storms, wave heights, and storm surges was recently evaluated for Lakes Erie and Ontario (Baird, 2019). The wave height analysis was completed by selecting the top 15 wave-height storms on Lake Erie from 2000 to 2013, then comparing the predicted wave heights for the same storms for a late-century RCP8.5 scenario. The results did not produce any consistent trends on the potential impacts of climate change on future wave heights (e.g., larger or smaller wave heights in the future). The analysis did, however, highlight the importance of lake ice cover on the generation of deep-water waves and propagation of those waves into the shoreline.

In the second part of the analysis (Baird, 2019), an hourly wind-wave hindcast was completed using spatially varying winds across Lake Erie for the historical baseline period (2000 to 2013) with actual ice-cover and then the same weather simulated for late-century with the RCP8.5 scenario with zero ice-cover (assumes no lake ice in the future).

For each grid cell in the wave model, hourly wave energy density was calculated for each 13-year wave hindcast. The results from the future hindcast were subtracted from the historical simulation to estimate the potential increase in future wave energy due to climate change. The results are summarized in Figure 3.3. In the shallow western basin of Lake Erie, the elimination of winter ice cover resulted in a 120% increase in the amount of wave energy reaching the shoreline. For the open bluff shorelines of the study area, the increase in winter wave energy is projected to be 70% to 80%, which is a significant increase.

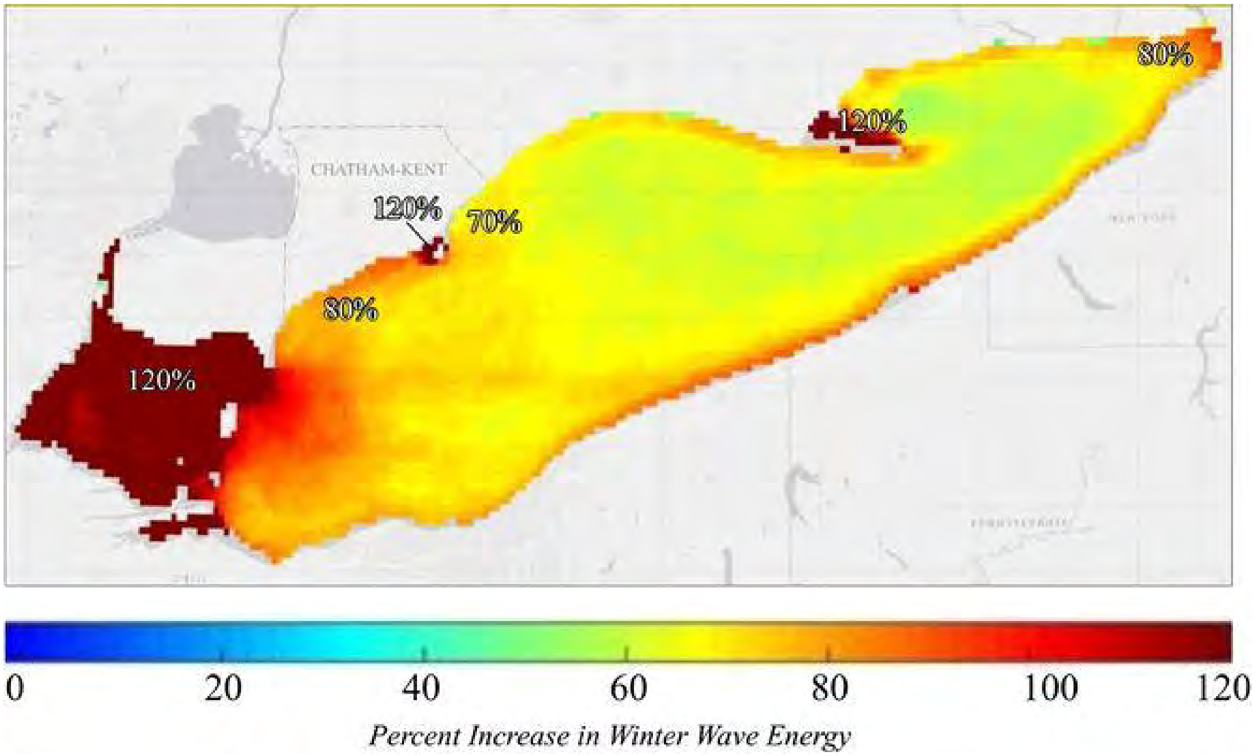


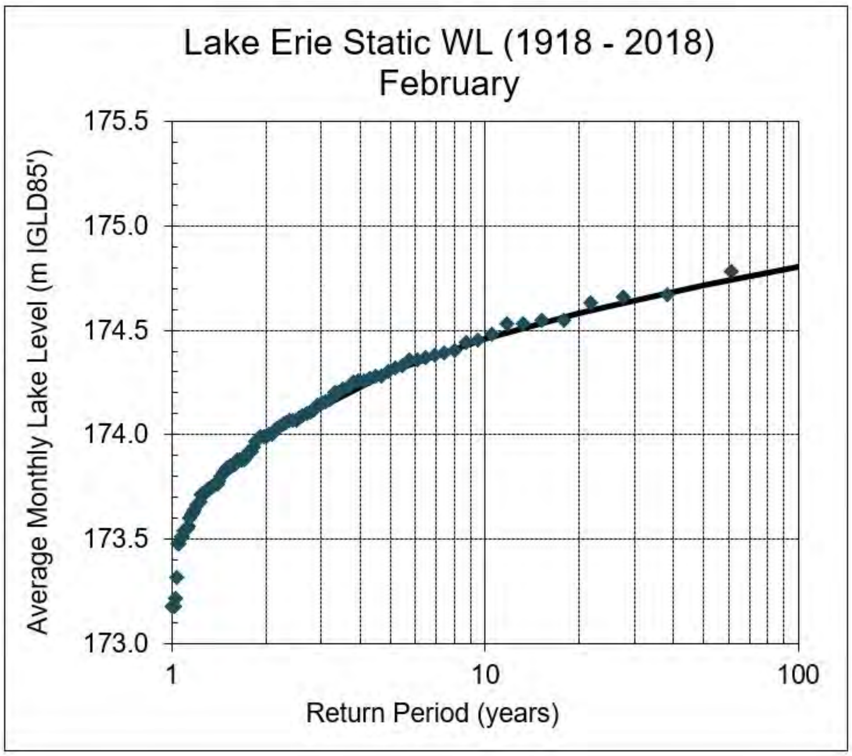

**Figure 3.3 Projected Increase in Winter Wave Energy for RCP8.5 (late century)**

### 3.1.4 Historical Lake Levels and Future Projections

Hourly water levels have been measured by Environment and Climate Change Canada at the Erieau Gauge since 1962. This information was last evaluated by the Ministry of Natural Resources and Forestry (MNRF) in 1989 to establish the 100-year lake level at Erieau, which is derived statistically by evaluating the joint probability of the historical static lake level conditions and the largest storm surge events. A sample of the return period analysis for the static lake levels in February is presented in Figure 3.4. A similar analysis for all the measured historical storm surges at Erieau is presented in Figure 3.5. The results of the joint probability analysis are presented in Table 3.1. The highest monthly 100-year lake level, which is also referred to as the 1% chance lake level, is calculated in April: 175.28 m, IGLD’85 (~1.8 m above Chart Datum, IGLD’85). Interestingly, this level is very similar to the 100-year lake level documented by MNRF in 1989.

**Table 3.1 Joint Probability Analysis for the 100-year Lake Level at Erieau**

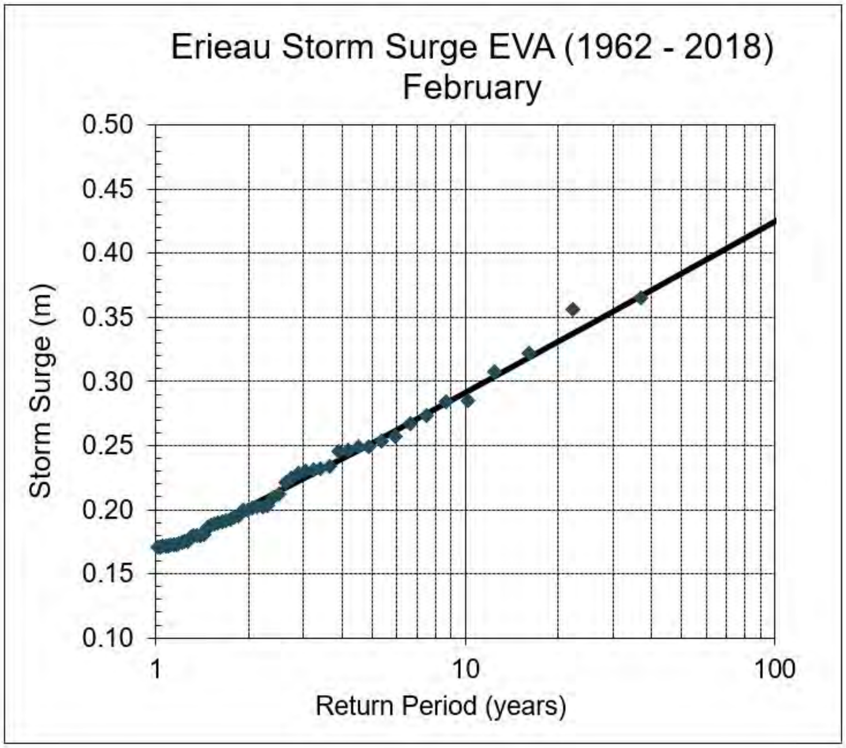
| | Erieau Joint Probability Flood Levels (m IGLD85') | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ARI (years) | Jan (Dec-Feb) | Feb (Jan-Mar) | Mar (Feb-Apr) | Apr (Mar-May) | May (Apr-Jun) | Jun (May-Jul) | Jul (Jun-Aug) | Aug (Jul-Sep) | Sep (Aug-Oct) | Oct (Sep-Nov) | Nov (Oct-Dec) | Dec (Nov-Jan) |
| 1 | 173.75 | 173.70 | 173.75 | 173.91 | 173.99 | 174.00 | 173.98 | 173.93 | 173.89 | 173.82 | 173.78 | 173.76 |
| 2 | 174.22 | 174.20 | 174.27 | 174.41 | 174.49 | 174.49 | 174.47 | 174.40 | 174.35 | 174.27 | 174.22 | 174.22 |
| 5 | 174.52 | 174.51 | 174.60 | 174.72 | 174.77 | 174.77 | 174.74 | 174.66 | 174.61 | 174.54 | 174.51 | 174.52 |
| 10 | 174.67 | 174.67 | 174.77 | 174.88 | 174.91 | 174.89 | 174.87 | 174.78 | 174.73 | 174.67 | 174.65 | 174.67 |
| 20 | 174.79 | 174.80 | 174.91 | 175.01 | 175.02 | 175.00 | 174.97 | 174.89 | 174.84 | 174.77 | 174.76 | 174.79 |
| 25 | 174.83 | 174.84 | 174.95 | 175.05 | 175.05 | 175.03 | 175.00 | 174.91 | 174.86 | 174.80 | 174.80 | 174.83 |
| 50 | 174.94 | 174.95 | 175.07 | 175.17 | 175.14 | 175.12 | 175.08 | 175.00 | 174.95 | 174.89 | 174.89 | 174.93 |
| 100 | 175.05 | 175.06 | 175.19 | 175.28 | 175.22 | 175.20 | 175.17 | 175.07 | 175.03 | 174.97 | 174.99 | 175.03 |
| Corr. Coeff. | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 1.000 | 0.999 |




**Return Period**

| Tr | X(T) |
|---|---|
| 1.5 | 173.84 |
| 2 | 174.00 |
| 5 | 174.30 |
| 10 | 174.46 |
| 20 | 174.58 |
| 25 | 174.62 |
| 50 | 174.72 |
| 100 | 174.80 |
| 200 | 174.88 |
| 500 | 174.98 |

**Figure 3.4 Return Period Analysis for Static Lake Level in February (1918 to 2018)**




**Return Period**

| Tr | X(T) |
|---|---|
| 1.5 | 0.19 |
| 2 | 0.20 |
| 5 | 0.25 |
| 10 | 0.29 |
| 20 | 0.33 |
| 25 | 0.34 |
| 50 | 0.38 |
| 100 | 0.42 |
| 200 | 0.47 |
| 500 | 0.52 |

**Figure 3.5 Return Period Analysis for Storm Surge at the Erieau Gauge (1962 to 2018)**

The historical static Lake Erie water levels, calculated from a coordinated network of water level gauges in Canada and the United States from 1918 to 2019, is plotted in Figure 3.6 (blue line). These data capture the seasonal rise and fall in Lake Erie water levels, plus longer-term trends of high and low lake levels. For example, the lowest recorded static water level on Lake Erie occurred during the drought of the 1930s and lows occurred again in the early 1960s. Extreme high lake levels occurred in the early 1970s, 1986, 1998 and 2019 (a new record high).

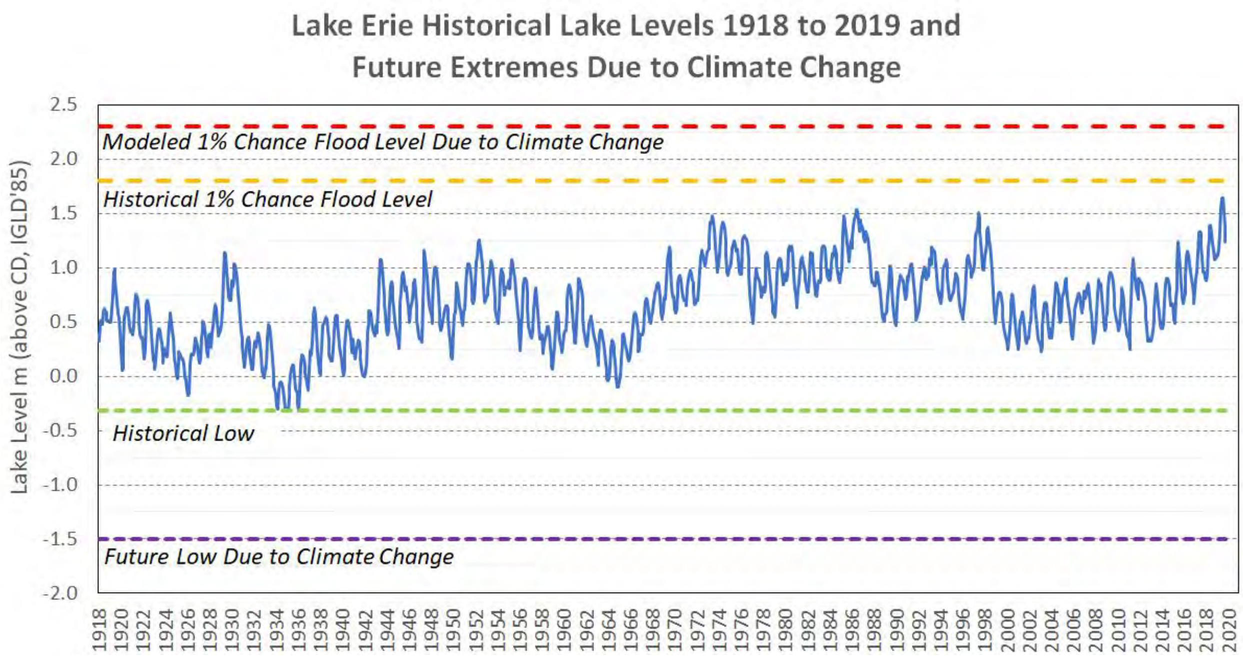



**Figure 3.6 Historical Monthly Mean Lake Erie Water Levels and 1% Chance Flood Levels**

The orange dashed line in Figure 3.6 is the 100-year lake level or 1.8 m above Chart Datum. Historically, this was the recommended elevation for establishing the coastal floodplain in Erieau, based on historical data. However, based on the results of the latest climate change research by ECCC (Seglenieks, 2018), it is no longer possible to predict future extreme lake levels from the historical record because of the evolving climate system. In other words, climate stationarity is no longer a valid assumption. We canot predict future extremes from the recorded historical lake levels.

During recent discussions with ECCC (ECCC, Open File 2020), historical research and ongoing technical studies to review the impacts of climate change on precipitation, evaporation, and ultimately lake levels in the Great Lakes, was reviewed. Collectively, the research on future lake levels suggests future extremes, such as the lows in the 1930s and the new record high of 2019, will become more extreme. In other words, lake levels will reach higher highs and lower lows. Based on the projected future extremes, an additional 0.5 m has been added to the historical 100-year lake level and both will be evaluated. Future low water conditions of 1.5 m below Chart Datum will be considered, which is more than 1.0 m lower than the historical low in the 1930s.

Finally, the latest conditions and projections for spring and summer water levels in 2020 were released by Environment and Climate Change Canada on March 5, 2020 (ECCC, 2020). At the beginning of March, the Lake Erie water level was 86 cm above the long-term average (2018-2019) and 9 cm above the previous record high for the beginning of the month. There is a 50% chance Lake Erie summer levels will peak within 10 cm of the 2019 high and a 5% chance the summer water levels will exceed the 2019 peak. The actual conditions will be related to the amount of rainfall in the Great Lakes basin over the next six months.

## 3.2 Littoral Cell Boundaries and Management Implications

Littoral cells define sediment compartments that contain all the sediment supply zones (e.g., eroding bluffs), transport pathways along the shoreline, and depositional environments where sand and gravel accumulate to stabilize the shoreline or create depositional features. The littoral cell boundary for the Chatham-Kent Lake Erie shoreline is presented in Figure 3.7. Along the Talbot Trail in the west, there is a zone of divergent sediment transport around Port Alma. The sediment that erodes from the bluffs west of Port Alma is transported towards Wheatley. Conversely, the bluff erosion from Port Alma to Erie Beach produced new supplies of sand and gravel that are transported toward the Rondeau peninsula. Sand and gravel eroded from the bluffs east of Rondeau Bay is transported to the southwest and supplies material for the beaches in the Provincial Park.

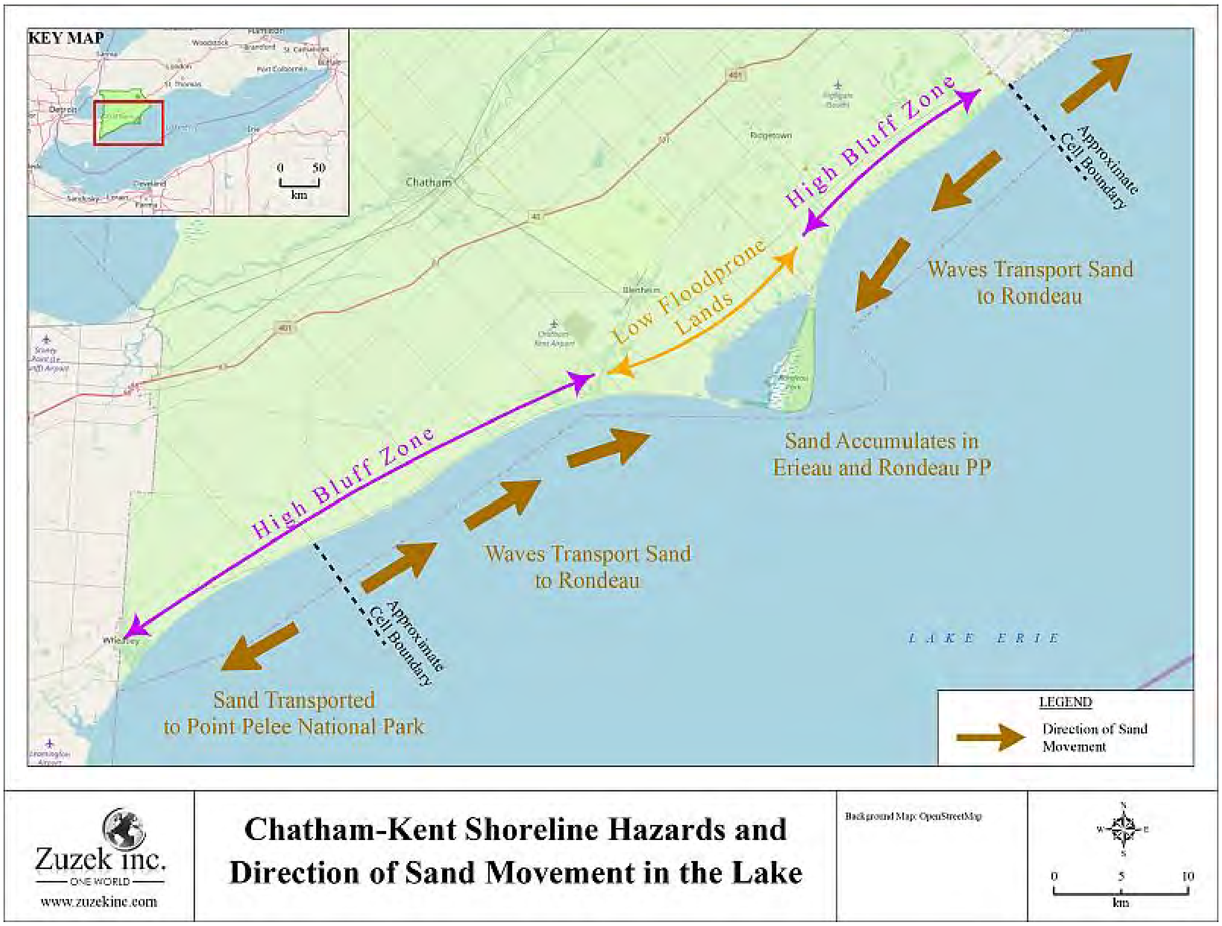



**Figure 3.7 Rondeau Bay Littoral Cell Boundaries**

Understanding littoral cell boundaries and processes is important when formulating coastal management alternatives, since decisions such as shoreline armouring in one region can result in unintended negative consequences in another area. For the Chatham-Kent Lake Erie shoreline, decisions to armour the bluffs east and west of Rondeau Bay, for example, would have a negative impact on the sandy shorelines in Erieau, the Provincial Park, and Rose Beach Line.

## 3.3 Shoreline Change Rates

Shoreline change rates can be measured at different temporal and spatial scales. For this study, we are interested in long-term rates that are representative of the overall trend for many decades (e.g., greater than 50 years), to support the vulnerability assessment and the selection of appropriate adaptation options. The methods and results from the shoreline change analysis within the study area are described in the following sections.

### 3.3.1 Bluff Recession Rates

The glacial sediment bluffs east and west of Rondeau have been eroding for thousands of years in response to lakebed downcutting, wave attack at the bluff toe, and upper slope failures due to groundwater movement/seepage. The sediment eroded from these bluffs is transported along the shoreline and ultimately deposited in the Rondeau Bay sand spit, as outlined in the littoral cell diagram in Figure 3.7. The eroded material in the west is transported toward Point Pelee National Park.

To quantify the long-term erosion rates along the bluff shorelines, the position of the top of bank was digitized in the 1955 aerial photography and the 2015 orthophotography. Then, shore perpendicular transects were measured at 20 m intervals along the shoreline between the 1955 and 2015 top-of-bluff lines. This analysis is depicted graphically in Figure 3.8 (yellow lines) for the Bluff Line area. In locations where either the historical or recent top of bluff are not discernable, no transect measurements are completed. Plus, areas with existing shoreline protection, which bias the long-term erosion rate, are also left out of the analysis.

Section A-B, which is shown in plan view in Figure 3.8, is presented in Figure 3.9. The location of the 1955 and 2015 bluff crests are noted, along with the abandoned road and new alignment of Bluff Line. The bluff has retreated 84 m in 60 years, for an annualized long-term recession rate of 1.4 m/yr. It is important to note that it is not just the bluff above the waterline that is eroding. As seen in Figure 3.9, the lake bottom also erodes as the bluff face migrates inland. The process is known as lakebed downcutting.

The individual bluff recession transects were grouped spatially and annualized (AARR: average annual recession rates). The results are presented in Figures 3.10 and 3.11. The black and grey transects identify four different spatial groups of transects, which were further analyzed statistically in Table 3.2. The long-term recession rates range from 0.21 to 1.39 m/yr.

**Table 3.2 Long-term Recession Rates for the Study Shoreline**

| | 20m Transects (unprotected) | | | | | |
|---|---|---|---|---|---|---|
| | Number of Transects | Transect Length (m) | Avg. Annual Recession Rate (m/yr) | Transect Std. Dev. (m) | Std. Dev (m/yr) | AARR+Std Dev. (m/yr) |
| **WEST** | | | | | | |
| Wheatley to Hodovick Road | 59 | 68.0 | 1.13 | 15.1 | 0.25 | 1.39 |
| Hodovick Road to Erie Beach | 689 | 25.3 | 0.42 | 9.0 | 0.15 | 0.57 |
| **EAST** | | | | | | |
| Rondeau to 490m East of Taylor Road | 85 | 9.0 | 0.15 | 3.4 | 0.06 | 0.21 |
| 490m East of Taylor Road to CK-Elgin County Line | 215 | 28.6 | 0.48 | 9.9 | 0.17 | 0.64 |

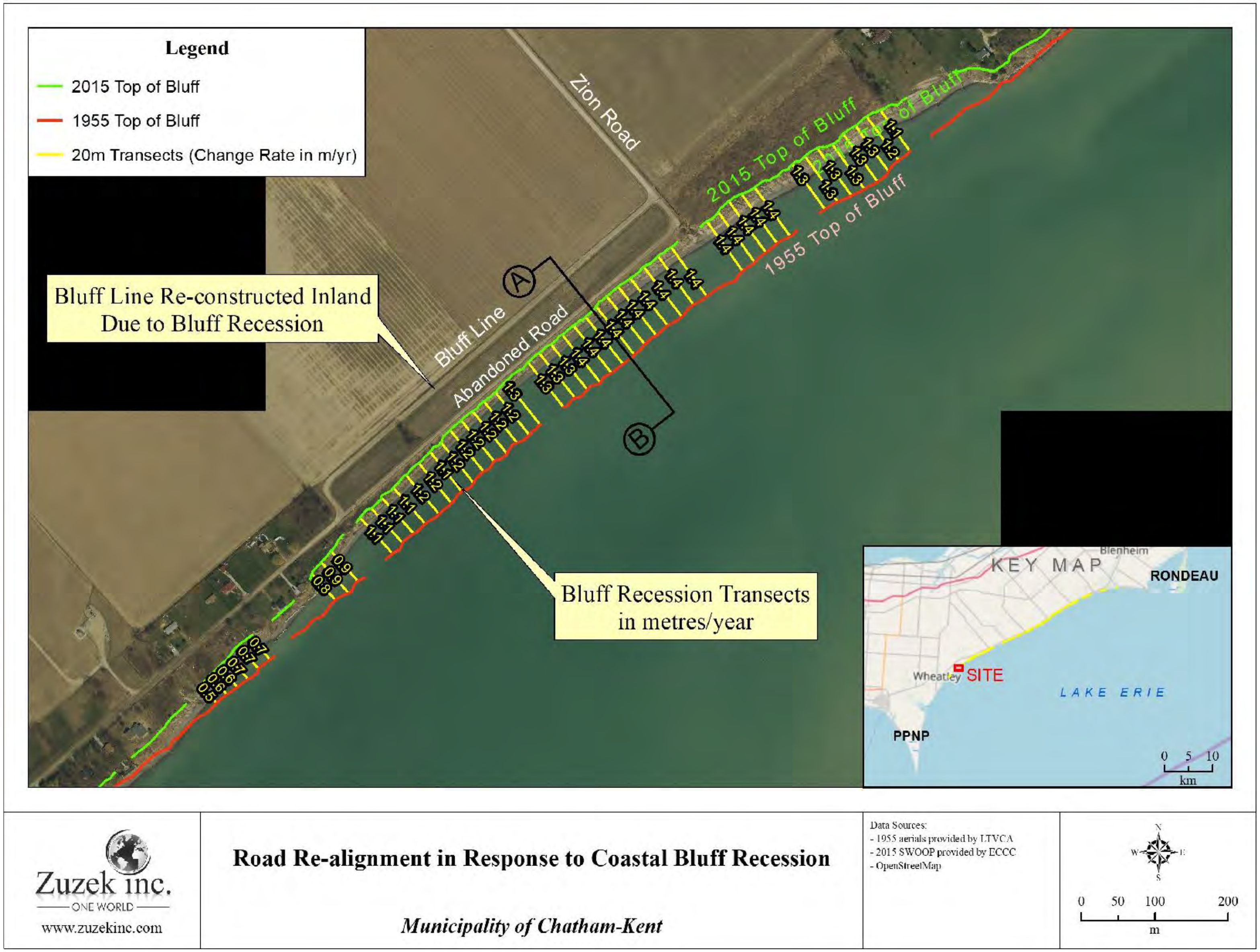



**Figure 3.8 Bluff Line Recession Transects from 1955 to 2015 (m/yr)**

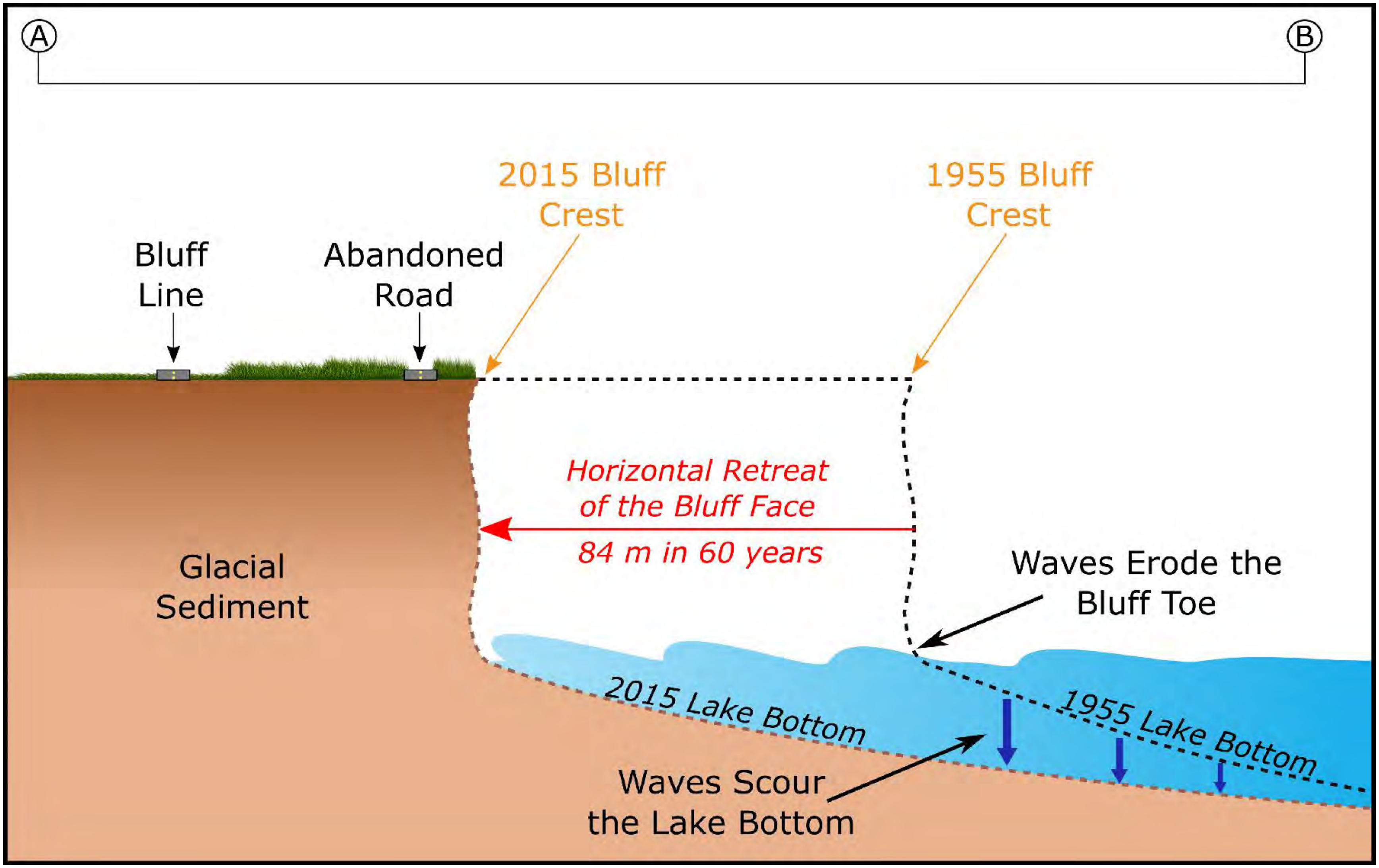



**Figure 3.9 Schematic Diagram of Bluff Erosion at Transect A-B**

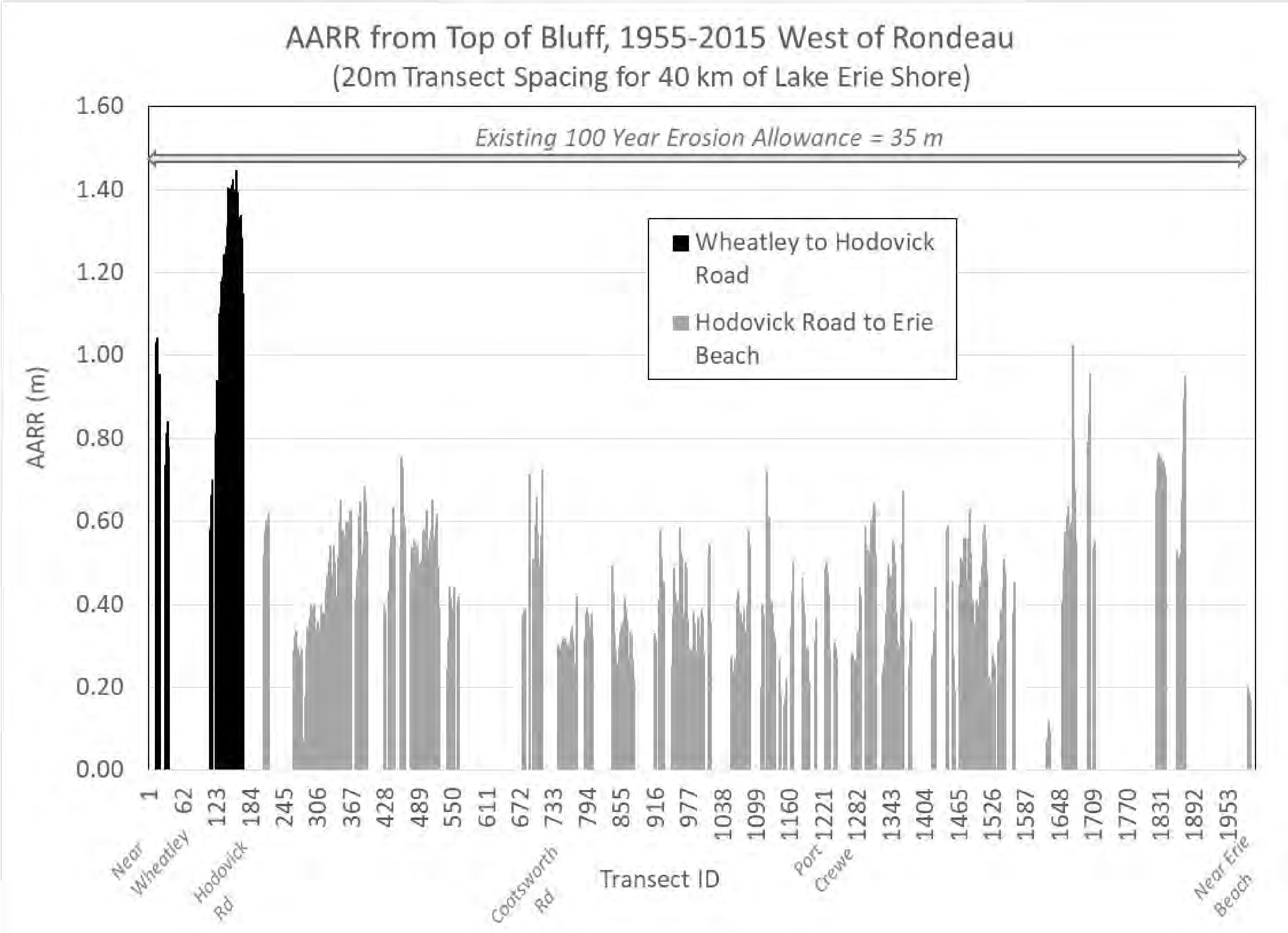



**Figure 3.10 Bluff Recession Transects West of Erieau (1955 to 2015)**

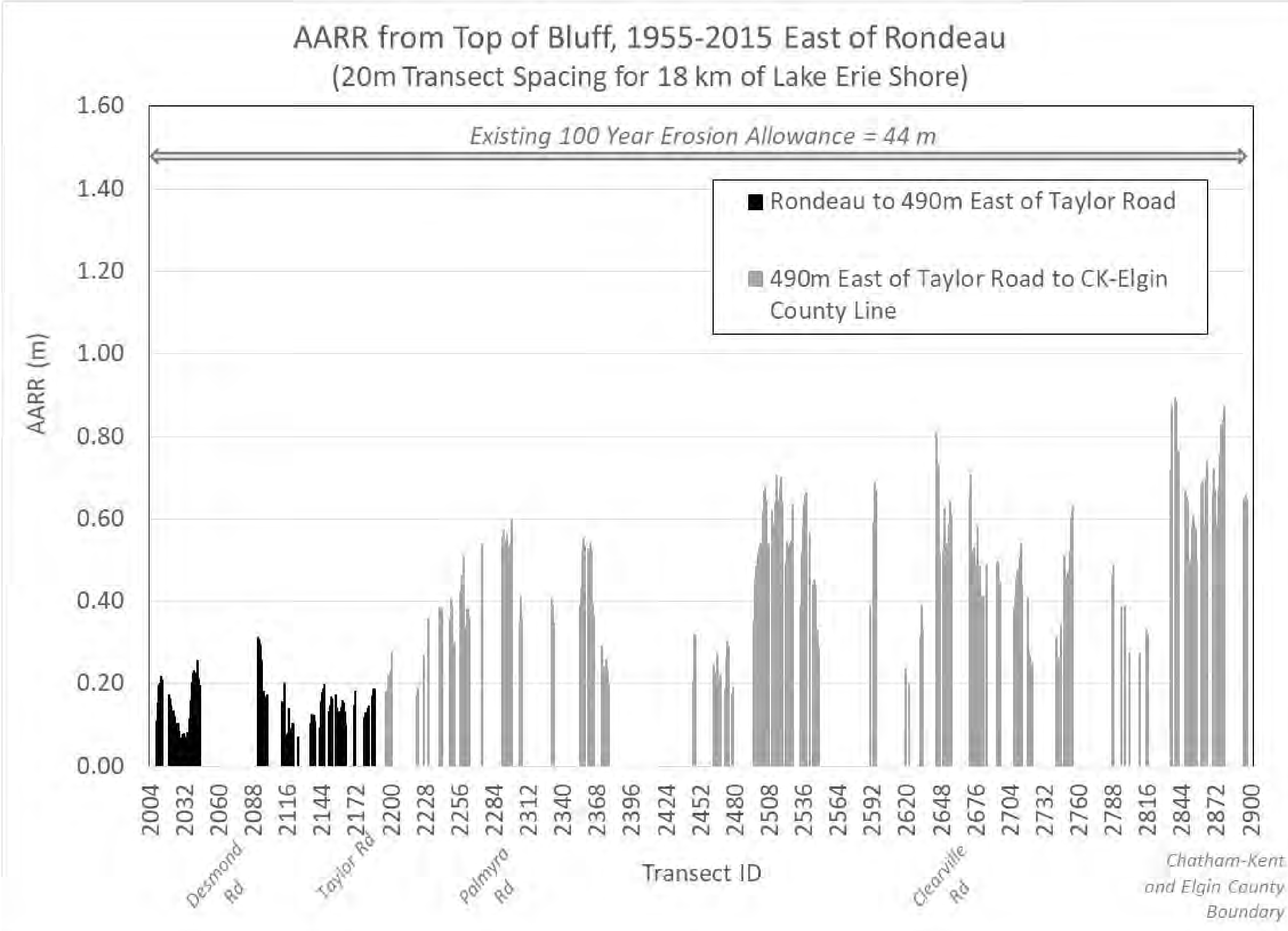



**Figure 3.11 Bluff Recession Transects East of Erieau (1955 to 2015)**

### 3.3.2 Rondeau Barrier Beach Evolution

The evolution of the Rondeau Barrier over the last 8,000 years was documented by Coakley (1989). Over this period, Lake Erie water levels increased roughly 8 m to their present range. The location of the Rondeau peninsula 2,000 years before present, when Lake Erie water levels were several meters lower, is presented in Figure 3.12 (left image, modern shoreline is a dashed line). As water levels continued to rise to their current range, Rondeau peninsula migrated onshore to its present location (right image in Figure 3.12).

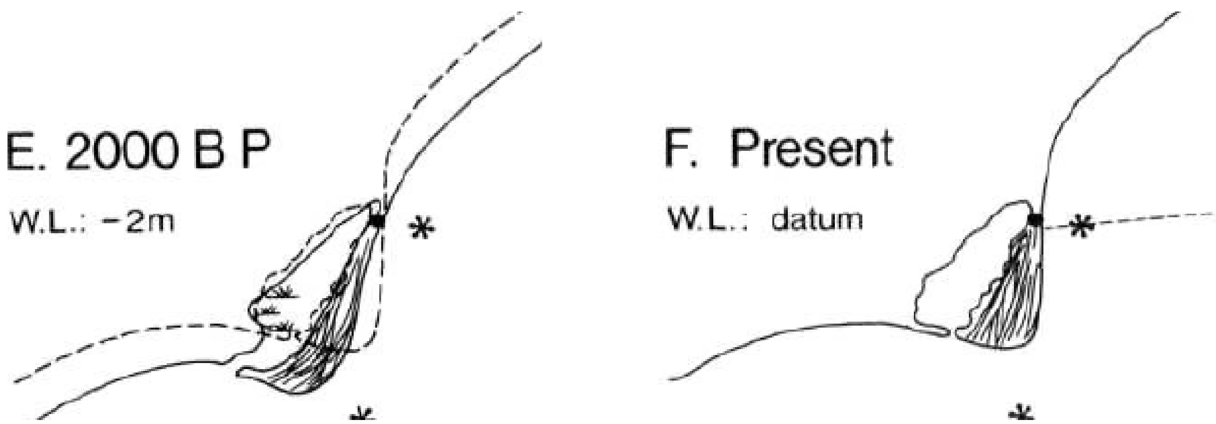



**Figure 3.12 Evolution of the Rondeau Peninsula, 2000 Years Ago to Present (Coakley, 1989)**

The coastal conditions in the mid-1800s were documented in Section 2.1. Since the mid-1800s when the first seawall was constructed and the navigation channel was stabilized, the evolution of the Rondeau Peninsula has been influenced by human disturbances. By trapping sediment on the west side of the navigation channel, the jetties have starved the tip of the peninsula, now the provincial park, from their natural supply of sand and gravel. The barrier beach was located at the mid-point of the east jetty in 1868. In response to the loss of sediment supply, the shoreline has responded by switching to an erosional state and has been migrating north for more than 150 years.

Figure 3.13 was taken from the east jetty, at the location of the old Lighthouse. The tip of the peninsula and marsh are seen in the distance. There was even a house (white) located on the barrier beach east of the east jetty (Figure 3.13). The rock berm in Figure 3.13 is still present on the 1974 provincial map of the navigation channel presented in Figure 3.14. However, the barrier is only attached by a thin tombolo (sand spit) and the remainder of the barrier beach has migrated substantially to the north (inland).

By the earlier 2000s, the rock berm was nearly submerged, as seen in Figure 3.15. The barrier beach continued to migrate north into the marsh, but a large depositional feature started to grow adjacent to (east of) the navigation channel, as seen in Figure 3.15.

The evolution of the Rondeau Provincial Park shoreline from 1868 to 2018 is presented in Figure 3.16, which chronicles 650 m of erosion over a 150-year period. West of the navigation channel, the opposite trend is observed, with steady advance of the shoreline in a lakeward direction due to the sand trapped by the west jetty. Figures 3.17 and 3.18 provide further information on the shoreline change rates east and west of the navigation channel. It is worth noting that while the southern tip of the Provincial Park has been eroding for 150 years, there has been some accretion along the southeastern shore of the park since 1955 (150 m in some locations).

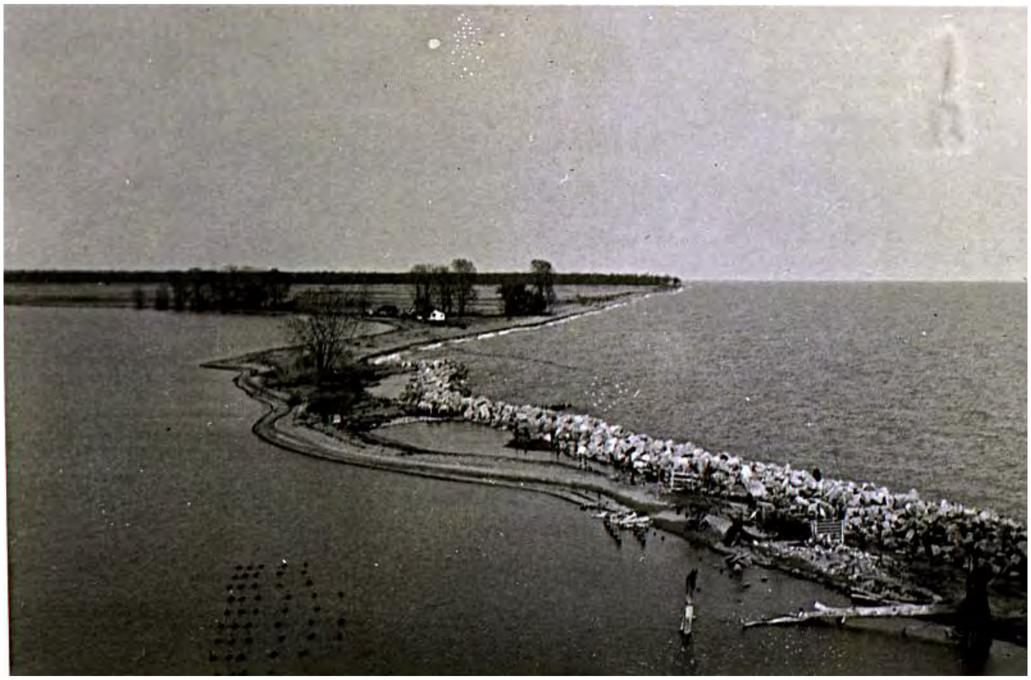


**Figure 3.13 Barrier Beach Looking East from Old Lighthouse, date unknown (image courtesy of J.Vidler)**

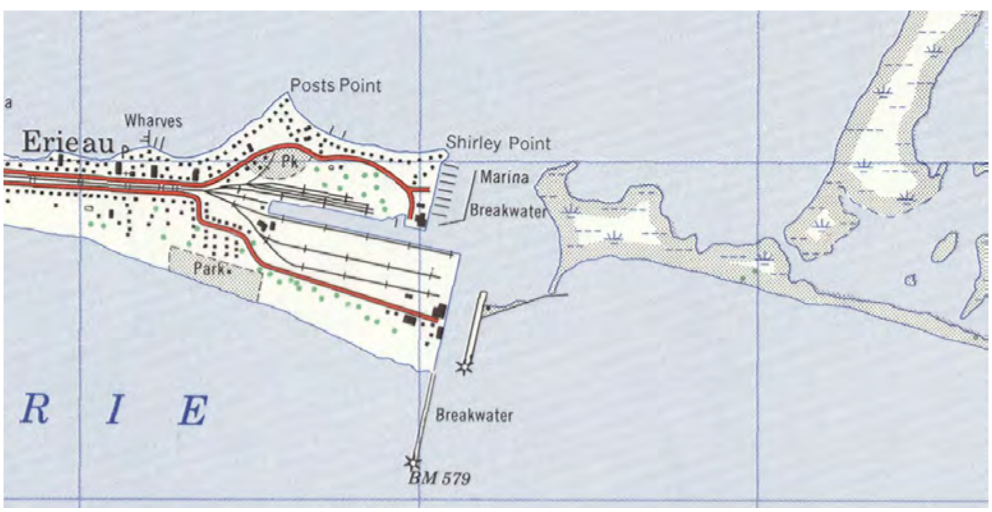



**Figure 3.14 1974 Navigation Channel (Image Courtesy of the Chatham-Kent Museum)**


**Figure 3.15 Navigation Channel and Erieau Looking West, 2002 (image courtesy of J.Vidler)**

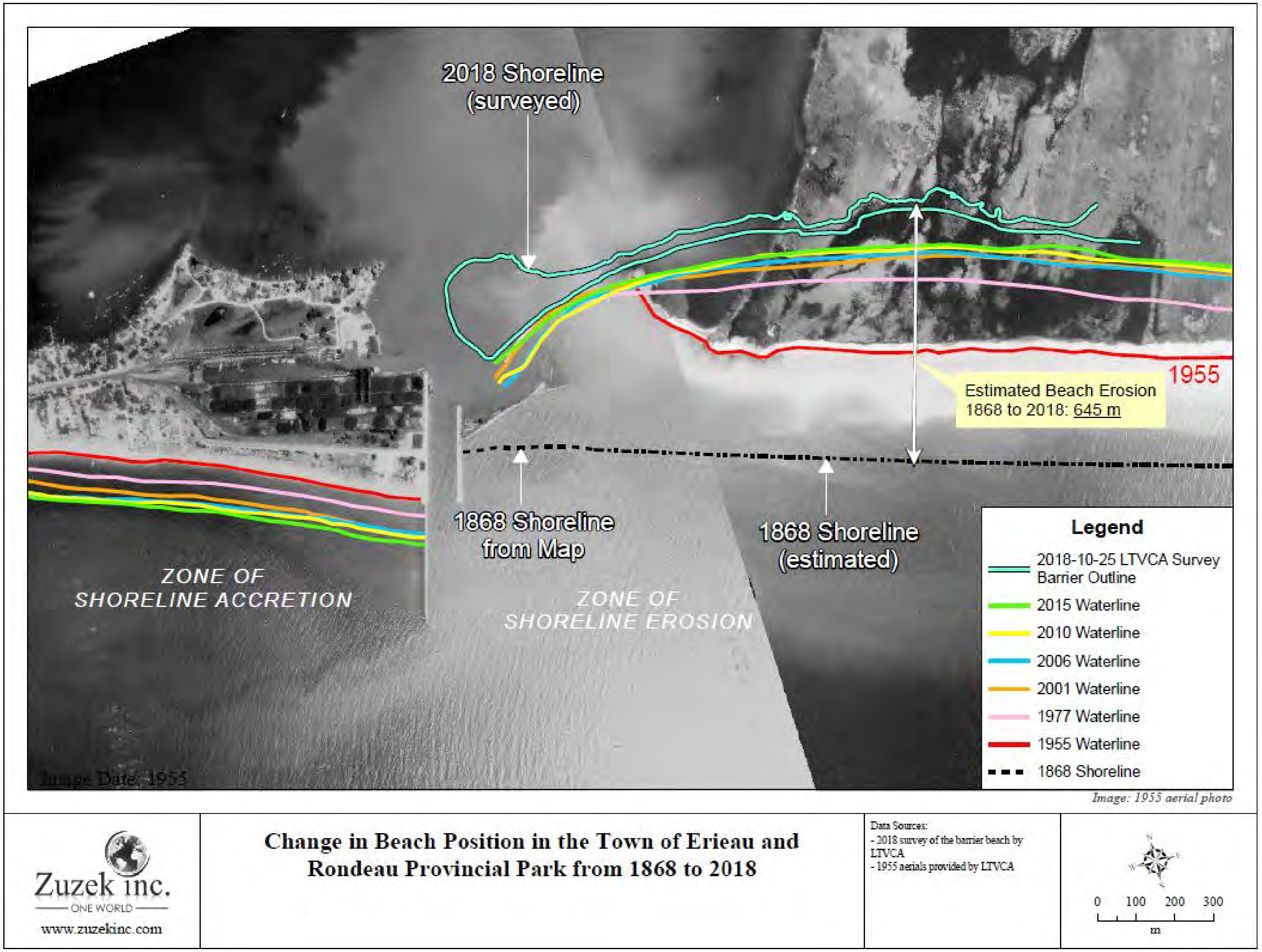



**Figure 3.16 Deposition and Erosion Trends West and East of the Navigation Channel**

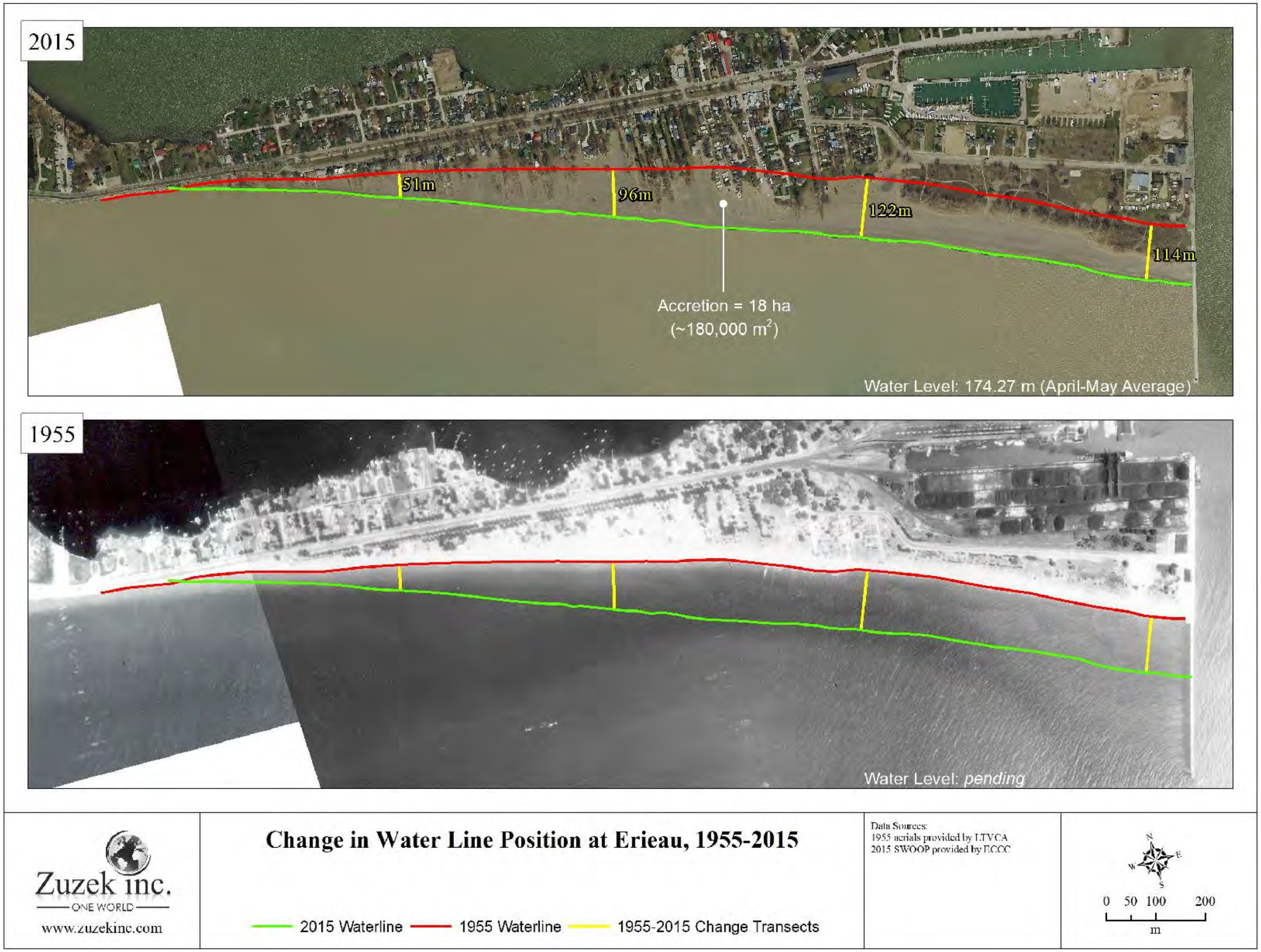



**Figure 3.17 Shoreline Change Rates for the Erieau Fillet Beach from 1955 to 2015**

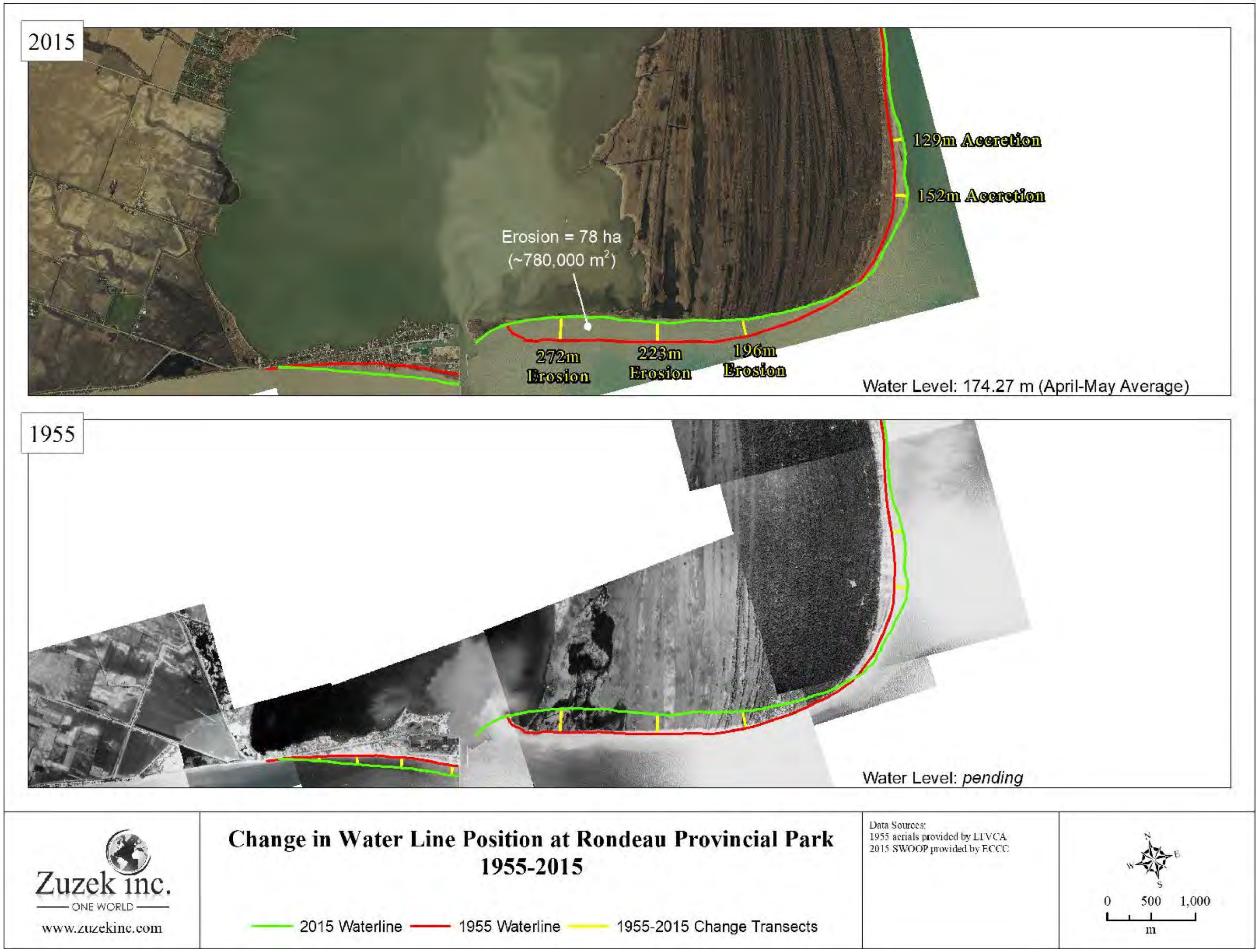



**Figure 3.18 Erosion and Depositional Trends for the Rondeau Peninsula**

### 3.3.3 Lake Bottom Profiles from Erieau to Erie Beach

The location of the lake bottom profiles surveyed along Erieau, Erie Shore Drive, and Erie Beach are presented in Figure 2.48. Line 2 is typical of the conditions at the west fillet beach in Erieau and is presented in Figure 3.19, along with the 2017 topographic LiDAR.

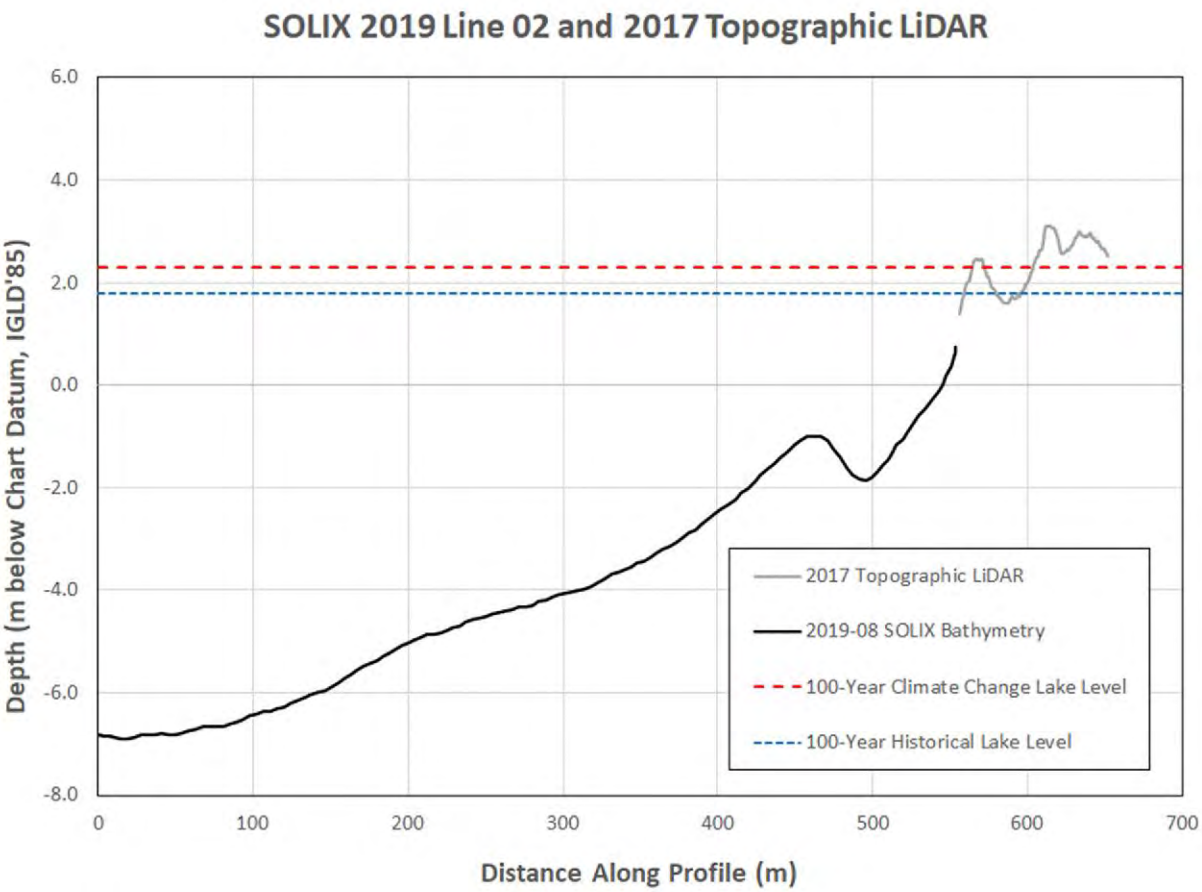



**Figure 3.19 Profile 2 at the Erieau West Beach**

Line 7 is located along Erie Shore Drive and the 2019 lake bottom profile is compared to the 1938 survey in Figure 3.20. There has been dramatic downcutting of the nearshore profile in front of the shore protection at Line 7. In 1938, the depth of water below the 100-year lake level was 2.2 m. When climate change and the lake bottom erosion over the last 80 years is considered, the depth of water in front of the wall is 4.3 m or almost double. Line 7 highlights the dual risk of higher high lake levels and lake bottom erosion along armoured shorelines.

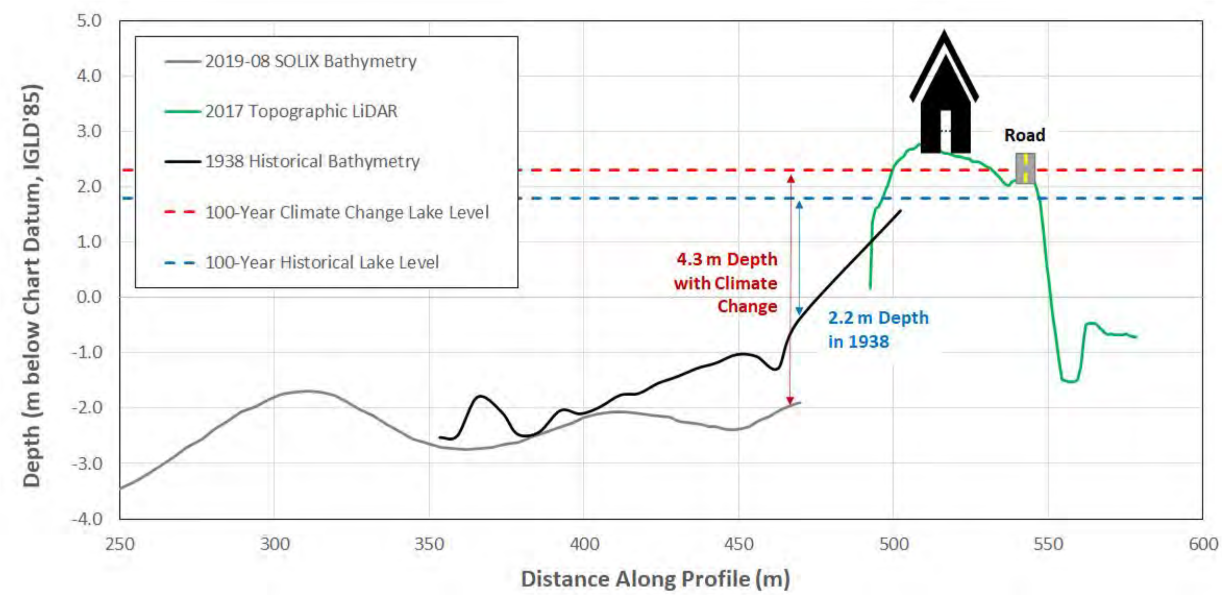



**Figure 3.20 Erie Shore Drive Line 7 in 1938 and 2019**

Line 13 was collected along the Erie Beach shoreline in the middle of the community. Figure 3.21 presents the 2019 lake bottom survey and the 2017 topographic LiDAR elevations. The land elevations are ~4 m above chart datum or almost 2 m higher than the 100-year lake level with climate change integrated. The comparison of the land elevations at Line 7 along Erie Shore Drive and Line 13 in Erie Beach contrast the different flood exposure between the two communities.

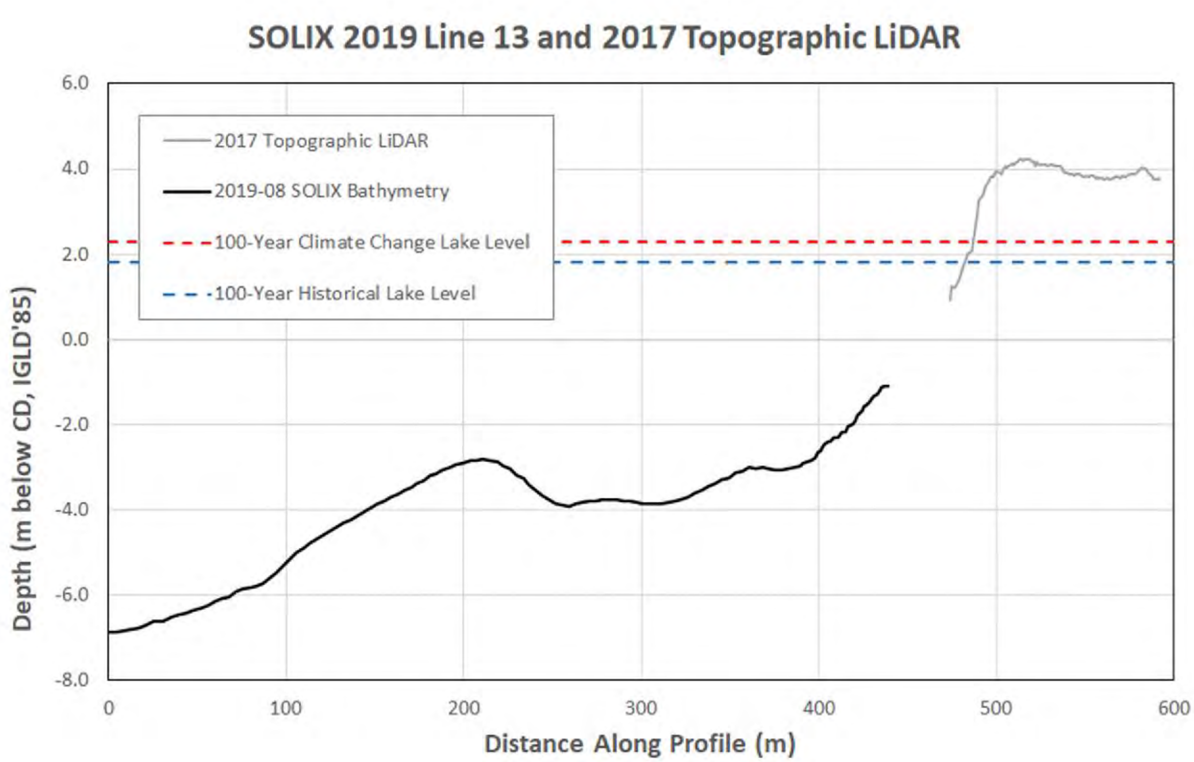



**Figure 3.21 Erie Beach Line 13 in 2019**

# 4.0 VULNERABILITY ASSESSMENT

Section 4.0 describes the methodology for the coastal hazard vulnerability assessment and results for the Chatham-Kent Lake Erie Shoreline Study.

## 4.1 Methodology

The methodology developed and applied for the erosion, flooding, low-water impacts, wetlands, nearshore water quality, sedimentation in the navigation channel, and changes in wave exposure in Rondeau Bay are described.

### 4.1.1 Property Parcel and Building Database

A digital property parcel and building database was obtained from the Municipality of Chatham-Kent in May 2019. The parcel data also included MPAC (Municipal Property Assessment Corporation) assessment data. The following methodology was followed to update and clean up the datasets for the vulnerability assessment:

1. The building polygon layer was reviewed for all areas susceptible to erosion and flooding along the Lake Erie shoreline. Missing building footprints were added or expanded as required to represent current conditions.

2. Buildings were attributed based on type, including primary (house), secondary (detached garage/out building), other (buildings <100 ft$^2$), trailers/mobile homes, and unknown (could not be identified with aerial image, street view software, or no longer present). Refer to Figure 4.1 for an example of the property parcel data and building footprints.

3. A GIS function (join by location) was used to link buildings inside their appropriate property parcel.

4. The MPAC assessment values do not distinguish between land and building values. Therefore, algorithms were developed to assign weightings for the value to land, primary and secondary buildings.


**Figure 4.1 Example of Property Parcels and Building Footprints**

### 4.1.2 Future Top of Bluff Projections

The measured bluff recession rates described in Section 3.4.2 were utilized to estimate the future position of the top of the bluff in 50 years. Since it is not possible to predict future storms, there is uncertainty in the predicted future top of bluff position. Therefore, a band or range is used based on the following calculations:

- Lakeward Limit: Is the sum of the stable slope allowance (3:1 H:V) measured from the toe of bluff plus 50 times the Average Annual Recession Rate. This landward edge features a 50% confidence limit (i.e., there is a 50% chance the bluff will erode faster).

- Landward Limit: the stable slope allowance (3:1 H:V) measured from the toe of bluff plus the Average Annual Recession Rate plus two standard deviations of the transect population times 50. This landward limit has a 97% confidence limit (there is a 97% change the bluff crest position will be lakeward of this line in 50 years).

A sample of the future top of bluff estimate is provided in Figure 4.2. The attributed buildings (primary and secondary) plus the property parcels are also included. All buildings that are located between the lake and the landward limit of the estimated future top of bluff were selected for the vulnerability assessment.

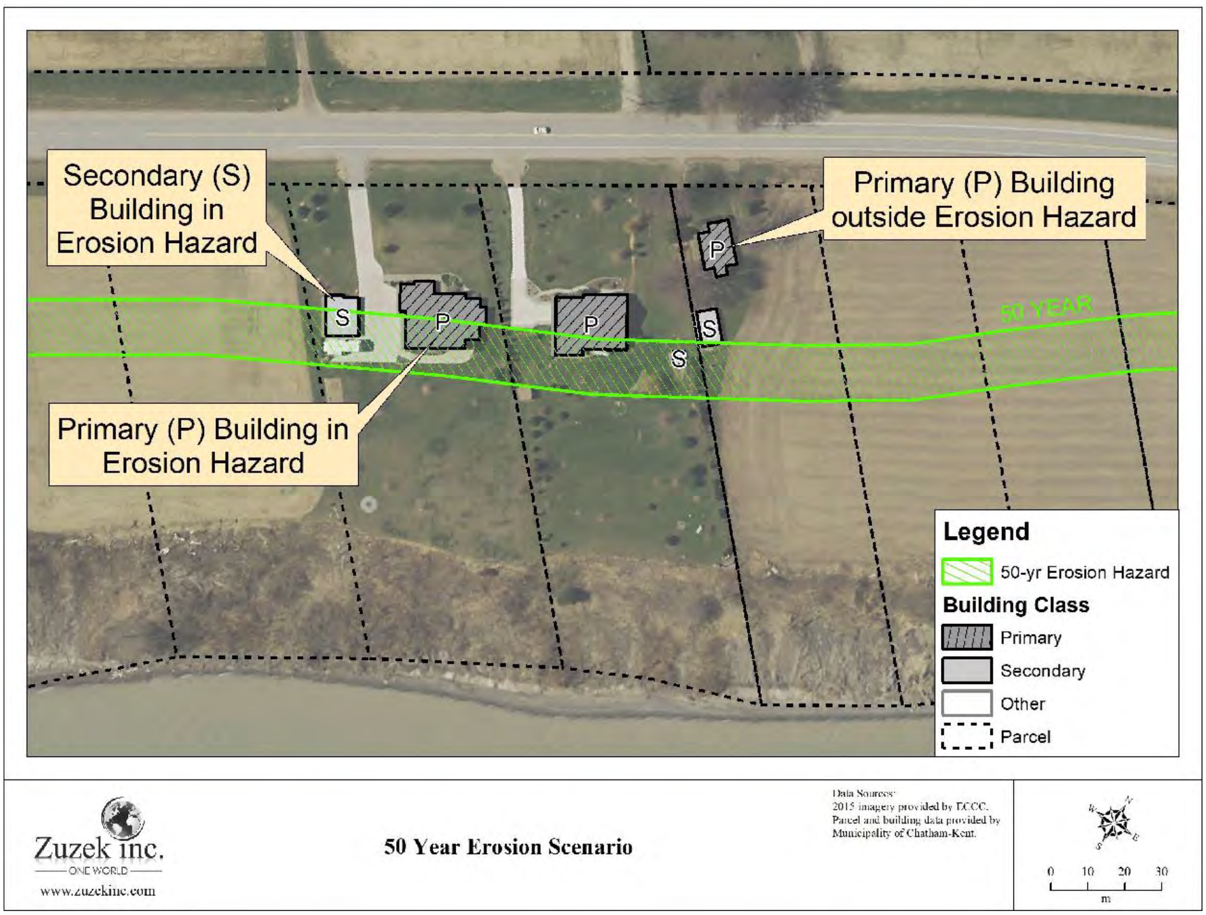



**Figure 4.2 Buildings and Property Parcels within the 50-Year Top of Bluff Estimate**

### 4.1.3 Flood Inundation Calculations

The property parcel and building database was also used for the flooding vulnerability assessment. The risk analysis focused on buildings and roads for the 1% chance flood level based on historical measured lake levels and the influence of climate change on future extremes. As documented in Section 3.2, the mid-century estimate for the influence of climate change on lake levels is more extreme conditions. In other words, higher highs and lower lows based on the latest ECCC research (Seglenieks, 2018 and ECCC Open File, 2020). The 100-year lake level of 175.3 m (IGLD’85) was used for the analysis, along with 175.8 m (IGLD’85) for the climate change 100-year lake level.

Figure 4.3 shows an example of the building polygon database for both primary and secondary structures, plus the extent of flooding for the 100-year lake level. Buildings that overlap with the flooded surface are selected for the vulnerability assessment.

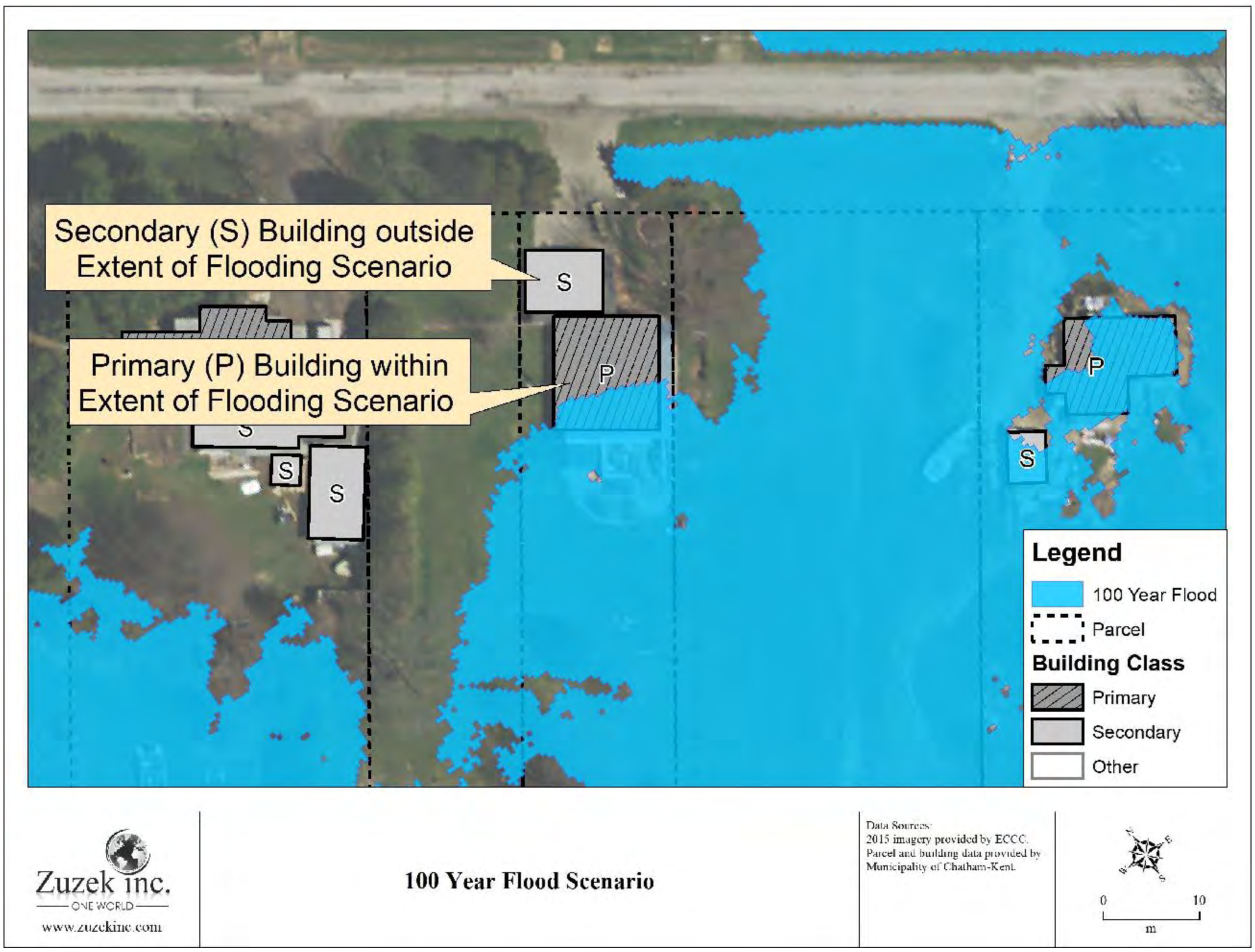



**Figure 4.3 Example of Overlay for Buildings with 100-Year Lake Level**

### 4.1.4 Other Impacts

Although the focus of the vulnerability assessment was on buildings and road infrastructure, the following additional impacts were reviewed:

- ***Low Water Impacts:*** Low water conditions can challenge the resilience of coastal communities by reducing depths in navigation channels and marina basins, plus isolate fixed docking systems from the lake. With Lake Erie establishing a new record high lake level in 2019, low water impacts are not topical but will be considered in the study when evaluating long-term adaptation concepts to increase community resilience to coastal hazards.

- ***Wetland Impacts***: At this time, a comprehensive ecosystem impact assessment related to coastal erosion and flooding is beyond the scope of this investigation. However, changes in the spatial extent of the coastal wetlands in Rondeau Bay has been reviewed and will be documented.

- ***Water Quality***: Although not a focus of the investigation, local water quality issues including nutrient runoff and private septic systems and weeping beds will be briefly reviewed.

- ***Sedimentation in the Navigation Channel***: The depth of the Federal Navigation Channel in Erieau is between 12 to 25 ft deep. Therefore, sedimentation currently does not affect safe navigation for the smaller vessels using the channel. However, the impacts of the detached eastern jetty will be evaluated and access to Rondeau Bay will be reviewed.

- ***Changes to Wave Exposure in Rondeau Bay***: The barrier beach that shelters the southern reaches of Rondeau Bay from Lake Erie is currently breached and has migrated inland more than 100 m in five years. The implications of a permanent breach on lake waves propagating to the bay will be reviewed.

## 4.2 Erosion Assessment Results

The erosion vulnerability assessment results were sub-divided into three zones as follows: 1) East boundary of Wheatley Provincial Park to Campbell Road, 2) Campbell Road to Charing Cross Road, and 3) the bluffs east of Rondeau Provincial Park. Refer to Figure 4.4 below for the three zones and the following sections for the results. Examples of the future top of bluff mapping are provided in Figures 4.5 and 4.6.

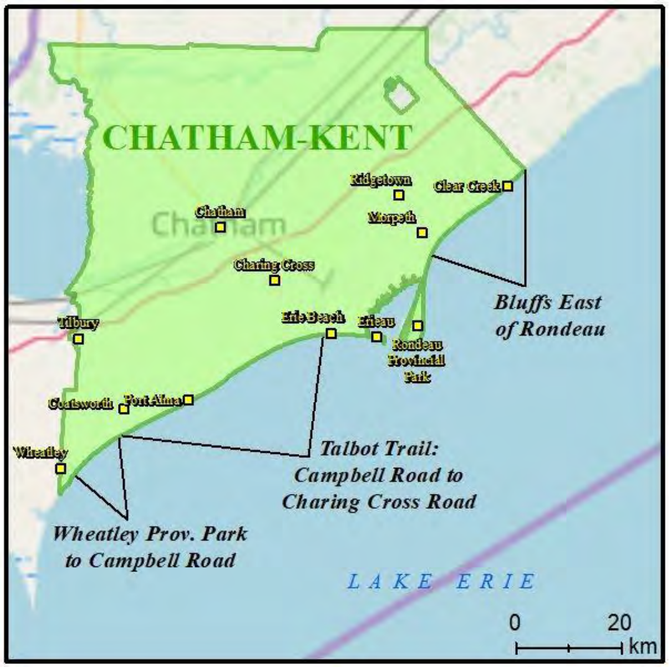



**Figure 4.4 Erosion Assessment Areas for Buildings**

### 4.2.1 Wheatley Provincial Park to Campbell Road

The proximity of the shoreline development to the 50-year top-of-bluff estimate adjacent to Wheatley Provincial Park is presented in Figure 4.6, Panel 4. Approximately 2.4 km of the lakefront development is projected to be impacted by erosion in 50 years, or less due to the impacts of climate change. As summarized in Figure 4.7, a total of 144 primary or secondary buildings were identified in the vulnerability assessment, with a total assessed value of $16.9 million.

Several sections of local roads are also projected to be impacted by erosion in 50 years or less, including Bluff Line, which was already re-located further inland. Refer to Panel 4 in Figure 4.6. Talbot Trail is located further inland and not impacted.

### 4.2.2 Campbell Road to Charing Cross Road (Talbot Trail Section)

The impacts of the projected 50-year top of bluff for the Talbot Trail section are summarized in Figure 4.5. A total of five locations are impacted by the future top of bluff position, including the existing closure at Coatsworth Road. This section of Talbot Trail was already moved once due to bluff erosion and the potential for a bluff failure causing a closure of the road.

A total of 295 primary and secondary buildings are projected to be impacted by erosion in 50 years or less for the 33 km section of Talbot Trail from Campbell Road to Charing Cross Road. The assessed value of the buildings is $42.8 million.

### 4.2.3 Bluffs East of Rondeau

The bluffs east of Rondeau Provincial Park feature a much lower density of shoe-string development along Lake Erie compared to the Talbot Trail. Consequently, only 39 primary and secondary buildings were identified by the erosion vulnerability assessment, with a combined assessed value of $6.5 million.

Rose Beach Line is presently closed east of Antrim Road and two sections of the road in this area were identified in the vulnerability assessment. Refer to Figures 4.6. Beyond Hill Road, the Talbot Trail becomes the west to east artery but is located 1.6 km to 2.4 km from Lake Erie and not at risk.

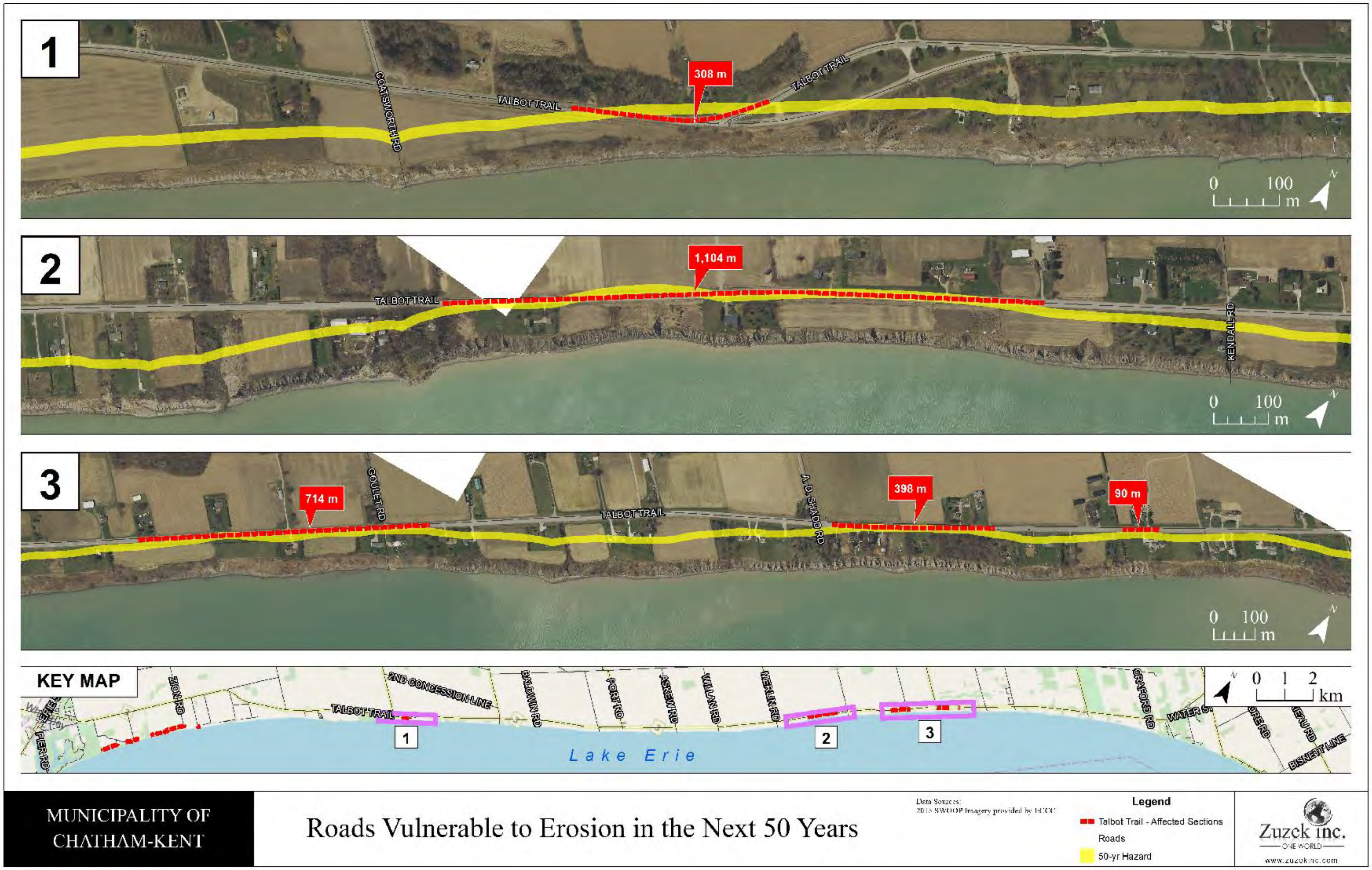



**Figure 4.5 Estimated 50-year Top of Bluff based on Historical Erosion Rates for Areas 1 to 3**

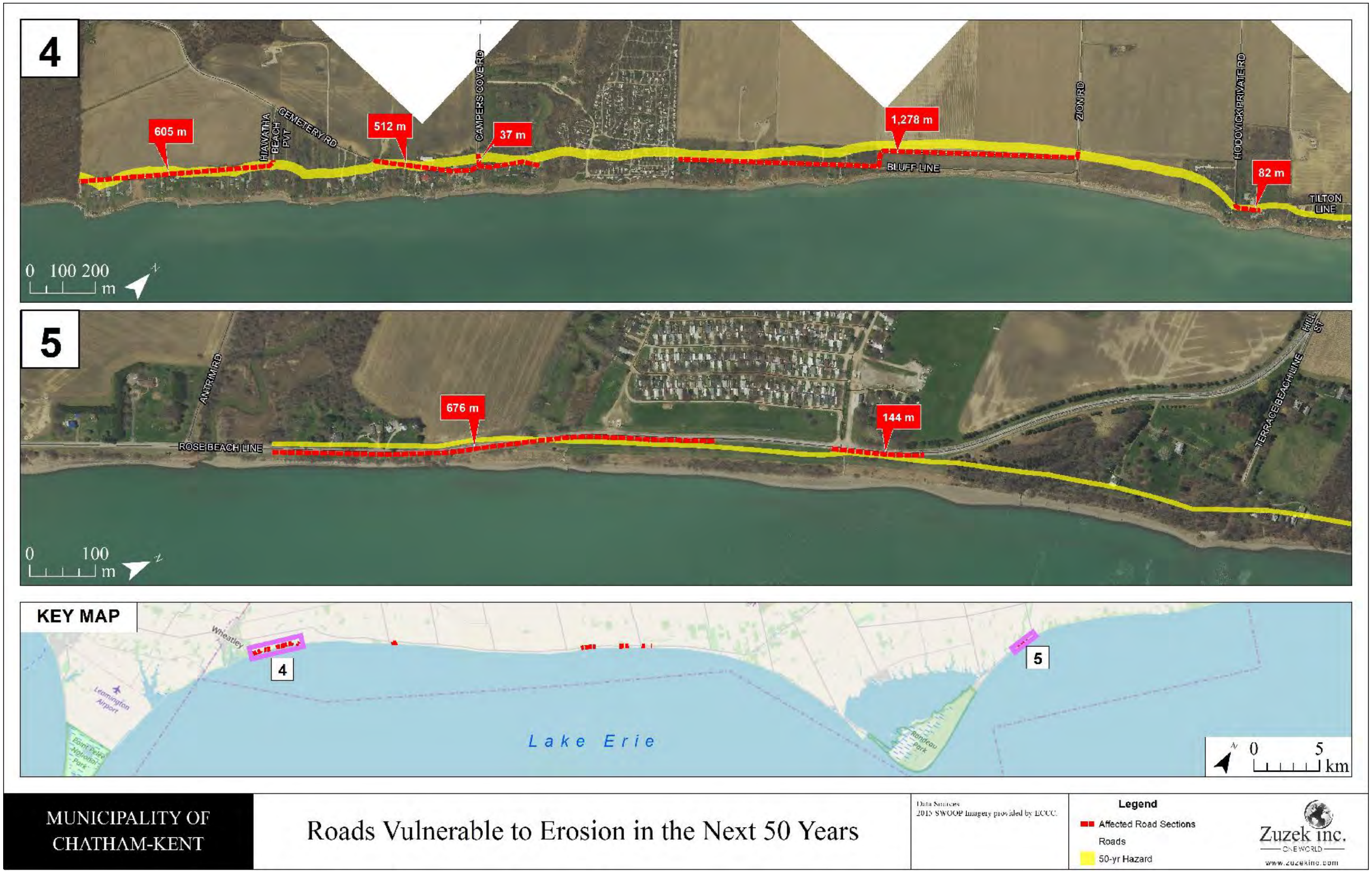



**Figure 4.6 Estimated 50-year Top of Bluff based on Historical Erosion Rates for Areas 4 and 5**

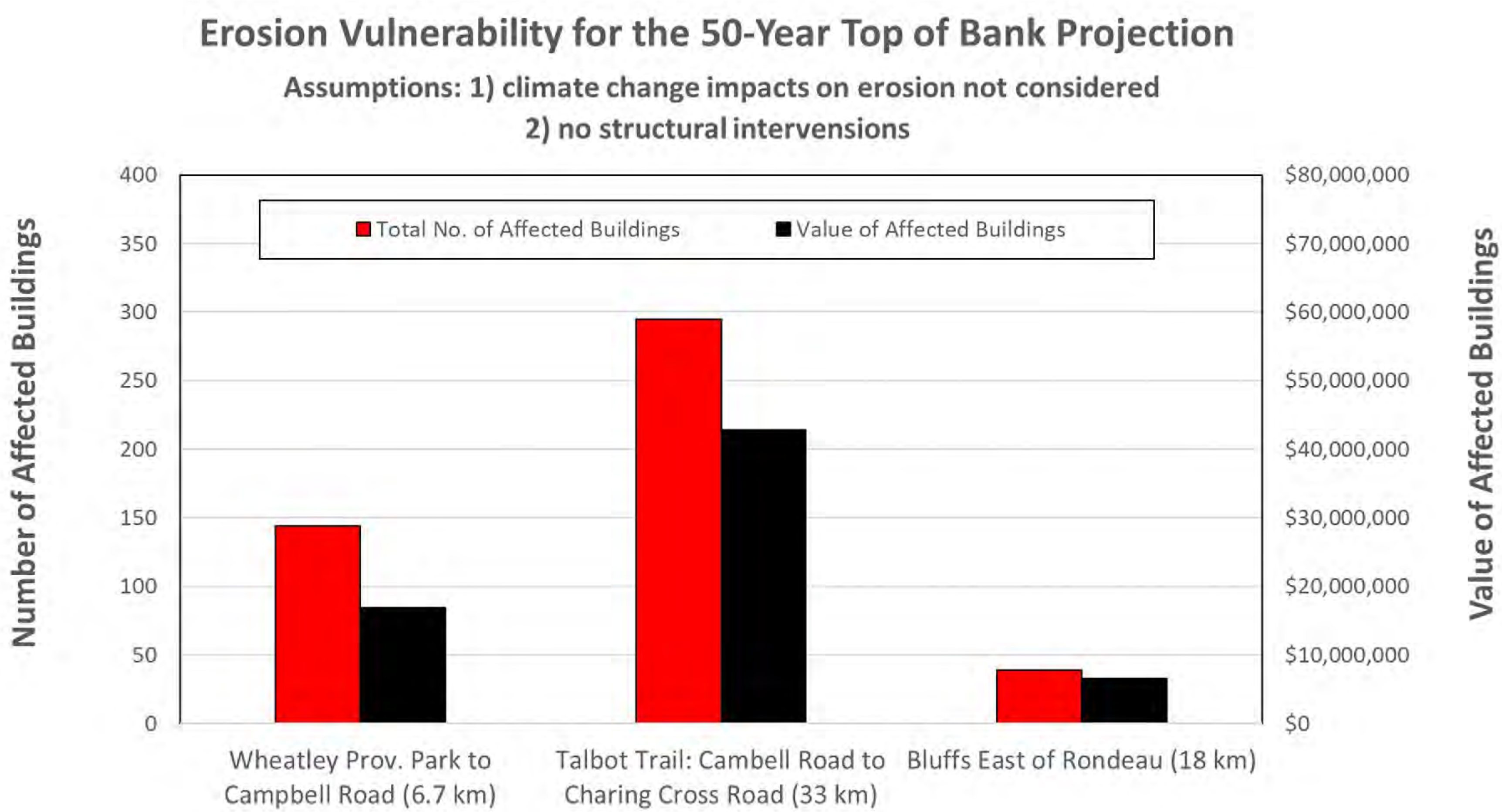



**Figure 4.7 Number and Assessed Value of Buildings Impacted by Erosion for the 50-year Top of Bluff**

## 4.3 Flood Assessment Results

The vulnerability of the study area shoreline to flood risks for the historical 100-year lake level and the 100-year lake level accounting for climate change was completed with GIS tools. A total of eight high-risk areas were identified, including the following four communities with exposure to Lake Erie: Holiday Harbour, Erie Beach, Erie Shore Drive, and Rose Beach Line. Four additional communities on Rondeau Bay were also selected, including the Village of Erieau, Shrewsbury, Rondeau Bay Estates, and The Summer Place.

The extent of the flood risks and potential economic damages are mapped in Figures 4.7 to 4.16. The results are summarized for the eight regions in the following sections.

### 4.3.1 Holiday Harbour

The extent of the flood risk is minimal for the Holiday Harbour area. Shallow ponding is predicted for several trailer lots along Gregory Line for the historical 100-year lake level (Figure 4.7). No primary or secondary buildings (with fixed foundations) were identified with the analysis. With the additional 0.5 m of water elevation for the climate change 100-year lake level, the extent of the flood risk increases along Gregory Line with 35 buildings in the floodplain with an estimated value of $2.7 million.

### 4.3.2 Erie Beach

The land elevations in Erie Beach are higher than the neighbouring Erie Shore Drive community, since it is the transition area from the high bluffs to the west to the low-lying bay communities. Isolated locations of ponding near the intersection of Bisnett Line and Towanda Boulevard were identified and some limited building flooding, as seen in Figure 4.7, for the historic 100-year lake level.

With the higher climate change 100-year flood level, a total of 17 buildings are in the floodplain. Their assessed value is $2.2 million.

### 4.3.3 Erie Shore Drive

Given the severity of the flood risk along Erie Shore Drive and the potential implications of a dike breach on interior flooding and ingress/egress to the Village of Erieau, additional analysis was completed. The inundation flood mapped in Figure 4.7 shows some affected areas along the waterfront lots of Erie Shore Drive. However, since the screening level spatial analysis cannot simulate wave overtopping and flowing water over the dike, the magnitude of the flood risk is not accurately captured for Erie Shore Drive.

The flood risk was further evaluated in Figure 4.9 to account for the effect of wave overtopping during the historical 100-year flood level in the top panel. This scenario also assumes the dike is breached, with Erie Shore Drive surrounded by water on both sides. The entire waterfront is classified as a velocity zone given the potential for waves to overtop the existing shoreline protection structures and the proximity of buildings. In addition, due to the low elevations along the road in the central portion of Erie Shore Drive, there is the potential for sheet flow across the road due to wave overtopping. This process was observed during the August 2019 storm event and several times during the fall of 2019. This process caused considerable damage to the north side of the dike and the shoulder of the road, resulting in temporary closures.

In the second panel of Figure 4.9, the entire shoreline is mapped as a velocity zone to identify the elevated risk of waves striking buildings. Based on the elevation of the road and the lake level for this climate change scenario, water will flow directly over the road and into the drain across a 1 km section of the dike (sheet flow zone). While a dike breach is not needed to flood the Burk Drain, the hydraulic forces associated with water flowing continuously over the dike could lead to a major slope failure.

The spatial extent of the flood in the Burk Drain and surrounding agricultural areas, if the Erie Shore Drive dike is breached, is mapped in Figure 4.10 for the 100-year lake level based on historical conditions (left) and climate change 100-year lake level (right). A total of 568 to 647 hectares of land would be flooded respectively for these two scenarios. In addition to the potential for structural damage to buildings and crop loses, the only emergency access route into and leaving the Village of Erieau would be completely inundated, as noted in Figure 4.10.

Figure 4.11 further evaluates emergency access and maps the depth of flood waters over the road network for Erie Shore Drive, Bisnett Line, and Erieau Road into the Village of Erieau for the two flood scenarios. This analysis only accounts for direct inundation, not wave affects. For the first 800 m of Erieau Road from Bisnett Line, the road is above both flood scenarios. However, for the remaining 2.5 km to McGeachy Pond, significant portions of the road are under water for the 100-year lake level (top panel) and the entire 2.5 km of road is under water for the 100-year lake level, accounting for climate change (bottom panel). Close to McGeachy Pond, the road would be covered by more than 1.5 m of flood waters, making it inaccessible by vehicles. While this impact has not been be translated into a potential economic damage, the implications for safe emergency access to and from the Village of Erieau would be significant.

The road centreline elevations are plotted on Figure 4.12 from west to east and compared to the two flood scenarios. The entire length of Bisnett Line is above the two flood levels. The cross section for Erieau Road shows the vulnerable areas west of McGeachy Pond for the two 100-year lake level scenarios. The most vulnerable section of Erieau Road is located between 1,800 and 3,000 m on the x-axis of Figure 4.12 (north-west of McGeachy Pond). Ross Lane and Vidler Avenue are dry during the historical 100-year lake level but flooded when the additional 0.5 m is included to account for climate change influences on lake levels.

To put the flood vulnerability in context for Erie Shore Drive, for the historical 100-year lake level, 123 primary and secondary buildings would be impacted, with an assessed value of $15.9 million. For the 100-year climate change lake level, the number of affected primary and secondary buildings increases to 141 with an assessed value of $18.2 million.

But the flood risk is not limited to Erie Shore Drive. If the dike breaches, buildings and agricultural crops inside the Burk Drain could be lost and the only ingress/egress route for the Village of Erieau would be completely inaccessible for vehicular traffic.

### 4.3.4 Rose Beach Line

Isolated locations of ponding were identified between Wildwood Line and Bates Line for the historical 100-year flood level. One building was impacted by flooding for this scenario with an assessed value of $52k. See Figure 4.7. With the higher climate change 100-year flood level, the vulnerability assessment identified three buildings with an assessed value of $578k potentially impacted by flooding. Refer to Figure 4.8. Some roads are also flooded. Overall, the flood risk is very low in the Rose Beach Line community.

### 4.3.5 Village of Erieau

Mariners Road and Ross Lane divides the Village of Erieau into the lake and bay communities. Given the history of sand deposition and dune development south of Mariners Road, the lake-facing community has low exposure to flooding for the historical 100-year lake level. However, a high-water table can still impact basements and crawl spaces, plus septic systems. North of Mariners Road, the development occurred on the former marsh shoreline of Rondeau Bay. Therefore, it is lower in elevation and 101 buildings are impacted by the 100-year flood, with an assessed value of $13.3 million. Refer to Figure 4.14.

When the climate change 100-year flood level is evaluated, the flood vulnerability increases dramatically for the Village of Erieau. South of Mariners Road, there is significant flooding around the marina basins. The development on the beach is mostly protected by higher ground. North of Mariners Road, however, there is extensive inundation in the densely developed bay community. A total of 357 primary and secondary buildings are impacted by the flooding with a combined assessed value of $45.6 million. The Village is the most vulnerable area for building damages to the higher climate change 100-year lake level in the study area. Also, as noted in Figure 4.11, a significant portion of Ross Lane is covered in water during this flood scenario.

### 4.3.6 Shrewsbury

The Shrewsbury community was developed on the fringe of Rondeau Bay in the coastal floodplain and it is vulnerable to high lake levels even in non-storm conditions. The extent of the inundation for the historical 100-year flood is noted in Figure 4.14. A total of 184 primary and secondary buildings are in the floodplain and combined have an assessed value of $9.4 million.

Like the Village of Erieau, the flood vulnerability increases dramatically for Shrewsbury for the climate change 100-year lake level, as seen in Figure 4.15, due to inundation further inland and deeper flood depths. The number of primary and secondary buildings impacted by the flood is 413 and together they have an assessed value of $22 million. It is worth noting the flood vulnerability and the potential for economic damages will increase dramatically in Shrewsbury if the Rondeau barrier beach is not repaired and lake waves are able to propagate into the bay.

### 4.3.7 Rondeau Bay Estates

Rondeau Bay Estates, like Shrewsbury, was built on the coastal wetlands that once fringed the entire perimeter of the bay (see Figure 2.1 and 2.3). It is a newer development than Shrewsbury and very resilient to flooding associated with the historical 100-year flood level. Only four buildings with a combined assessed value of $299k, are potentially impacted by the floodplain associated with this flood. See Figure 4.14. This is a good example of the Avoid strategy, where regulating new development on hazardous lands played an important role in reducing the flood risk in Rondeau Bay Estates.

When the additional 0.5 m is added to the 100-year flood level to account for climate change, the number of impacted primary and secondary buildings increases to 45 and they have a combined assessed value of $6.8 million. Refer to Figure 4.15. Since the development in Rondeau Bay Estates was regulated and constructed to be above the historical 100-year flood level, it is not surprising that adding 0.5 m to the flood level for climate change results in significantly higher damages. The contrast to this analogy is Erie Shore Drive, where the flood damage was already very high for the historical 100-year lake level ($15.9 million), but only increased to $18.2 million for the climate change 100-year lake level.

### 4.3.8 The Summer Place

The Summer Place trailer park was constructed on very low land at the head of Rondeau Bay, possibly on former wetlands based on the conditions of the neighbouring property. As seen in Figure 4.14, most of the site is below the historical 100-year lake level. A total of 125 primary and secondary buildings are in the floodplain associated with the historical 100-year flood. The assessed value of the buildings, both fixed structures and trailers, is $2.6 million.

When the additional 0.5 m is added to the 100-year lake level to account for climate change, the entire development and surrounding landscape are covered in water (Figure 4.15). A total of 142 primary and secondary buildings are flooded, with a combined assessed value of $3.6 million.

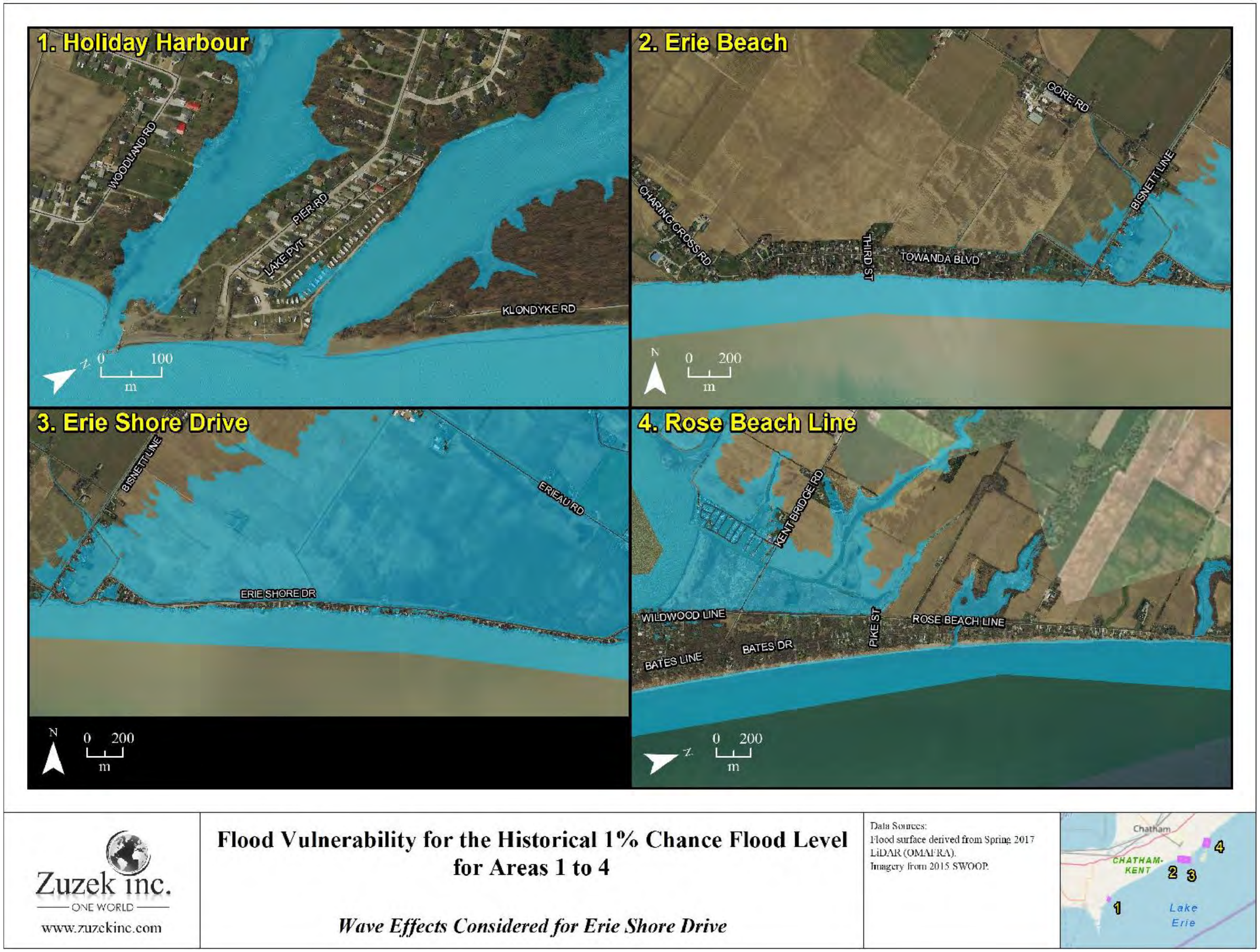



**Figure 4.7 Coastal Community Flood Vulnerability for the Historical 100-year Lake Level**

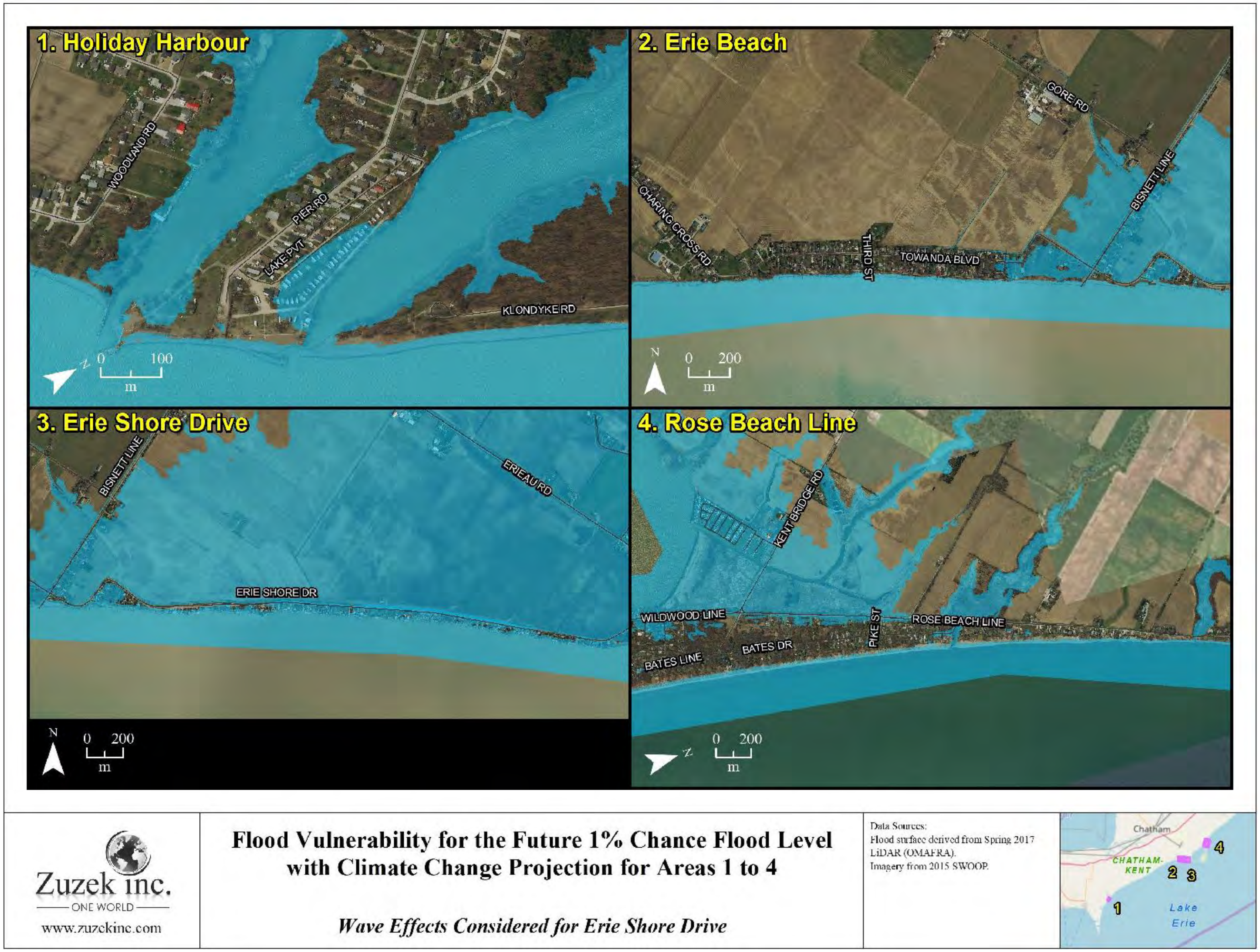



**Figure 4.8 Coastal Community Flood Vulnerability for the 100-year Lake Level with Climate Change**

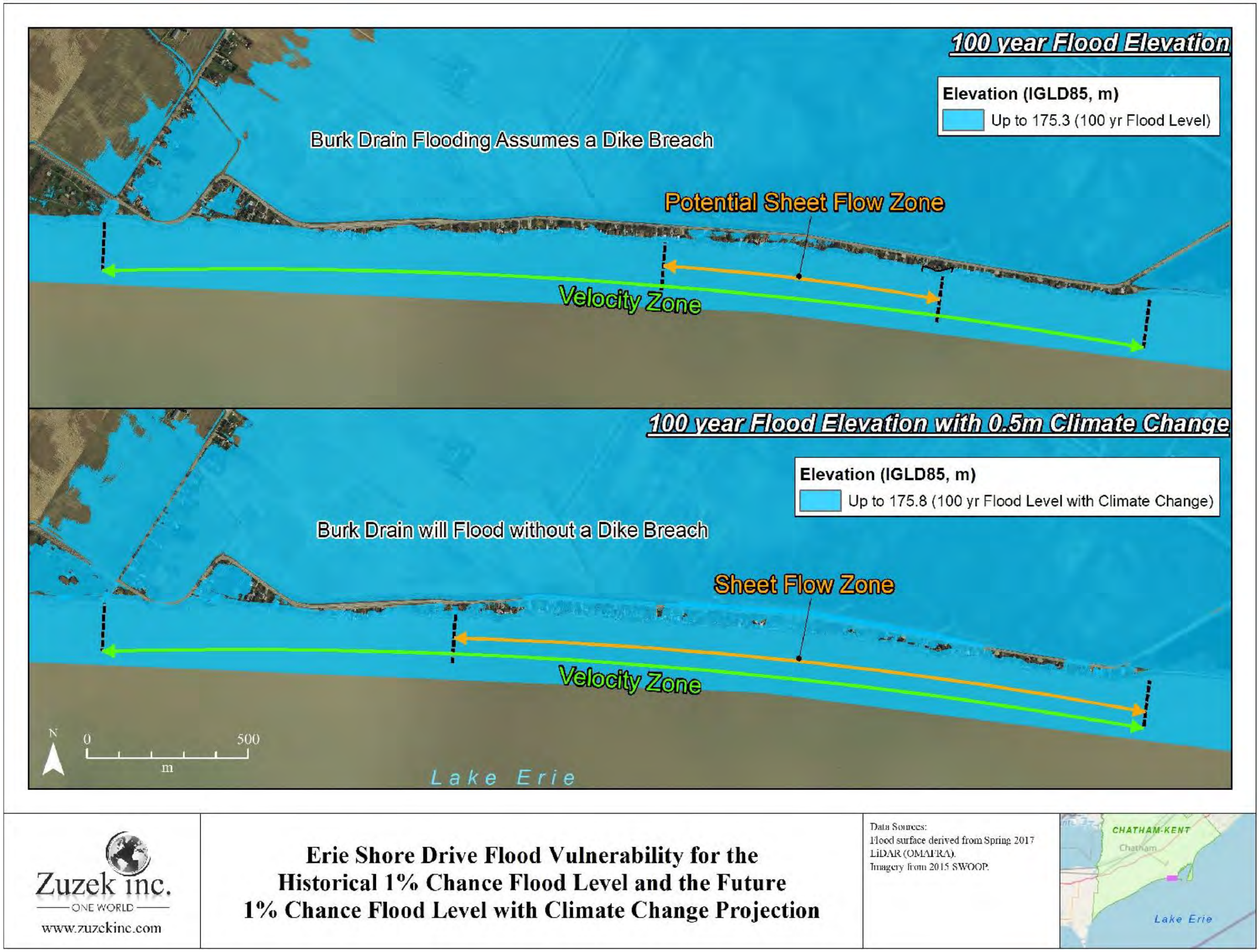



**Figure 4.9 Erie Shore Drive Flood Risk with Wave Effects**

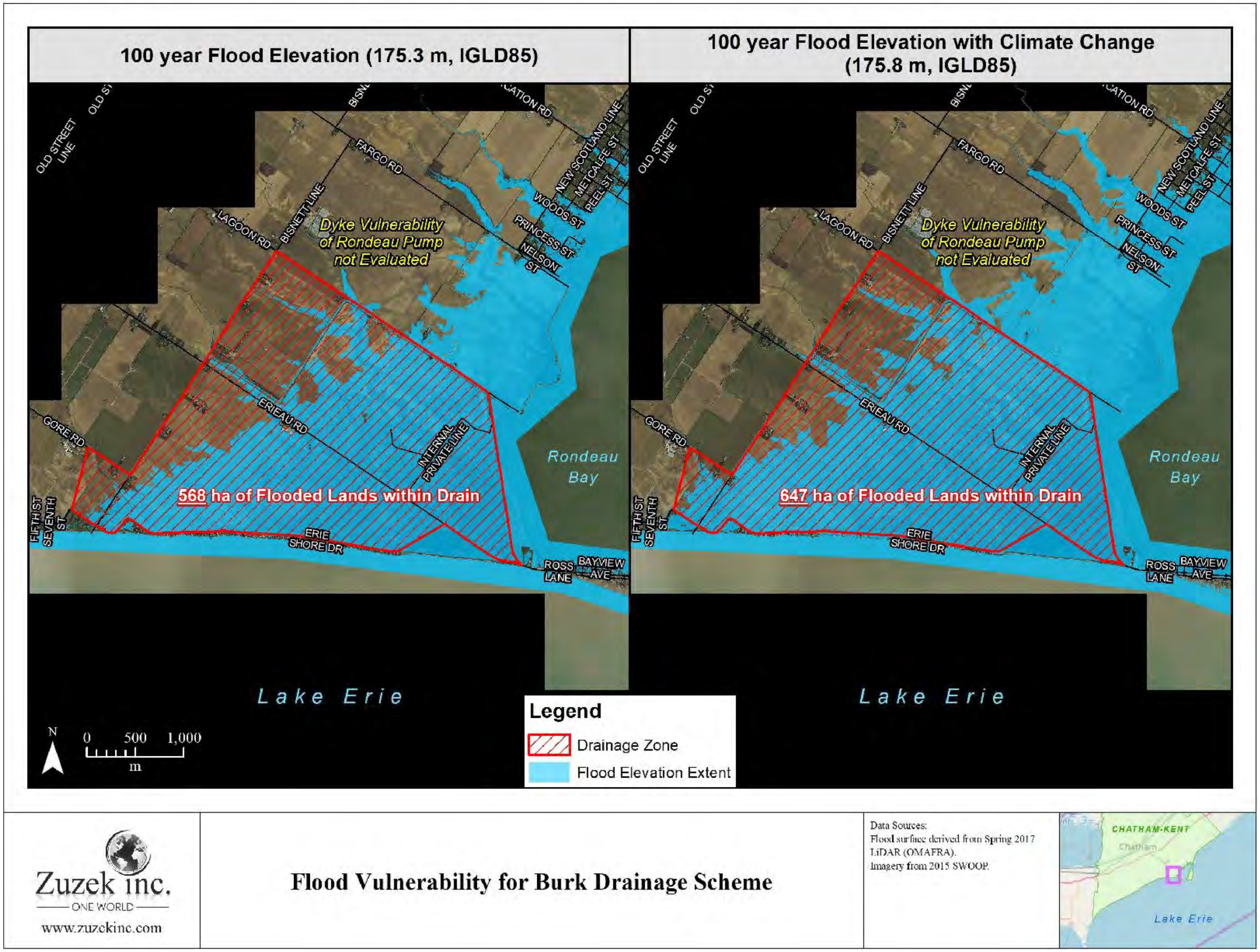



**Figure 4.10 Flooding Extent in the Burk Drain for an Erie Shore Drive Dike Breach**

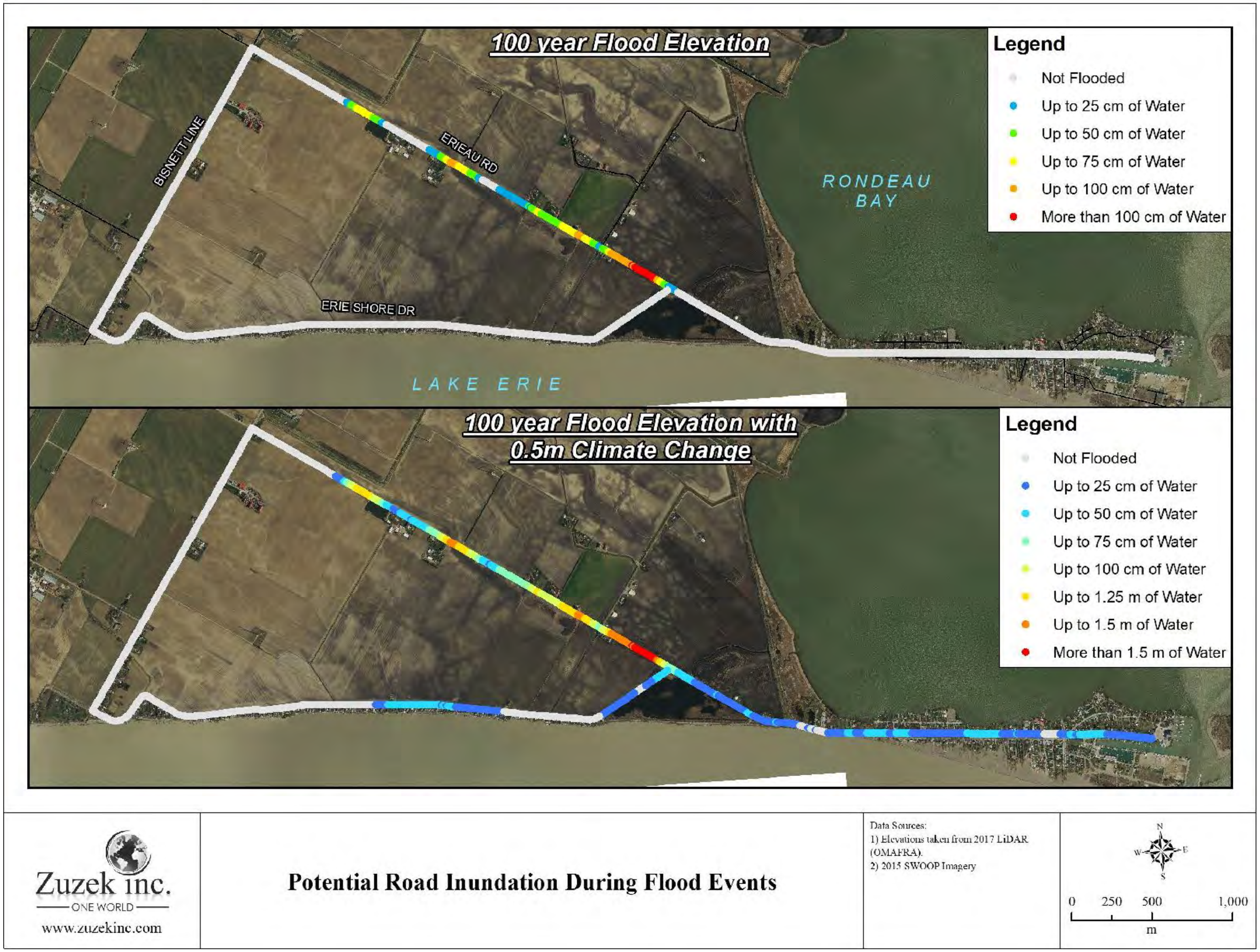



**Figure 4.11 Road Flooding for a Dike Breach (Historical 100-year Lake Level and 100-year with Climate Change)**

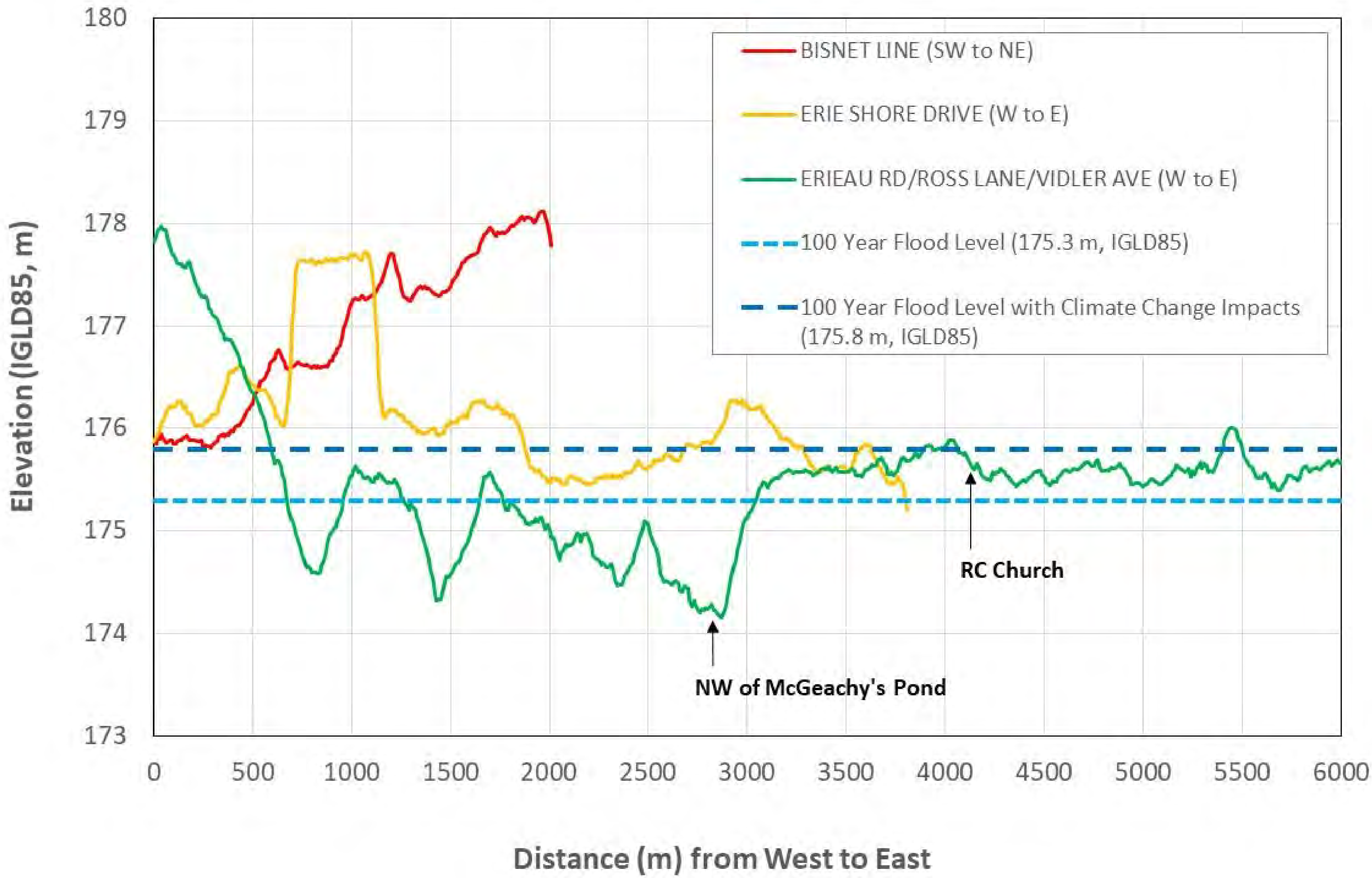



**Figure 4.12 Road Centreline Elevation Around Burk Drainage Scheme (from 2017 OMARFA LiDAR) with Historical and Climate Change 100-year Flood Levels**

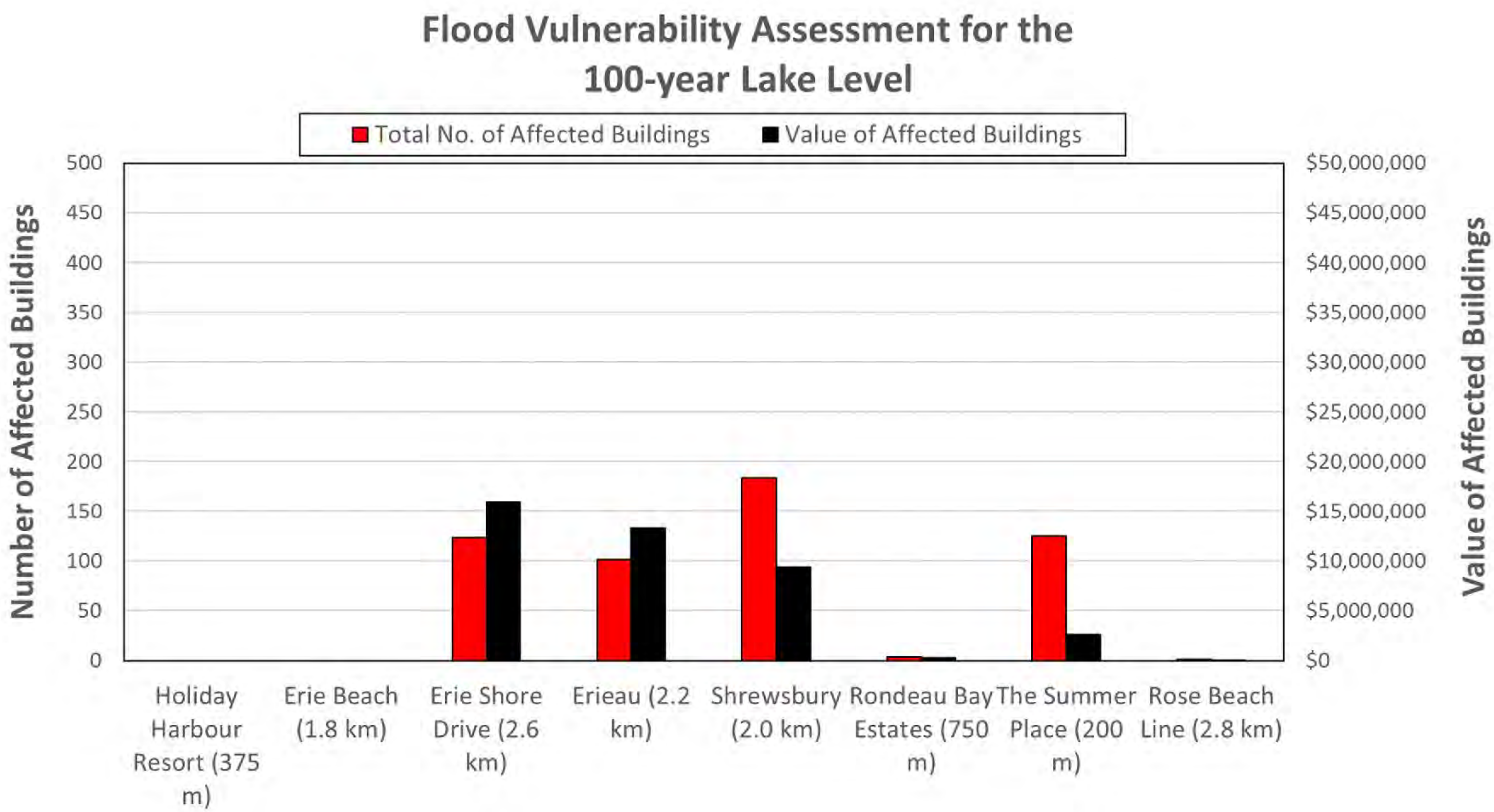



**Figure 4.13 Number of Buildings and Assessed Value for the Historical 100-year Lake Level**

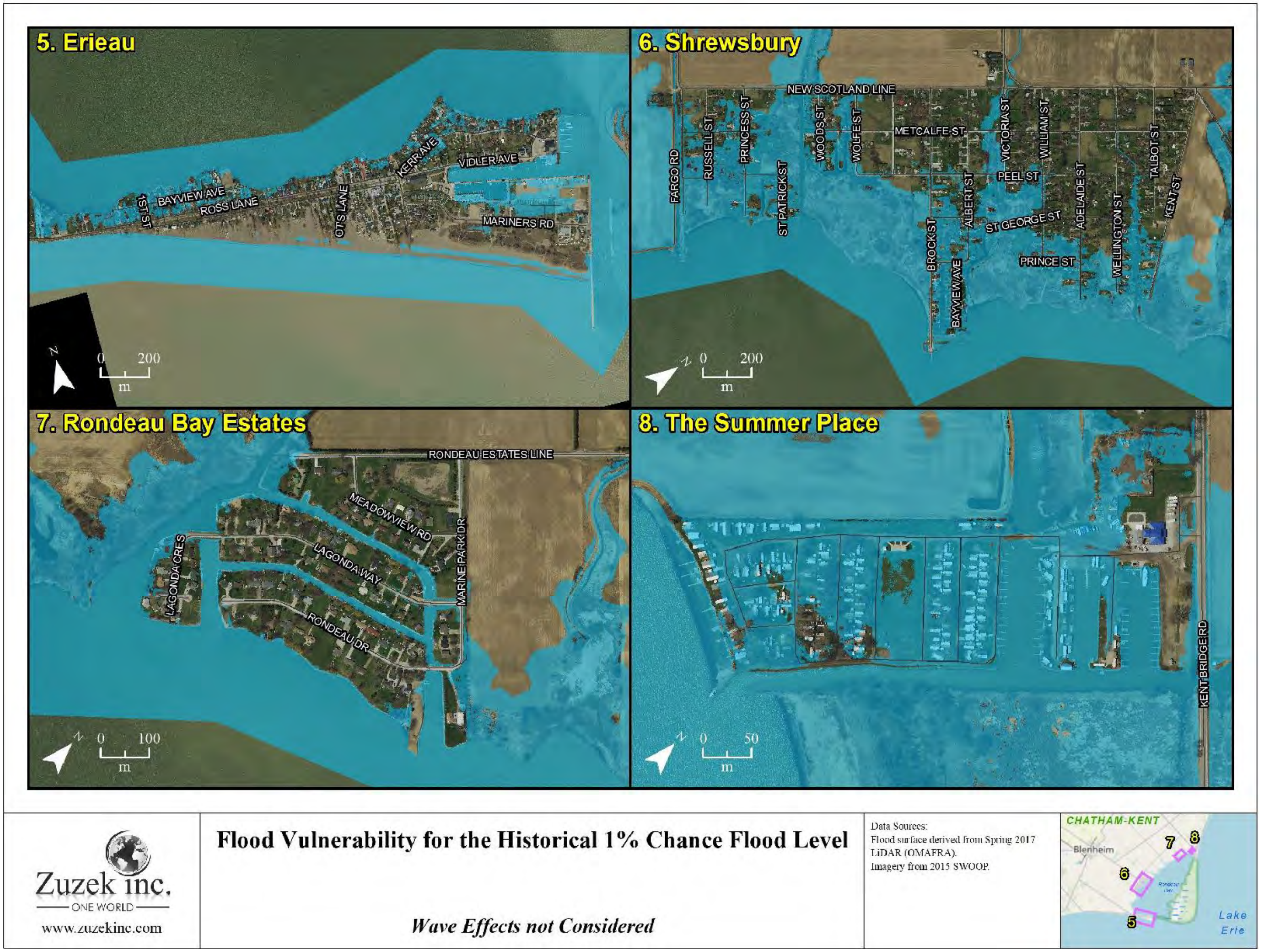



**Figure 4.14 Bay Community Flood Vulnerability for the Historical 100-year Lake Level**

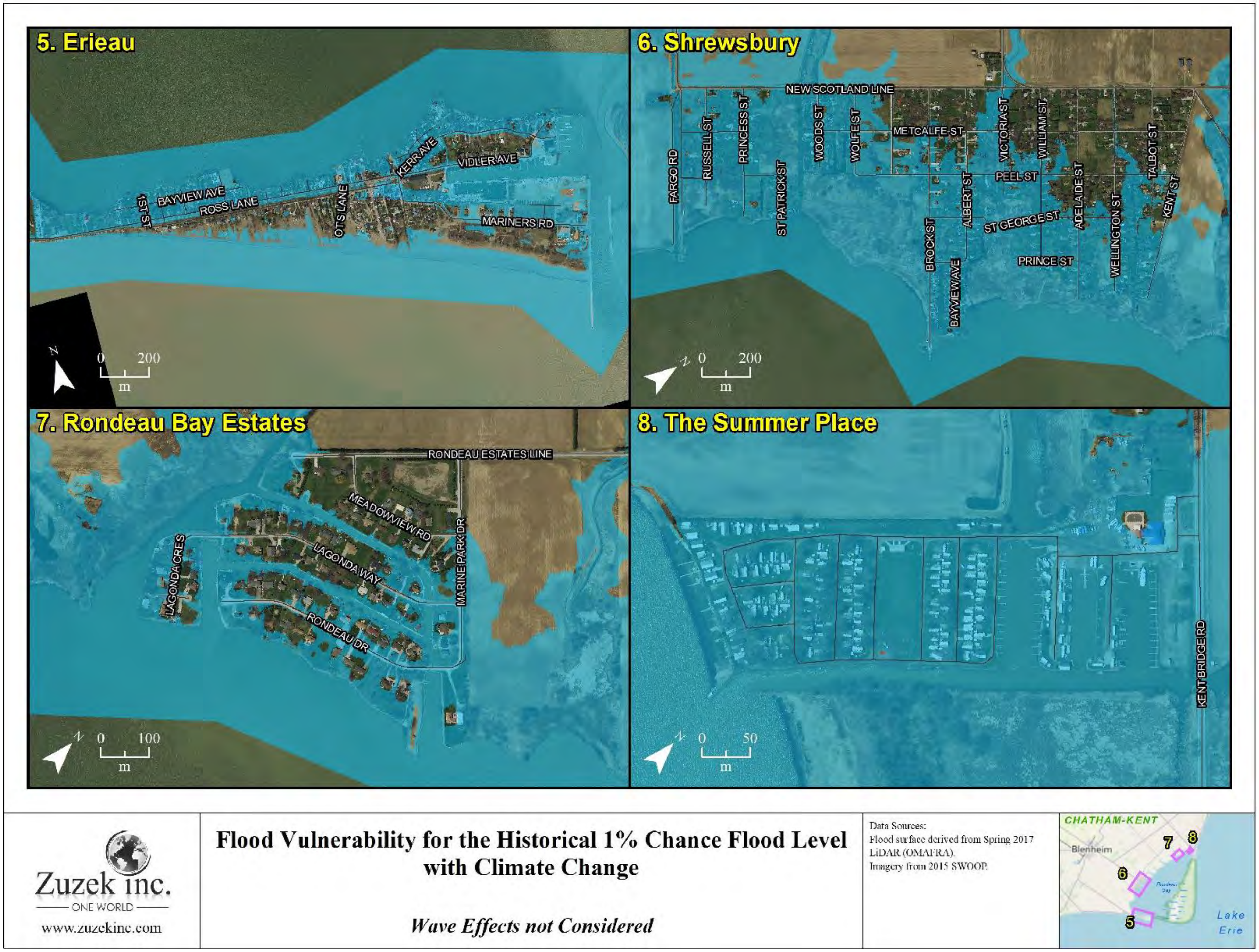



**Figure 4.15 Bay Community Flood Vulnerability for the 100-year Lake Level with Climate Change**

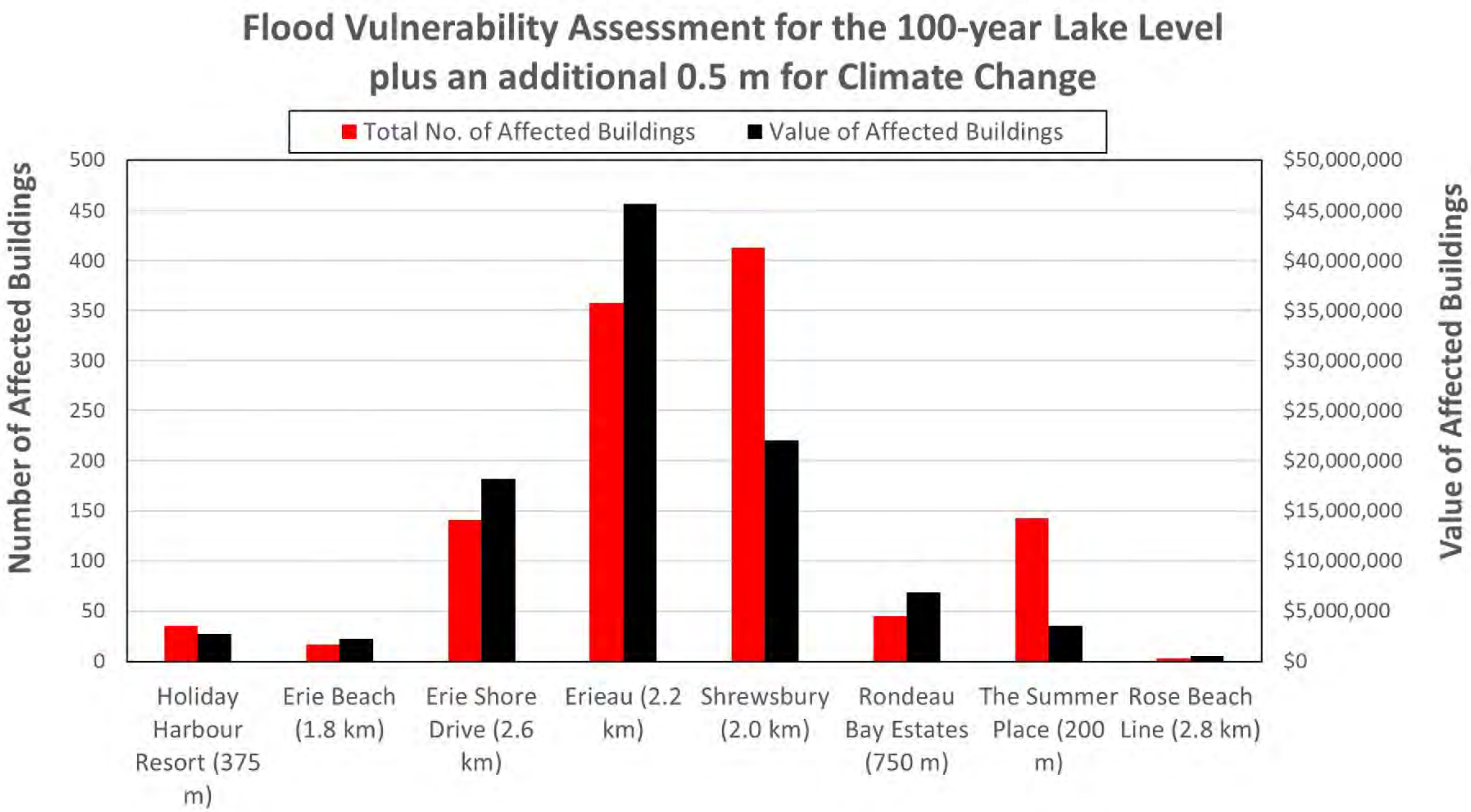



**Figure 4.16 Number of Buildings and Assessed Value for the 100-year Lake Level with Climate Change**

## 4.4 Low Water Impacts Due to Climate Change

While the current high lake levels have put the focus of the vulnerability assessment on impacts associated with flooding and accelerated erosion rates, we should not ignore the potential for low lake levels to return and impact the community. The historical low on Lake Erie occurred in February 1936, 0.32 m below Chart Datum (IGLD'85). Refer to Figure 3.6. The projected mid-century low is roughly 1.3 m lower, at 1.5 m below Chart Datum.

To put these low water levels in perspective, the spatial extent of the water in Rondeau Bay for the 1936 low is seen in the left panel of Figure 4.17. All the shoreline communities in the bay would be separated from the water by a dry lake bottom. However, when the estimated future low is considered, the amount of water in the bay decreases dramatically. The community of Shrewsbury would be separated by more than 1 km of exposed bottom lands in the bay. Prolonged low water periods could have negative impacts on access to the navigation channel, fish habitat, recreational boating access in the bay, and submerged aquatic plants. Development regulations must also guard against encroachment into the lake during low water levels, as this development will become vulnerable to future high levels, which are part of the natural cycle.

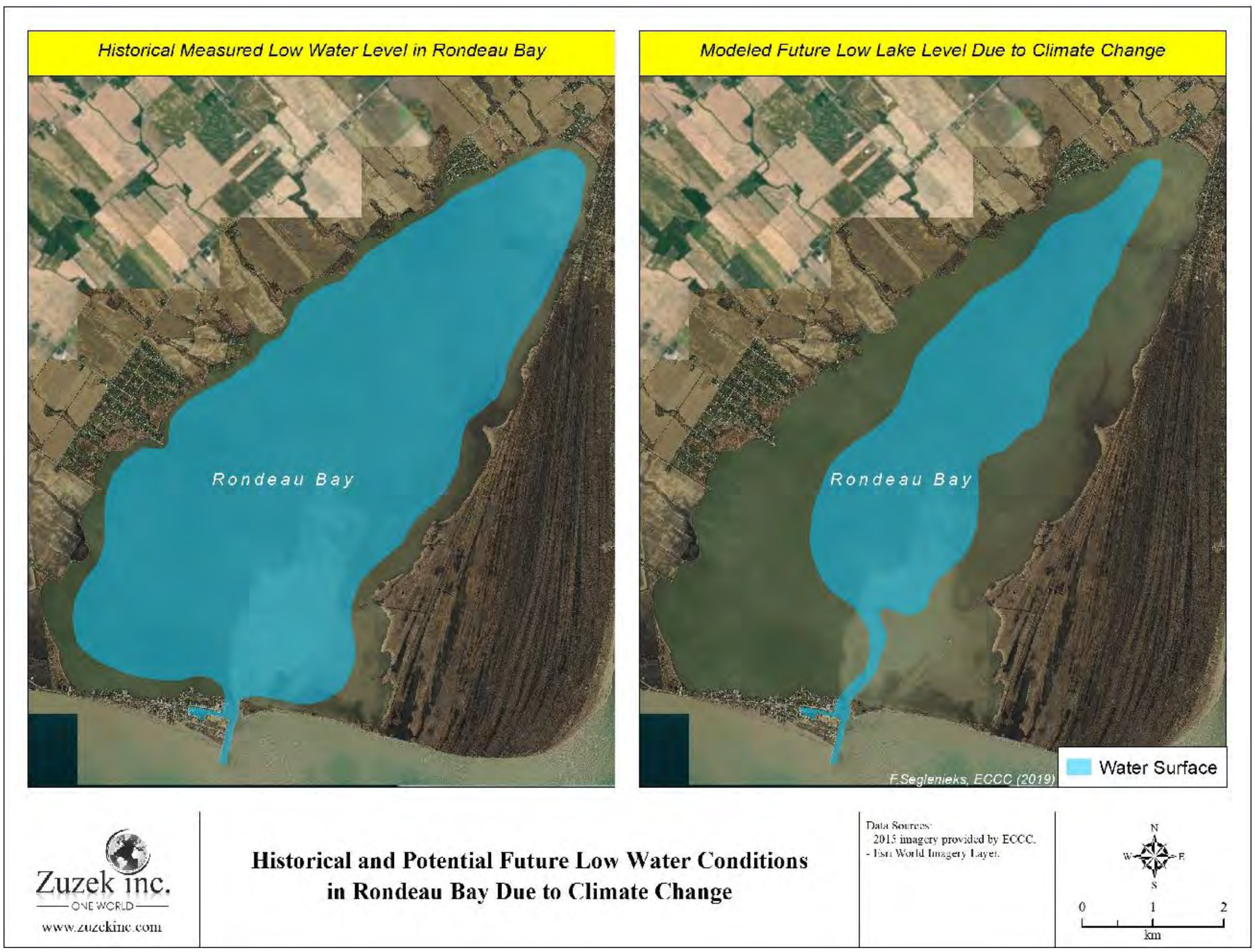



**Figure 4.17 Estimated Spatial Extent of Rondeau Bay during the Drought of the 1930s and Projected Open Water due to Future Climate Change Influence**

## 4.5 Shoreline Erosion Impacts on Coastal Wetlands

The coastal wetlands along the Lake Erie Shoreline of Chatham-Kent occur primarily in the sheltered waters of Rondeau Bay. As depicted in the 1849 map of the bay from NOAA (see Figure 2.1), prior to intensive settlement and agricultural activities in the area, the entire bay was fringed by extensive coastal wetlands.

By 1910, development was occurring in Shrewsbury and the construction of numerous dikes between the new community and Erieau soon followed, including the Rondeau Drain, Third Concession Drain, and the large Burk Drain. The dikes that now separate the drains from the lake eliminated the fringing coastal wetlands in this area.

The recent years of high lake levels have dislodged large sections of emergent wetland vegetation in Rondeau Bay, possibly due to increased wave exposure and shoreline erosion. Figure 4.18 provides examples of these large floating islands of wetland vegetation. Where they originated is unknown, but one potential location is the southwest corner of the Provincial Park.

**Figure 4.18 Large Floating Islands of Former Emergent Marsh**

With the erosion and recession of the barrier beach, this region of the bay is exposed to more energy than the historical conditions that existed when the wetlands were created. As seen on Figure 4.19, a total of 160 hectares of marsh has eroded on the backside of the former barrier beach from 1955 to 2015. Other wetland habitat, such as the rivermouth wetlands at Wheatley Provincial Park, would also be vulnerable to extended periods of low lake levels.


**Figure 4.19 Loss of Wetlands in Rondeau Provincial Park**

## 4.6 Terrestrial Nutrient Loading to the Nearshore

The impacts of nutrient loading from agriculture and coastal communities on nearshore water quality and central Lake Erie hypoxia (Zhou et al, 2013; Scavia et al, 2014) have not been investigated for the vulnerability assessment. However, it is worth noting that eutrophic conditions were observed within the agricultural drains, as seen in Figure 4.20. In addition, high static lake level conditions can compromise septic weeping beds in low-lying communities, such as Shrewsbury, which does not feature municipal sewage treatment. Refer to Figure 4.21. Short-term flooding can also inundate septic weeping beds and lead to system failure and nutrient loading directly to the bay and lake.


**Figure 4.20 Eutrophic Conditions in Burks Drain Channel**

**Figure 4.21 May 7, 2019 High Water Conditions in Shrewsbury**

## 4.7 Sedimentation in the Navigation Channel

Given the historical use of the Erieau port for Lakers transporting coal, the navigation channel is still sufficiently deep (12 to 20 ft) for the commercial fishing fleet and recreational boaters. However, with the progressive recession of the Rondeau Barrier Beach and detachment from the east jetty, sediment is now driven into the navigation channel during storm events from the east, south-east, and south. Figure 4.22 documents more than 100 m of westward migration since 1977 for the tip of the barrier beach, referred to locally as Seagull Island. Since 1955 the barrier has migrated west by 580 m. If this channel sedimentation is not mitigated, it will eventually compromise boat access to and from Rondeau Bay.

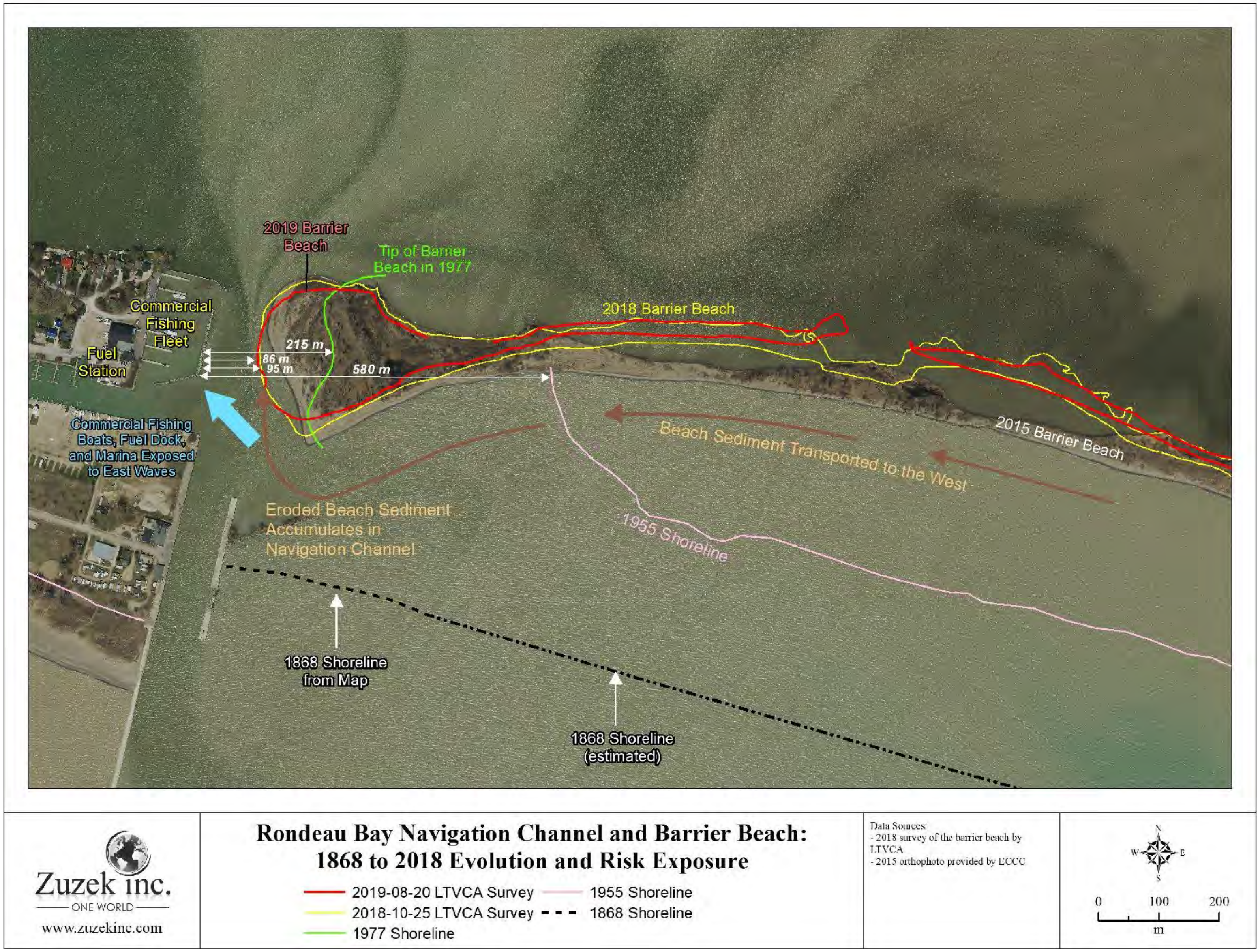



**Figure 4.22 Evolution of the Rondeau Barrier Beach and Sedimentation in the Navigation Channel Since 1955**

## 4.8 Changes in Wave Exposure in Rondeau Bay

The existing breach in the Rondeau barrier beach and the gap between the east jetty and Seagull Island, represents major threats to the infrastructure in the navigation channel and marina basin, including the fuel dock and commercial fishing fleet basin.

Offshore wind speed data is available from the US Army Corps of Engineers Wave Information Studies (WIS) hindcast from 1960 to 2014. The long-term wind and wave dataset were utilized to evaluate various wind and wave scenarios for the navigation channel and Rondeau Bay. In Table 4.1, the return period wind speeds are summarized in both metres per second and kilometres per hour.

**Table 4.1 Extreme Value Analysis for WIS Output 92154**

| | *Wind Speed (m/s)* | *Wind Speed (km/hr)* |
|---|---|---|
| 1-Year Wind Speed | 21.7 | 78.1 |
| 5-Year Wind Speed | 24.5 | 88.2 |
| 10-Year Wind Speed | 25.6 | 92.2 |
| 50-Year Wind Speed | 28.1 | 101.2 |
| 100-Year Wind Speed | 29.1 | 104.8 |

Based on the local wind speeds and the assumption that Rondeau Bay is fully protected from lake waves, wave heights with a return period of 1-, 10- and 100-years were predicted. Refer to Table 4.2. To investigate the influence of a breach in the barrier beach on wave heights and the potential for lake waves to propagate into the bay, Shuto's non-linear shoaling algorithm (1974) and Goda's wave-breaking formulation were applied (1985). Table 4.3 summarizes the return period wave heights in 20 m depths offshore of Rondeau Provincial Park and also the associated waves that could propagate through a breach in the barrier beach with a depth of 2 m below Chart Datum. The 100-year wave height in Rondeau Bay increases from 1.0 m for a fully sheltered scenario, to 2.69 m for a breach. Since wave energy is proportional to the square of the wave height, the amount of energy reaching the community of Shrewsbury would increase by a factor of seven for this breach scenario.

**Table 4.2 Rondeau Bay Return Period Waves Heights with the Barrier Beach and 100-year Lake Level (175.3 m, IGLD'85)**

| *Wind Generated Waves Inside Rondeau Bay with Sheltering from the Barrier Beach (Hs= significant wave height, Tp= peak period)* | | |
|---|---|---|
| 1-Year Wave | Hs = 0.8 m | Tp = 3.3 s |
| 10-Year Wave | Hs : 0.91 m | Tp = 3.6 s |
| 100-Year Wave | Hs = 1.0 m | Tp = 3.8 s |

**Table 4.3 Rondeau Bay Return Period Waves Heights without the Barrier Beach and 100-year Lake Level (175.3 m, IGLD'85)**

| | | |
|---|---|---|
| ***Lake Erie Deep Water Waves (20 m) offshore of Rondeau Provincial Park*** | | |
| 1-Year Wave | Hs = 3.9 m | 8.0 s |
| 10-Year Wave | Hs = 5.0 m | 8.5 s |
| 100-Year Wave | Hs = 6.2 m | 9.5 s |
| ***Lake Erie Waves Entering the Bay through a Breach (-2 m CD depth)*** | | |
| 1-Year Wave | Hs = 2.48 | |
| 10-Year Wave | Hs = 2.57 | |
| 100-Year Wave | Hs = 2.69 | |

# 5.0 COMMUNITY AND GOVERNMENT ENGAGEMENT

Section 5.0 summarizes the community engagement in Chatham-Kent and meetings with senior levels of government.

## 5.1 Let's Talk Chatham-Kent Online Engagement Site

Let's Talk Chatham-Kent is an online engagement site for the community. The study used the platform to communicate with the public and share digital information throughout the investigation: https://www.letstalkchatham-kent.ca/chatham-kent-lake-erie-shoreline-study.

The site was designed to help the community stay informed and engaged. They could monitor the site for updates, meeting announcements and registration as well as provide input (e.g., an online survey). The Document Library gave the public access to resources, particularly if people could not attend the local community meetings. Resources to download included:

- Chatham-Kent Lake Erie Shoreline Study plan of work
- Posters with background information
- Presentations from the public meetings and to Council
- Draft adaptation options presented and discussed with the community at Meeting #3

## 5.2 Local Community Meetings

The community meetings were an important opportunity to share study information with the community and seek their input. The goal was to engage the community and ask for and listen to their perspectives on vulnerable areas, key issues, needs and wants, and how to overcome the impacts and build community resilience to coastal hazards.

### 5.2.1 Community Meeting #1 (April 10, 2019) - Introducing the Project

The first community meeting was held on April 10, 2019. This meeting introduced the project to the community, including the study design, the underlying principles, schedule, anticipated technical outputs, and the role envisaged for stakeholders. To encourage wide community participation, the centrally located Erieau Fire Hall in Erieau, Ontario was selected. Two meetings were scheduled: an afternoon session (2:00 pm) and an evening session (6:00 pm). However, due to the overwhelming response by the community for the first afternoon session, a second afternoon session was added at 3:30 pm. Roughly 250 individuals attended the three meetings.

The Agenda was designed to include presentations by the project leads and a question and answer session. The content included:

- **Presentation 1 – Why does climate change matter in the Chatham-Kent region?**
    - Background on climate change and projected changes in future air temperatures.
    - Implications of climate change for coastal areas in the Chatham-Kent region were discussed, including water level variability, reduced ice cover, higher erosion

rates, more frequent winter flooding, and increased damage to coastal infrastructure.
    - The Chatham-Kent Lake Erie Shoreline Study will use the best-available climate change approaches such as scenario-based vulnerability and impact assessment. Adaptation planning will address negative impacts and take advantage of opportunities.
    - There are four general adaptation approaches when dealing with coastal hazards and climate change impacts, including: avoid, accommodate, protect, and retreat.
    - Climate change adaptation can be used as a catalyst for increasing resilience to coastal hazards.
- **Presentation 2 – What are we trying to achieve?**
    - This study is one of the first to research climate change impacts on coastal storms and future ice cover in the Great Lakes. The findings of this research were presented.
    - The goal for the Chatham-Kent Lake Erie study is to use this information to evaluate vulnerable communities, infrastructure, and ecosystems.
    - Co-develop climate change adaptation concepts and management options with the community of Chatham-Kent to increase coastal resilience.
    - Some initial information on coastal hazards was reviewed.
- **Posters – Background Information**
    - Five posters were set up at the venue to inform the community of important factors for the study, including: 1) dynamic shoreline processes, 2) direction of longshore sediment transport, 3) impacts of high lake levels on hazards, 4) climate warming impacts on future lake ice, and 5) examples of flooding and erosion hazards. They are archived on the Let's Talk Chatham-Kent site and provided in Appendix A.

#### *5.2.1.1 Key Outcomes and Feedback*

The most important aspect of the meeting was introducing the study to the Chatham-Kent community, including the plan of work, schedule, and how to remain engaged and informed on the study progress. All attendees received a business card with a link to the Let's Talk Chatham-Kent engagement site.

An Exit Survey was handed out to get information on the level of concern in the community for the two issues being addressed in the project. For coastal flooding and erosion, most of the surveys indicated people had high concern. Similarly, most of the respondents had high concern for climate change. Feedback was also provided on the clarity of the information presented, additional topics for future meetings, logistics, and length of the meeting. Refer to Appendix A for a blank copy of the Exit Survey.

### 5.2.2 Community Meeting #2 (June 19 and 20, 2019) – Building Community Resilience

The second community meeting focused on sharing results from the research portion of the study but also actively talking with the community about adaptation and resilience. Due to previous community interest, four 2.5-hour sessions were scheduled on June 19 (1:30 pm and 6:00 pm) and June 20 (9:30 am and 1:30 pm) at Erieau Fire Station, Erieau, Ontario. Refer to Figure 5.1 for a picture of the room setup, which included breakout tables.

**Figure 5.1 Meeting #2 Breakout Tables**

The first activity at the meeting was a mapping exercise which explored the community's shoreline erosion and flooding concerns. Upon arriving, participants were asked to locate on a map the most important areas for erosion [red dots] and flooding [blue dots] along the Chatham-Kent shoreline. The dots tended to focus on three areas of concern, namely Erieau, Rose Beach line, and Erie Shore Drive. See Figure 5.2 below. The results from the four meetings are presented in Appendix A.

**Figure 5.2 Meeting Attendees Identifying Areas of Erosion and Flooding**

The Study Team presented the results of the vulnerability assessment, including impacts of flooding and erosion to existing buildings, infrastructure and the environment (see Section 4.0 for details). The economic value of the buildings impacted was reported. In order to set the scene for the adaptation activity to follow, several case study examples demonstrated where avoid, accommodate, protect and retreat options were implemented to address coastal flooding and erosion risk.

Participants were engaged in discussions on “Building Community Resilience” and what adaptation strategies would be needed to support this goal. Small break-out groups were used to talk over solutions to the erosion and flooding challenges along the Lake Erie shoreline. These facilitated break-out sessions were directed by three questions:

Question #1 - A goal of adaptation solutions is to increase community resilience to shoreline flooding and erosion now and in the future. Resilience generally means “... building capacity to bounce back, and to learn, adapt, and improve so the community is better prepared for future climate change impacts”. From your perspective, what does community resilience mean? How could your community become more resilient?

Participants described community resilience from a range of perspectives such as accepting a certain risk tolerance, awareness of risks, available resources, ability to bounce back quickly, cohesive community, collaboration, communications, informed community, and having proactive plans in place. Ideas for how the community could become more resilient included: making hard choices for the long-term, living with impacts, mitigating where you can, understanding trade-offs between long-term and lowest-cost solutions, adopting a consistent approach, agency collaboration and coordinated implementation, proactive risk management, developing a long-term vision, and education and communication.

Question #2 - When making community decisions to deal with shoreline flooding and erosion, potential solutions can be ranked based on a range of evaluation criteria. Can you provide some examples of criteria that you think should be used?

The table discussions from the sessions are summarized in the word cloud in Figure 5.3, which highlights the dominant words participants used to define the assessment criteria for decision making (the larger the word, the more times it was selected). These criteria would be tabled as part of the community discussion of draft adaptation options in the November 26, 2019 Public Meeting #3.


**Figure 5.3 Word Cloud on Suggested Evaluation Criteria**

Question #3 - Four general types of adaptation solutions were presented - accommodate, avoid, protect, and retreat for addressing coastal erosion and flooding hazards. Think about three areas: flooding/erosion in low-lying areas; erosion along high bluff areas; erosion of the Rondeau Barrier Beach and exposure of the navigation channel, fuel dock, and wetlands to coastal storms. What actions could be done in the short-term and long-term?

Participants discussed a range of ideas of how to address the flooding and erosion challenges along the Chatham-Kent coast. The recommended solutions were different depending on the area. Figure 5.4 shows that the most common solution for high bluffs was retreat, while accommodate was preferred for low-lying areas.


*High Bluff Approach*


*Low-lying Areas*

**Figure 5.4 Word Cloud on Suggested Adaptation Approaches for High Bluffs and Low-Lying Areas**

An Exit survey was used to solicit feedback on "the meeting" with respect to the presentation content and usefulness of break-out groups (see Appendix A for a copy). In order to understand the community participation, it also asked people, "to tell us a bit about yourself?" and to describe where they live, farm or work, operate a business or recreate in the Municipality of Chatham-Kent. Most respondents (67%) lived directly abutting the lake.

Participants were asked again to provide their judgement on criteria for community decision making and from a list select their top three criteria. Results were used to inform the criteria for developing and evaluating the adaptation options (see Section 6.2, Figure 6.1).

#### *5.2.2.1 Feedback and Key Outcomes*

A top-of-mind issue tabled by the community was the need for more coordinated and collaborative implementation of coastal hazard planning and management (e.g., local, regional, provincial and federal). The community would also like a "one stop window" for advice and approvals for addressing issues. Protecting property, the permanence and durability of the solutions, and affordability for the landowners, were the most popular evaluation criteria.

### 5.2.3 Community Meeting #3 - Presentation of Draft Adaptation Concepts

The Study Team organized two public consultation meetings on Tuesday November 26, 2019 (1:00 pm and 6:00 pm) at a larger venue, the Links of Kent Golf Club in Chatham, to provide more capacity for community participation. Total attendance was 230 people. A picture of the discussion during a breakout session is provided in Figure 5.5.

**Figure 5.5 Breakout Table Discussion from Meeting #3**

The focus of the meetings was the presentation of the draft adaptation concepts and management options, by geographic region, for a "Resilient Chatham-Kent Lake Erie Shoreline" (see Section 6.5) and to invite the community to review, assess and comment on these options.

Facilitated break-out groups were organized to discuss the adaptation concepts for: Region 1: High Bluff Areas; Region 2: Erie Beach, Erie Shore Drive, and the diked farmland; Region 3: Flood-prone Communities around Rondeau Bay; and Region 4: Federal Navigation Channel and Rondeau Barrier Beach (see Figure 5.6). Participants were asked to evaluate the options using community-based criteria: protection of property, their permanence and durability, affordability, and maintaining natural shoreline health (see Figure 6.1).

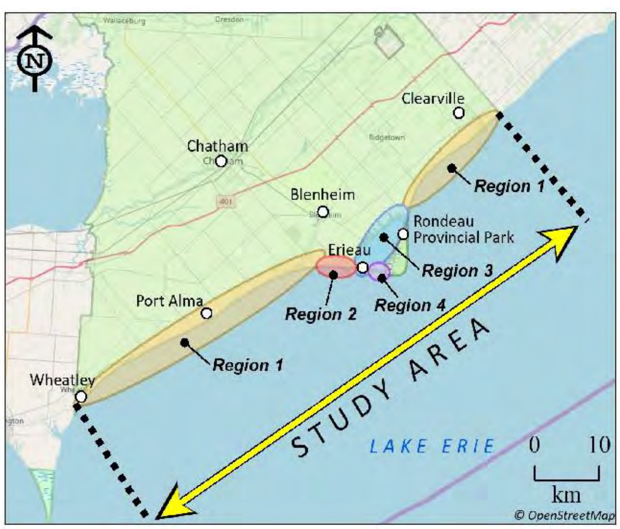



**Figure 5.6 Four Regions of the Study Area**

#### *5.2.3.1 Feedback and Key Outcomes*

The key goal of Public Meeting #3 was to present the draft "Adaptation and Management Options" and provide an opportunity for the community to review the options and voice their opinion in order to inform adjustments to the final recommended adaptation options.

Feedback from the community discussions on the adaptation options included:

- All the options are very expensive and likely not affordable.
- Need one-window approval with government agencies, including Federal, Provincial, Conservation Authority, and Chatham-Kent.
- Need to simplify [planning] and permitting for retreat (e.g., make exclusions for not meeting requirements such as offset of home to road allowance).
- Should include "no protection" and the "status quo" as a draft adaptation option.
- Feedback: need more details and costs, such as costs for individual property owners
- Erie Shore Drive Revetment: shows stone revetment over roof line; does the property owner have the option of raising their property so they can see the lake?
- Who pays? Should not only be those that live along the shoreline. Cost-sharing is needed.
- Missing Option: voluntary property buy-outs.
- Everything in the list of draft adaptation options is a long-term solution but they are struggling with short-term/immediate erosion and flooding issues. Need more emphasis on short-term options.
- Armour stone revetment option for Erie Shore Drive: Will this eliminate the view? Can I build up the property? Not willing to pay if I lose my view. Maintenance is extremely important.
- New option suggested for Erie Shore Drive: offshore breakwaters.
- Retreat options could create new ecosystems.

An Exit Survey was handed out (see Appendix A) that gave participants the opportunity to identify their preferred adaptation option for their region and to assess it using the community-based evaluation criteria. Additionally, they could provide input on how to improve the adaptation options presented at the meeting and what they liked or disliked about them.

## 5.3 Southwestern Ontario Shoreline Roundtable

The Southwestern Ontario (SWON) Roundtable was formed in the summer of 2019 to bring together Municipalities and Conservation Authorities with similar coastal hazard challenges in the region. The geographic representation includes the St. Clair River, Lake St. Clair, the Detroit River, and the western half of Lake Erie. The Roundtable is presently chaired by Don Shropshire, Chief Administrative Officer for the Municipality of Chatham-Kent and it addressed recommendations from Community Meeting #2 to engage with senior levels of government.

### 5.3.1 First Roundtable Meeting in Chatham

The first SWON Roundtable meeting was held in Chatham on August 1, 2019 and attended by over 30 representatives from the Municipalities, Conservation Authorities, and Protected Area managers. Information was provided by the attendees on coastal hazards and infrastructure challenges across the region due to record high lake levels and storms. The benefits of the Roundtable to raise the profile of these issues and speak as a single voice for the region to jointly pursue solutions, was confirmed and further meetings were planned.

### 5.3.2 Second Roundtable Meeting with Senior Levels of Government

September 19, 2019 a second meeting of the SWON Roundtable was held in London, Ontario and representatives from the Provincial and Federal government were also invited. Over 60 individuals attended in-person and via conference call. Following a welcome by Don Shropshire, Pete Zuzek provided an overview presentation on several coastal hazard and climate change studies in Southwestern Ontario.

The Provincial and Federal representatives in attendance then provided background information on their Department's and Ministry's mandate with coastal hazards, existing policies or programs that could support additional vulnerability studies, and potential funding opportunities. Key highlights are summarized below.

- Senior levels of government typically do not provide funding for private shore protection and there are no such active programs.
- The Federal government currently funds the Disaster Mitigation and Adaptation Fund (DMAF) to address large-scale shoreline hazards and solutions. It may be a potential funding source for the SWON communities.
- The Ministry of Municipal Affairs and Housing (MMAH) administers a program called the Disaster Recovery Assistance Program to help landowners recover from natural disasters.
- MMAH also administers the Municipal Disaster Recovery Assistance program to recover from natural disasters that impact municipal infrastructure.
- The Ministry of Environment, Conservation and Parks (MECP) has formed a new branch called "Adaptation and Resilience Branch" to build programs to help communities with the types of issues discussed at the meeting. They are in the early planning stages of an environmental plan, online tools, and a more coordinated government approach. There is currently no active funding.

The current high lake levels and the associated coastal hazards have created a series of large and complex problems for coastal communities, municipalities, and Conservation Authorities. No single group, agency, or level of government can solve these problems alone. It is the hope of the SWON Roundtable that senior levels of government will continue to collaborate and jointly pursue cost-effective, innovative, and ecologically sensitive long-term solutions that consider the impacts of climate change. Further virtual meetings are planned in 2020.

# 6.0 CLIMATE CHANGE ADAPTATION OPTIONS

A key objective of the Chatham-Kent Lake Erie Shoreline Study was the integration of future climate change projections into the development of long-term community-scale adaptation concepts that increase resilience to coastal hazards. The following report sections elaborate on the concept of community-scale adaptation solutions to enhance resilience, summarize the evaluation criteria developed during the engagement process in 2019, review the approach followed to develop the concepts, summarize options considered but not selected, and then review the various adaptation options by region.

## 6.1 Community-Scale Adaptation and Resilience

Coastal systems in the Great Lakes operate and change at large scales, such as the littoral cells described in Section 3.4.1. Therefore, the physical processes responsible for erosion of the coastal bluffs, transport of sediment along the shoreline, and accumulation in depositional beaches, must be studied at this scale to fully understand all the linkages and feedback mechanisms. For example, if large sections of eroding shoreline are permanently hardened and erosion stops, while there may be local benefits, significant downdrift impacts will occur due to the reduction of the natural sediment supply.

The community of Erieau is a good example within the boundaries of the study area. In the early 1800s, the south shore of Rondeau Bay was a series of wayward islands. In the early 1840s the first jetties were constructed for the navigation channel. The jetties were re-constructed in 1872 and two large islands were connected with a breakwater west of the west jetty. The sand that was previously transported to the tip of Rondeau Provincial Park was diverted and formed the footprint for the present Village of Erieau. As noted on the sign entering the Village, "Mother Nature's Gift to Us". No doubt a significant gift, but it has come at the expense of the barrier beach and forested tip of Rondeau Provincial Park, which has eroded 650 m north over the last 150 years since the construction of the Erieau jetties. These types of impacts are referred to as unintended consequences, since we did not have the scientific knowledge to predict the outcome. However, there have been significant impacts and the goal of coastal management is to avoid these types of consequences moving forward.


The adoption of a community-scale approach to the development of adaptation concepts seeks to avoid these types of negative impacts to the adjacent or downdrift shoreline, based on advanced knowledge of our coastal systems. The application of these principles will be further explained in the introduction of the adaptation concepts.

Resilience thinking is also a key part of the adaptation concept development. With respect to coastal management, resilience is measured as the ability of communities to bounce back from storms and learn from the impacts, adapt accordingly, and implement better solutions so the community is prepared for future storms and an uncertain future due to climate change. Therefore, a resilient coastal community must embrace the following approaches to coastal management and hazard mitigation:

- Plan for the historical range of coastal hazards and those projected for the future due to climate change.
- Recognize that coastal systems are dynamic, and change is an ongoing natural process, not something that needs to be stopped at all costs.
- Understand that natural shoreline processes, such as erosion and deposition, are necessary to protect beaches and coastal ecosystems, along with the goods and services they provide to society.
- Avoid solutions that result in negative near- and far-field impacts to adjacent lands, physical processes, coastal ecosystems, and shoreline infrastructure.
- Adopt a balanced approach to solution development that equally considers economic, environmental, and social benefits and consequences of the solutions.
- Consider a range of adaptation approaches to address individual site conditions and select options that maintain natural coastal processes, avoid negative impacts, and balance economy, ecosystem, and social interests.

## 6.2 Criteria for the Adaptation Options

Feedback from the three community meetings was used to develop a series of criteria to develop and evaluate the adaptation options. Figure 6.1 summarizes the top ten criteria based on the percentage of the respondents that completed the Exit Survey from the second meeting (June 19th and 20th, 2019). The top two responses - protect property and permanence/durability - are interrelated and reflect the desire for long-term solutions that protect our investment in coastal assets, including land, buildings, and infrastructure. Affordability for the landowners also ranked high, with approximately 50% of the respondents selecting this criterion. Another important criterion is the protection of human health, identified by roughly 40% of the individuals who completed the survey, which is reflective of the very high vulnerability of the communities.

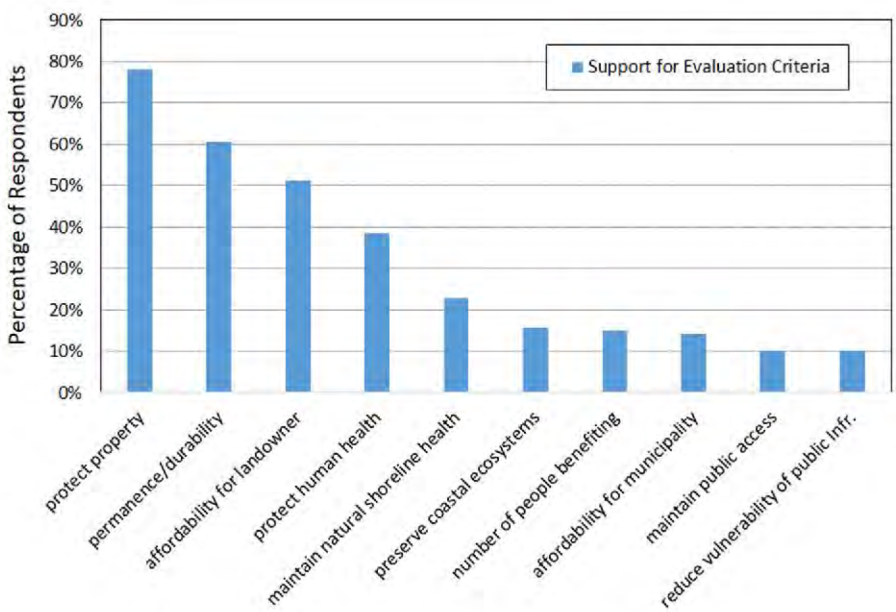



**Figure 6.1 Ranking of Evaluation Criteria by Attendees at PIC#2**

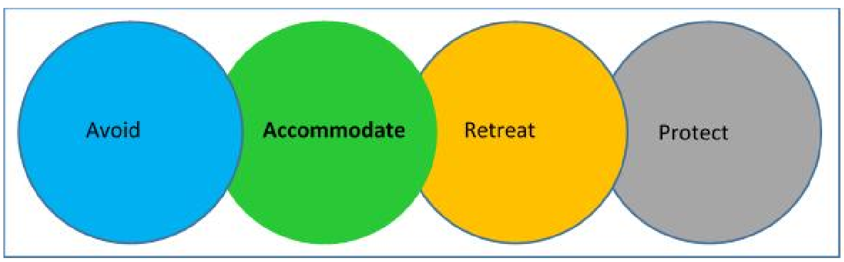
The remaining six criteria were selected by 10 to 20% of the survey respondents and included maintaining natural shoreline health, preserving coastal ecosystems, the number of benefiting people, affordability to the Municipality, maintenance of public access, and reducing vulnerability to public infrastructure.

### 6.2.1 Types of Adaptation Strategies

Consistent with best practice for coastal adaptation planning and the principles of a resilient coastal community, including a balanced approach and considering a wide range of adaptation options, the strategies developed for the Chatham-Kent Lake Erie Shoreline Study are grouped into four broad categories as follows:

- **Avoid**: reduce exposure by ensuring new development does not occur on hazardous land. Development setbacks for erosion and flooding embrace the principles of 'avoid'. This is a very effective strategy for new development but it does not address existing development, which is a major challenge for the study area.

- **Accommodate**: an adaptive strategy that allows for continued occupation of coastal properties while changes to human activities or infrastructure are made to reduce coastal hazards and vulnerability. For example, raising the foundation of a flood-prone building will reduce vulnerability and enable continued occupation of a site.




- **Retreat**: a strategic decision to withdraw or relocate public and private assets exposed to coastal hazards when the costs to accommodate or protect are not affordable, fail to produce a positive benefit-cost ratio, or are not permitted due to regulations or legislation.

- **Protect**: a reactive strategy to protect people, property, and infrastructure. This is the traditional approach used in the Great Lakes and often the first considered. Examples include armour stone revetments and seawalls.

Numerous examples of these four adaptation strategies were presented at the public meetings. Refer to Appendix B for additional information.

## 6.3 Approach and Costing for Concept Development

The following approach and assumptions were followed for the development of the adaptation concepts, by Region:

- The concepts focus on community-scale solutions to increase resilience. Lot-by-lot recommendations will not be generated.

- The concepts developed for the regions have not be optimized for an individual lot, since this is a planning study. In other words, the concepts could be further refined based on local site conditions resulting in local differences with the design.
- The concept sketches are not suitable for construction.
- The impacts of climate change on future lake level extremes and the associated nearshore water wave climate were included in the design of the concepts.
- Recent (2019) depth surveys completed for Erie Beach, Erie Shore Drive, Erieau, and the Rondeau Barrier Beach were considered to reflect current conditions, where possible.
- The Protect options were prepared for a 50-year planning horizon and acceptable levels of damage requiring occasional maintenance would be expected. For Erie Shore Drive, an alternative design was prepared for a 25-year planning horizon that would feature some acceptable damage requiring occasional maintenance. A third design for Erie Shore Drive was prepared for a 20-year planning horizon and would require regular maintenance.

The data collecting and costing strategy developed to prepare the concept level opinion of cost for the various adaptation option included:

- Unit costs for materials, such as quarried armour stone, were based on our internal database and more than ten recent local construction projects in Southwestern Ontario.
- All historical construction costs were updated for inflation to present value (2020).
- A 5% engineering design fee was added to all construction components.
- An additional 5% was added for permitting, tendering, and construction observation.
- Since all projects would require at least two years to design, permit and construct, all costs were indexed by 4%.
- Where possible, a range of costs was provided. The low range was the actual cost minus 20% to account for the fact that no optimization was completed for the designs and lot by lot information was not integrated. For the high range, 20% was added to the actual cost, which represents a contingency.
- The cost range for moving primary and secondary buildings was verified by a local construction company that re-locates structures. The relocation costs include purchasing a new lot and moving the buildings.
- The financial estimates were focused on initial capital costs, including land acquisition and material/construction costs. All expenditures were assumed to be present value costs. No discounting was completed on expenditures that would occur in the future (e.g., the cost to move a house in 20-years was not adjusted to present value).
- Future maintenance for the Protect options was not included in the capital cost estimates. However, for planning purposes future maintenance of all shoreline protection structures should be assumed. A standard industry estimate is 1% of the capital costs. The Protect options designed for a 50-year planning horizon would require significantly less maintenance than the structures designed with a 20-year planning horizon.

## 6.4 Protection Options Considered but Not Selected

Several protection options were considered for the adaptation concepts and then ultimately excluded from the study for the reasons outlined below.

### 6.4.1 Shore Perpendicular Groynes

Shore perpendicular groynes constructed with steel are a common type of shoreline protection throughout the Chatham-Kent Lake Erie shoreline. Two examples of failed steel sheet pile groynes are provided in Figure 6.2. For eroding shorelines, they have the following limitations:

- Groynes cause negative impacts to adjacent properties by trapping sediment and disrupting the natural delivery of sand and gravel to adjacent lots. Refer to Figure 6.3 for a schematic diagram of groyne impacts. Also, accelerated erosion typically occurs at the end of a groyne field and can extend for several hundreds of metres, resulting in negative impacts to adjacent property.
- For eroding coastlines, such as the Chatham-Kent Lake Erie shoreline, groynes do not stop or slow down lakebed downcutting beyond their footprint. Eventually, lakebed downcutting (lowering of the lake bottom) undermines the structure and they fail. Also, they do not provide slope stability protection for high bluff environments.
- If properly designed for sandy shorelines, groynes can trap sand and gravel during low lake levels, but they are often not effective at holding beach material during high lake levels when cross-shore currents can erode the sand between the groynes, which is when the protection is needed the most (Philpott, 1986; Kamphuis, 2005).
- Steel will corrode in the harsh lake environment and ultimately the groynes fail due to deteriorated steel sheets or broken welds. Refer to the bottom photo in Figure 6.2.

Groynes are not effective long-term protection for eroding shorelines. Based on our experience and profession judgement, groynes were not considered for any Protect options in this report.

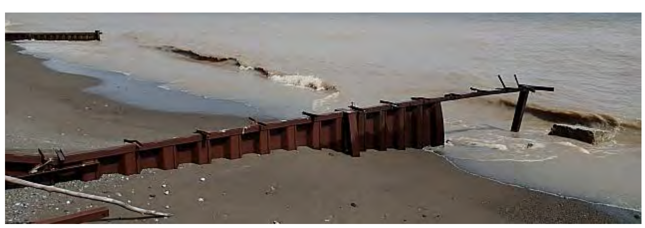


**Figure 6.2 Steel Sheet Pile Groynes in Failure (top: sheet missing from the tip; bottom: vertical sheets corroded at the waterline)**

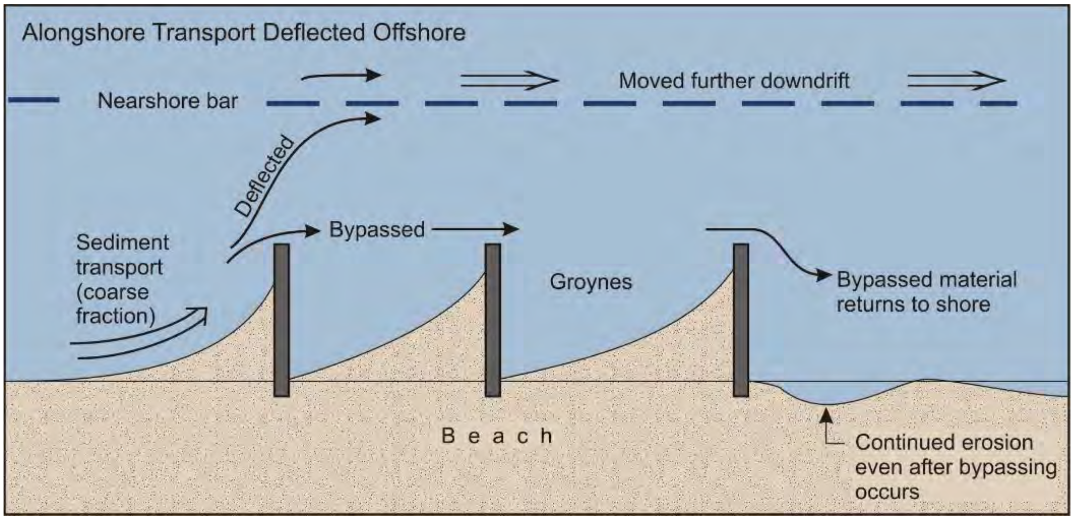



**Figure 6.3 Groyne Impacts on Adjacent Shoreline**

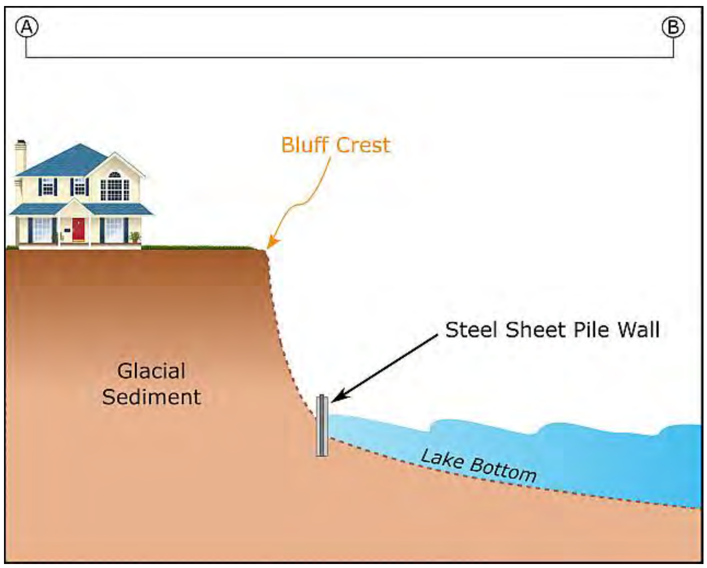
### 6.4.2 Vertical Shore Parallel Seawalls

Throughout the Great Lakes, vertical seawalls are another common type of shoreline protection constructed on private properties. They are typically built with steel sheet pile, concrete blocks, or poured concrete. An example of a failed concrete seawall along Erie Shore Drive is provided in Figure 6.4. These structures were not selected for inclusion in the adaptation options for the following reasons:

- Vertical walls reflect incoming energy downward and away from the structure toe, which accelerates lakebed downcutting. Eventually, lowering at the toe leads to undermining and failure, as seen in Figure 6.4. Flood risks increase when the walls fail.
- If proper allowance for wave overtopping is not included, scour behind the structure can occur, which undermines the stability of the wall and slope. When constructed at the base of an eroding bank or bluff, if geotechnical considerations are not included for the slope, groundwater, and drainage, slope failures eventually destroy the wall. See Figure 6.5. Flanking erosion at the property boundaries is also a common failure mechanism.
- Vertical walls do not stop downcutting of the lake bottom lakeward of the structure, which allows larger waves to continually reach the wall, eventually leading to a failure. These processes are highlighted graphically in Figure 6.6.


**Figure 6.4 Failed Concrete Wall, Erie Shore Drive**

**Figure 6.5 Failed Sheet Pile Wall due to Lack of Slope Design**



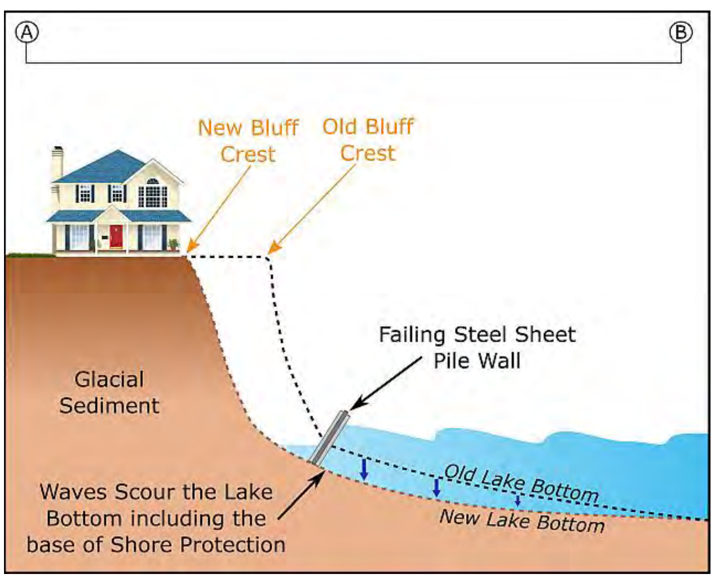




**Figure 6.6 Schematic Diagram of a Vertical Wall (top) and Failure Mechanisms for Eroding Shorelines and Lakebed (bottom)**

### 6.4.3 Offshore Breakwaters

Offshore breakwaters are constructed of quarried armour stone in the Great Lakes and built lakeward of the waterline. Multiple structures are built in succession, as seen in Figures 6.7 and 6.8. When properly designed, they intercept incoming wave energy and create semi-sheltered conditions along the shoreline. The distance offshore, length, crest elevation, and gap width influence the response of the beach behind the structures, which can range from a salient (widened beach but not connected to the breakwater, see Figure 6.8) to the formation of a tombolo (beach connects to the offshore breakwater, middle breakwater in Figure 6.7).

They are typically used in sandy environments, since their effectiveness is linked to the breakwaters ability to trap the alongshore movement of sand. For the Eastern Beaches breakwater's in Toronto (Figure 6.7), the area is a depositional sink for sand due to the Ashbridges Bay Headland. For the Presque Isle example (Figure 6.8), 38,000 cubic yards of beach nourishment is still required annually to ensure the breakwaters work effectively and that a protective beach is maintained.

Offshore breakwaters are one of the most expensive erosion mitigation alternatives in the Great Lakes, given the need to construct them in deep water using a barge and marine equipment. A large volume of rock is required to establish a stable base and build the crest elevation to the design water level. This concept was initially evaluated for Erie Shore Drive and discarded due to the high cost associated with a deep nearshore, marine construction, and the need for extensive beach material (trucked to the site). The initial cost range was $18,000 to $24,000 per metre and did not include future beach nourishment costs. Plus, since waves can still propagate through the gaps, the breakwaters would provide less wave overtopping protection than a continuous armour stone revetment. The preliminary cross-section is presented in Figure 6.9.

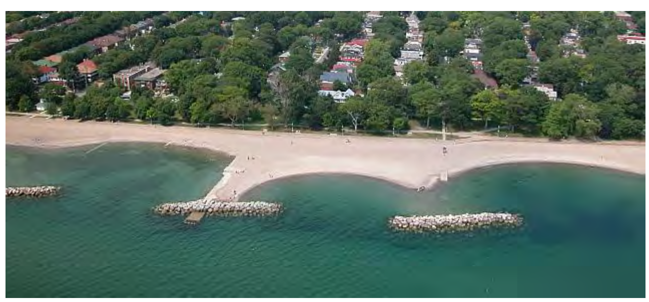


**Figure 6.7 Offshore Breakwaters Eastern Beaches, Toronto**

**Figure 6.8 Offshore Breakwaters Presque Isle State Park, Pennsylvania**

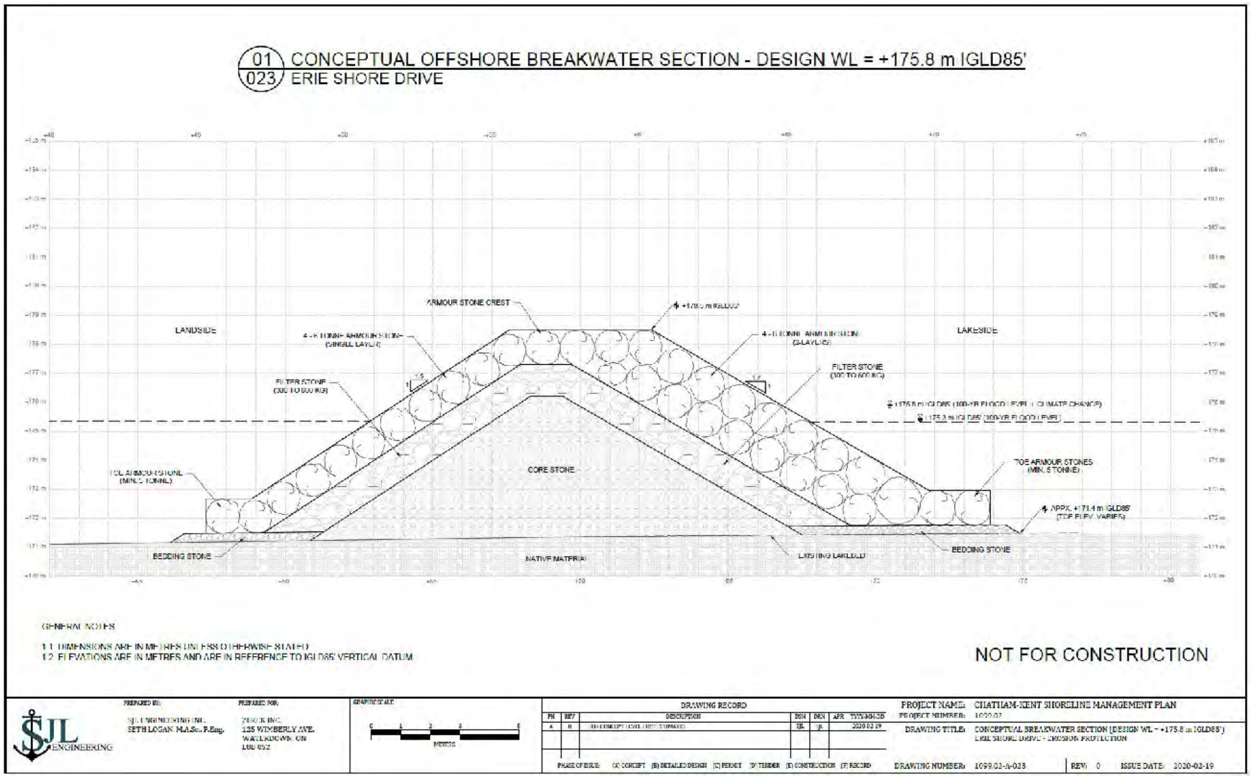



**Figure 6.9 Offshore Breakwater Cross-section (beach nourishment not shown)**

## 6.5 Adaptation Options by Region

The adaptation options by region are summarized in Section 6.5, from Wheatley to the eastern study boundary. Additional details on the cost estimates is provided in Appendix C.

### 6.5.1 Region 1A – Wheatley, Detroit Line, and Pier Road

Region 1A is located between the navigation channel at Wheatley Harbour and Wheatley Provincial Park to the north-east. Overall, the flood vulnerability is low in Region 1A. To date, shoreline erosion has generally been mitigated with private shoreline protection structures. However, emerging issues with the rapid deterioration of the Wheatley Provincial Park shoreline, and implications for the adjacent shoreline, require additional investigation.

#### *6.5.1.1 Avoid*

Option 1-1 was developed specifically for the eroding shoreline along Wheatley Provincial Park and the adjacent lands.

- *Option 1-1 Long-term Planning Study for Wheatley Provincial Park and Area*: The rapid rate of shoreline erosion along Wheatley Provincial Park has been alarming and threatens to undermine the stability of the entire region, including the Two Creeks area. The former day-use camping area will soon be an island and separated from the mainland park. This could threaten the stability of the Holiday Harbour peninsula and raises serious concerns about the future of the Provincial Park. Therefore, a long-term planning study, with participation from the Ontario Parks, Wheatley Provincial Park, the Municipality of Chatham-Kent, the Lower Thames Valley Conservation Authority, and local landowners is recommended to develop a coordinated long-term plan for the shoreline. The approximate limits of the study area are presented in Figure 6.10.


**Figure 6.10 Extent of Wheatley Shoreline Erosion Planning Study (approximate limits)**

#### *6.5.1.2 Region 1A General Adaptation Options*

The following general adaptation options for Wheatley, Detroit Line, and Pier Road are recommended (refer to Appendix B for additional details and examples):

- *Option A Higher Regulatory Standards (Avoid)*: Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate.
- *Option B Evaluate Existing Land Use Policies and Zoning Regulations (Avoid)*: Re-evaluate existing land-use policies, zoning regulations, septic system requirements, and building standards along the eroding and flood prone shorelines to avoid future challenges with development and coastal hazards.
- *Option C – Maintain Existing Shoreline Protection Structures (Protect)*: Complete regular maintenance following accepted coastal engineering design principles. Consider changing failing vertical walls to sloped armour stone revetments.
- *Option D – Construct New Shore Protection (Protect)*: Complete an engineering design study and build new shoreline protection. Sloping armour stone revetments are the recommended alternative, not vertical walls.
- *Option E – Raise Grades and/or Foundations (Accommodate)*: Increase elevations around existing buildings and recreational areas above the 100-year flood level or a new standard, to decrease flood risk and improve overland drainage. Site grading plans at the local scale may be required. Septic tile beds may also require updating.
- *Option F – Relocate Buildings Inland (Retreat)*: Relocate existing buildings to the furthest inland location on a lot or to a new lot.

### 6.5.2 Region 1B – Bluffs East of Wheatley Provincial Park to Erie Beach

Several generic adaptation strategies were identified for Region 1B and are described below. These options generally deal with planning to avoid future risks. However, given the severity of the vulnerability to further bluff erosion in Region 1B, including 439 primary and secondary buildings vulnerable to erosion in 50-years (or less due to climate change), and eleven sites where the coastal roads are threatened by erosion, two long-term community-scale adaptation solutions were developed.

#### *6.5.2.1 Region 1B General Adaptation Options*

The following generic adaptation options for the bluffs of Region 1B were selected based on the vulnerability assessment and represent planning alternatives, short-term actions, and longer-term strategies (refer to Appendix B for additional details and examples):

- *Option A Higher Regulatory Standards (Avoid)*: Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate.
- *Option B Evaluate Existing Land Use Policies and Zoning Regulations (Avoid)*: Re-evaluate existing land-use policies, zoning regulations, septic system requirements, and building standards along the eroding bluffs to avoid future challenges with development and erosion hazards.

- *Option F – Relocate Buildings Inland (Retreat)*: Relocate existing buildings to the furthest inland location on a lot or to a new lot.
- *Option G – Construct Moveable Buildings (Avoid/Retreat)*: Construct all future development with appropriate structural support to facilitate future relocation when at risk to erosion and flooding hazards (e.g., structural support such as I-beams included in the foundation design).

#### *6.5.2.2 Protect Option 1-2 Armour Stone Revetment*

To address the long-term erosion rate for the bluff shorelines in Region 1B, and the projected increase in the future erosion rate due to reduced winter ice cover, a large 40 km armour stone revetment was developed for Option 1-2 with a 50-year planning horizon. Refer to Figure 6.11. The toe of the 2-layer armour stone revetment is keyed into the lakebed to accommodate 1.0 m of future downcutting. The bluff slope would be regraded to a stable long-term angle and include drainage details to address groundwater flows. Access to the shoreline for construction would be gained by ramps cut down the bluff at strategic locations. Construction equipment would travel along the toe of the existing bluff on the core stone to deliver the material to construct the revetment.

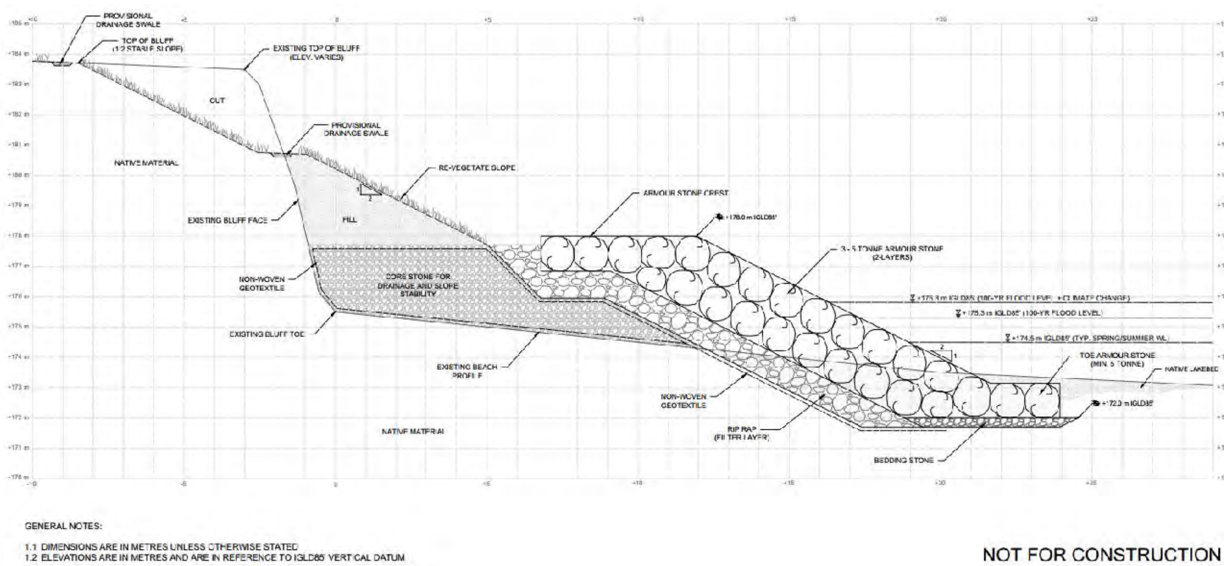



**Figure 6.11 Option 1-2 Armour Stone Revetment and Slope Regrading with Drainage System**

With the elements in the concept sketch, theoretically, storm damage would be within acceptable limits and require some maintenance for the 50-year planning horizon. However, with future uncertainties for lake levels and wave energy due to reduced winter ice-cover, maintenance could become more significant over time. The estimated capital costs for Option 1-2 range from $596 to $892 million.

#### *6.5.2.3 Retreat Option 1-3 Relocate Talbot Trail and Buildings Inland*

The second long-term community-scale adaptation strategy for Region 1B is the relocation of the Talbot Trail and at-risk buildings further inland. The road would be re-aligned somewhere within the shaded red area of Figure 6.12. The existing development along the bluffs would access the re-aligned Talbot Trail by the existing north-south road network. Sections of the current re-alignment would be decommissioned when threatened by erosion. The estimated capital costs to realign the road is $34.7 million.

Existing buildings would also be relocated inland when threatened by bluff erosion and slope instability. The vulnerability assessment identified 235 primary buildings and 204 secondary buildings between the lake and the 50-year estimate for the future top of bluff. The estimate includes the purchase of a new 0.5-acre parcel of land and the costs to move the buildings. The cost range is $33.3 to $61.9 million. The combined cost for Option 1-3 ranges from $68.0 to $96.6 million, which is roughly 10% of the cost for Option 1-2.


**Figure 6.12 Talbot Trail Relocation Zone**

### 6.5.3 Region 1C – Bates Line/Drive and Rose Beach Line to Mckinlay Road

The shoreline in Region 1C is located between the eroding bluffs in the east and the depositional shoreline of Rondeau Provincial Park to the south. While the shoreline position can fluctuate with cycles of high and low lake levels, major persistent erosion threats were not identified. The flood vulnerability is also low, with only minimal impacts when the climate change 100-year lake level was evaluated. Consequently, only the general adaptation concepts were selected for Region 1C, as outlined in Section 6.5.3.1.

#### *6.5.3.1 Region 1C General Adaptation Options*

The following general options may be appropriate on a lot-by-lot basis to address local issues:

- *Option A Higher Regulatory Standards (Avoid)*: Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate.
- *Option B Evaluate Existing Land Use Policies and Zoning Regulations (Avoid)*: Re-evaluate existing land-use policies, zoning regulations, septic system requirements, and building standards along the eroding and flood prone shorelines to avoid future challenges with development and coastal hazards.
- *Option C – Maintain Existing Shoreline Protection Structures (Protect)*: Complete regular maintenance following accepted coastal engineering design principles. Consider changing failing vertical walls to sloped armour stone revetments.
- *Option E – Raise Grades and/or Foundations (Accommodate)*: Increase elevations around existing buildings and recreational areas above the 100-year flood level or a new standard, to decrease flood risk and improve overland drainage. Site grading plans at the local scale may be required. Septic tile beds may also require updating.
- *Option F – Relocate Buildings Inland (Retreat)*: Relocate existing buildings to the furthest inland location on a lot or to a new lot.
- *Option G – Construct Moveable Buildings (Avoid/Retreat)*: Construct all future development with appropriate structural support to facilitate future relocation when at risk to erosion and flooding hazards (e.g., structural support such as I-beams included in the foundation design).

### 6.5.4 Region 1D – Mckinley Road to Hill Road

The biggest challenge for Region 1D is the closed section of Rose Beach Line between Antrim and Hill Road due to ongoing shoreline erosion and slope instability. The recommendations for the general adaptation options and options for Rose Beach Line are provided in the following sections.

#### *6.5.4.1 Region 1D General Adaptation Options*

Several general adaptation options were selected for Region 1D, including higher regulatory standards, evaluating existing zoning regulations, and construction of moveable buildings, should further development be pursued.

- *Option A Higher Regulatory Standards (Avoid)*: Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate.
- *Option B Evaluate Existing Land Use Policies and Zoning Regulations (Avoid)*: Re-evaluate existing land-use policies, zoning regulations, septic system requirements, and building standards along the eroding bluffs to avoid future challenges with development and erosion hazards.
- *Option G – Construct Moveable Buildings (Avoid/Retreat)*: Construct all future development with appropriate structural support to facilitate future relocation when at risk to erosion and flooding hazards (e.g., structural support such as I-beams included in the foundation design).

#### *6.5.4.2 Protect Option 1-4 Armour Stone Revetment*

To protect the eroding bluff along Rose Beach Line and re-open the road, an armour stone revetment concept with a 50-year planning horizon was selected for Option 1-4. As with all shoreline protection structures, some storm damage would occur but is expected to be within acceptable limits and require occasional maintenance over the planning horizon. Refer to Figure 6.13 below for the spatial extent of Option 1-4. The cost range to construct the revetment and repair/upgrade the road following construction is $18.2 to $26.7 million. Revetment maintenance would be in addition to these capital costs.


**Figure 6.13 Rose Beach Line Armour Stone Revetment**

#### *6.5.4.3 Retreat Option 1-5 Decommission Rose Beach Line from Mckinley Road to Wildwood*

A retreat concept was developed for Rose Beach Line that includes de-commissioning Rose Beach Line, utility relocations, and upgrading New Scotland Line as an alternative west-to-east route. The components of Option 1-5 are presented visually in Figure 6.14 and include:

- Decommissioning 2 km of Rose Beach Line from Mckinlay Road to Hill Road (a portion of Rose Beach would remain at the terminus near Hill Road for access to existing properties). Municipal infrastructure and utilities, such as watermains, would also be removed and relocated.
- Upgrades to 4.6 km of New Scotland Line including bridge replacements.

- Three new access roads for existing development on the north side of Rose Beach line (see Figure 6.14 for connections to Mckinlay Road, Antrim Road, and Wildwood Trailer Park). The purchase of land for the road improvements was included.

The cost range for the retreat option is $12.1 to $14.6 million.


**Figure 6.14 Rose Beach Closure and Upgrades to New Scotland Line**

### 6.5.5 Region 1E – Hill Road to East Study Boundary

The section of Lake Erie shoreline from Hill Road to the eastern boundary of the Municipality features very low vulnerability to coastal hazards, especially when compared to the high bluffs along Talbot Trail. With the estimated future 50-year top of bank, only 23 primary buildings in Region 1E are impacted by erosion. For comparison, at total of 235 primary buildings are threatened along Talbot Trail (Region 1B).

Another major distinction between Region 1E in the east and western half of the study area, is the location of Talbot Trail in proximity to the lake. As outlined in Section 4.2.3, the closest proximity of this important east-west artery to the lake is 1.6 km. Therefore, given the very low number of primary buildings threatened by erosion and the absence of any risk to the Talbot Trail for many centuries, community-scale adaptation concepts were not developed for Region 1E. Several site-specific recommendations are provided in the following section.

#### *6.5.5.1 Region 1E General Adaptation Options*

These generic adaptation options for the bluffs in Region 1E were selected to avoid future hazards or deal with localized threats, including:

- *Option A Higher Regulatory Standards (Avoid)*: Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate.
- *Option B Evaluate Existing Land Use Policies and Zoning Regulations (Avoid)*: Re-evaluate existing land-use policies, zoning regulations, septic system requirements, and building standards along the eroding bluffs to avoid future challenges with development and erosion hazards.
- *Option F – Relocate Buildings Inland (Retreat)*: Relocate existing buildings to the furthest inland location on a lot or to a new lot.
- *Option G – Construct Moveable Buildings (Avoid/Retreat)*: Construct all future development with appropriate structural support to facilitate future relocation when at risk to erosion and flooding hazards (e.g., structural support such as I-beams included in the foundation design).

Refer to Appendix B for additional details and examples of the options.

### 6.5.6 Region 2A – Erie Beach

The community of Erie Beach is located between Charing Crossing Road and Bisnett Line and features approximately 2 km of shoreline. The shoreline is protected with a near-continuous protection scheme featuring steel sheet pile walls and groynes. Unlike the neighbouring Erie Shore Drive, the community was not built on a dike and is located on higher ground. Consequently, the vulnerability to coastal flooding is low. The beach profile data collection in August 2019 (Section 3.3.4) did highlight deep nearshore conditions along Erie Beach, so regular monitoring and maintenance of existing shoreline protection structures is recommended.

#### *6.5.6.1 Region 2A General Adaptation Options*

Since community-scale adaptation options were not required for Erie Beach, several generic adaptation options were selected to reduce future hazards or deal with localized threats, including:

- *Option A Higher Regulatory Standards (Avoid)*: Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate.
- *Option C Maintain Existing Shore Protection Structures (Protect)*: Complete regular maintenance following accepted coastal engineering design principles. Consider changing failing vertical walls to sloped armour stone revetments.
- *Option D – Construct New Shore Protection (Protect)*: Complete engineering design study and build new shoreline protection. Sloping armour stone revetments are the recommended alternative, not vertical walls.
- *Option E – Raise Foundations and Grades (Accommodate)*: Increase elevations around existing buildings and recreational areas above the 100-year flood level or a new standard, to decrease flood risk and improve overland drainage. Site grading plans at the local scale may be required. Septic tile beds may also require updating.

Refer to Appendix B for additional details and examples of the options.

### 6.5.7 Region 2B – Erie Shore Drive

Historical mapping has shown that the Burk Drainage Scheme was once the fringe of the Rondeau Bay Marsh. Prior to European colonization, Erie Shore Drive was likely a dynamic sandy barrier beach that separated the lake from the marsh and meadows of the bay. The dike was constructed at the back of the sandy barrier beach to protect the re-claimed agricultural lands between Bisnett Line and Lagoon Road in the Burk Drain. Development followed on the beach lakeward of the dike, and eventually a road was added. As noted in the vulnerability assessment in Section 4.4, the community has very high exposure to coastal hazards, including erosion and flooding. A dike breach would flood over 500 hectares of interior farmland in the Burk Drainage Scheme and make Erieau Road inaccessible to vehicular traffic, thus isolating the Village of Erieau from emergency services outside the community.

These risks are magnified during the current period of high lake levels and Erie Shore Drive has been repeatedly flooded since 2017. Emergency measures were constructed on the north slope of the dike (i.e., concrete blocks and rock chutes) to convey wave overtopping across the road and into the agricultural drain.

The overall stability of the dike has been closely monitored by the Municipality of Chatham-Kent and several reports (2018, 2019) have been issued by Geotechnical Engineering Firm Golder Associates. In a March 3, 2020 report (Golder, 2020a), deteriorating conditions along the dike were reported and the current mitigation approach was noted as unsustainable (e.g., rock chutes). The report indicated there was a 5 to 40% change of wave overtopping conditions that would render the dike unstable with progressive failures, leading to a significant breach and interior flooding.

Based on this recommendation, on February 28, 2020 Mayor Darrin Canniff declared a state of emergency under the Emergency Management and Civil Protection Act. Then, on March 2, 2020, the Municipality of Chatham-Kent Council passed a By-law to permanently close a part of Erie Shore Drive effective March 9, 2020. Authority was delegated to the General Manager of Infrastructure and Engineering Services to complete emergency repairs to the dike. The emergency repairs are now complete and the latest Golder report (2020b) indicated the dike is stable to marginally stable for a flood event lasting up to four days.

As noted in Section 3.4.4, there has been significant erosion of the lake bottom in front of the Erie Shore Drive community. At Line 7, the water depth below the 100-year lake level at the base of the seawall has increased from 2.2 m to 3.8 m from 1938 to 2019. When climate change is factored into the 100-year lake level, the water depth at the base of the seawall is 4.3 m.

With this context, a series of community-scale adaptation concepts and sketches were developed for Region 2B and where appropriate a concept level opinion of cost was generated. The general single lot adaptation options are not appropriate for Erie Shore Drive, given the need for a community-scale solution following the ongoing emergency repairs.

#### *6.5.7.1 Avoid and Accommodate*

During these challenging times, the one short-term adaptation option that should be considered is emergency repairs, Option H, as outlined below:

- *Option H Emergency Shore Protection*: if existing shoreline protection structures fail along Erie Shore Drive while the road is closed, repairs should be made to avoid further flooding risks. The Lower Thames Valley Conservation Authority and Ministry of Natural Resources and Forestry are currently approving emergency repairs, where appropriate, using like for like (e.g., a failed seawall replaced with another seawall).

### *6.5.7.2 Option 2-1 Protect Concepts*

Option 2-1 was developed for Erie Shore Drive to address the shoreline erosion and flooding hazards, reduce wave overtopping to protect the road, and upgrade the stability of the earth dike to standards consistent with the Municipal Drainage Act. A sensitivity analysis was completed for the erosion mitigation and there are three versions of Option 2-1, as follows:

- *Option 2-1a 50-year Armour Stone Revetment and Dike Reconstruction*: A two-layer armour stone revetment was developed for a typical cross-section along Erie Shore Drive (with an existing steel sheet pile wall) that accounts for the influence of climate change on future lake levels. The concept was prepared for a 50-year planning horizon. Storm damage would be within acceptable limits and require only occasional maintenance. The toe of the structure is keyed into the lakebed to accommodate 1.0 m of future downcutting. Finally, the crest elevation reduces wave overtopping to an acceptable level for the 100-year design condition. It should be noted that given the very deep nearshore conditions that exist along Erie Shore Drive, the crest elevation of the revetment is 179.0 m IGLD'85 and would obscure views of the lake from many residences. Refer to Figure 6.15a. The cost estimate for 3.3 km of revetment is $46.2 to $69.3 million.

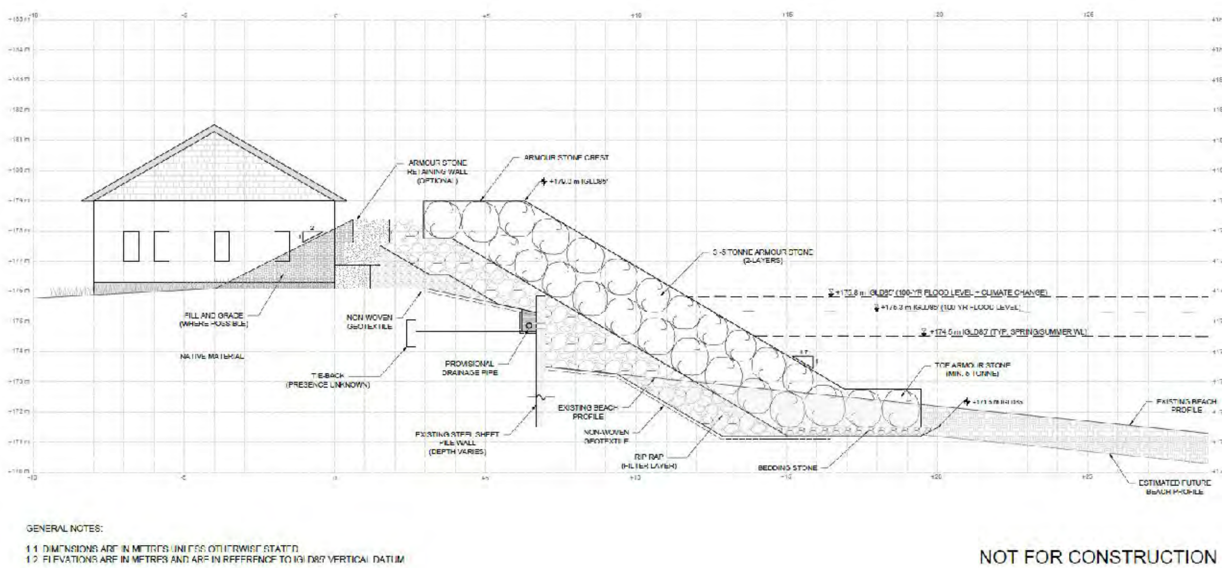



**Figure 6.15a 50-Year Planning Horizon Armour Stone Revetment for Erie Shore Drive**
(note: for this typical example, the building would need to be relocated on the lot)

Even with the Option 2-1a revetment, many of the homes would require floodproofing to ensure the foundation and building contents are protected during storms at the 100-year lake level. Home relocations may also be required due to the proximity of the revetment to the homes, as seen in Figure 6.15a. Updated septic systems will also be required in some cases. The Option 2-1a opinion of cost assumes half the homes require raised foundations and new septic systems. Details of these costs are provided in Appendix C.

In response to the dike stability concerns raised by Golder (2020a), the Municipality of Chatham-Kent has developed a Protect concept for the dike, drain, road, and local drainage. A new higher dike is constructed north of Erie Shore Drive for 2.1 km and a new Lakeshore Drain is excavated. Refer to Figure 6.15b. This option would require the purchase of agricultural land to the north of the current drain. The residential property would also be drained by a series of catch basins that would collect water at the edge of the new road and direct it to a stormwater pond. The opinion of cost for the new dike, drain, property drainage is $5.9 million. The costs increase to $10.0 million to repair and re-open Erie Shore Drive.

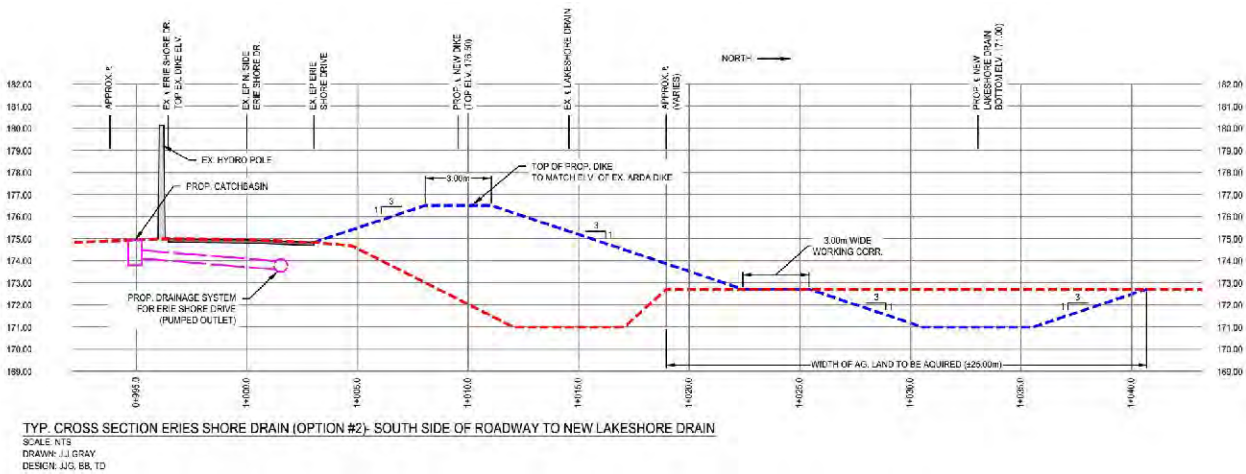



**Figure 6.15b New Dike, Drain, Property Drainage, and Road for Erie Shore Drive** (sketch by the Municipality of Chatham-Kent)

Based on the multiple upgrades required for this protect concept, the cost range is $59.2 to $84.4 million.

- *Option 2-1b Crest Elevation Sensitivity Analysis (climate change water levels not considered)*: The Option 2-1 revetment was re-designed without consideration for the effects of climate change on the 100-year lake level as part of a sensitivity analysis. Refer to Figure 6.16. The concept was prepared for a 25-year planning horizon. Storm damage would be within acceptable limits for the historical lake level range over a 25-year period. However, if lake levels exceed historical extremes (e.g., a newer record high water level), maintenance would be more frequent.

  Option 2-1b features two-layers of large armour stone (2 to 4 tonnes) and includes an allowance for 1.0 m of future lake bottom downcutting. The crest elevation was reduced to 178.0 m IGLD'85, since the influence of climate change on the 100-year lake level was not considered. This option also includes the new dike and drain, plus drainage for the residential lots, and a new re-surfaced Erie Shore Drive, as outlined in Figure 6.15b.

When the influence of climate change is removed from the design, the cost for the Option 2-1b revetment, including floodproofing homes, new septic systems, and upgrading the dike, decreased to $45.7 to $64.3 million.  About a 20% reduction versus the Option 2-1a costs.  The full costing details are provided in Appendix C.

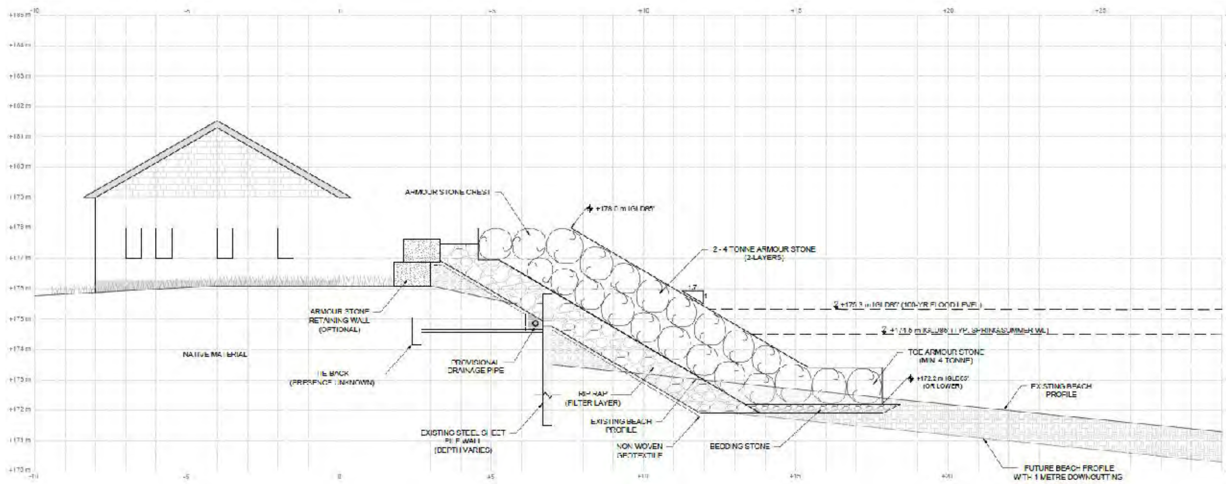



**Figure 6.16  25-Year Planning Horizon Armour Stone Revetment for Erie Shore Drive**

- *Option 2-1c Berm Section (reduced planning horizon with regular maintenance):* A third variation of Option 2-1 was developed using a rock berm structure, as seen in Figure 6.17 below.  Rather than two layers of large quarried armour stone, the sloping rock structure features a wider gradation of quarried stone and a mid-slope bench.  The berm section is easier to construct, since the placement of individual stones is not required.  Plus, the wider gradation for the outer layer reduces the cost per tonne for the stone.

  There is no allowance for future downcutting, but the structure does feature a gentler slope and the mid-slope bench, which reduces overtopping volumes and allows for some resettlement.  Consequently, the crest elevation was reduced to 177.5 m IGLD'85.  The berm section was prepared for a 20-year planning horizon and would require maintenance to address stone re-adjustment following severe storms.

  The Option 2-1a upgrades to the dike, drain, road, and residential drainage are also included in Option 2-1c (as outlined in Figure 2.15b).  The cost estimate to floodproof homes, re-build septic systems, upgrade the dike and road, and construct the shoreline protection, ranges from $36.8 to $50.7 million.  While this is a substantial reduction over the Option 2-1a costs (~40%), it must be emphasized that the planning horizon for Option 2-1c is only 20 years (versus 50-years).

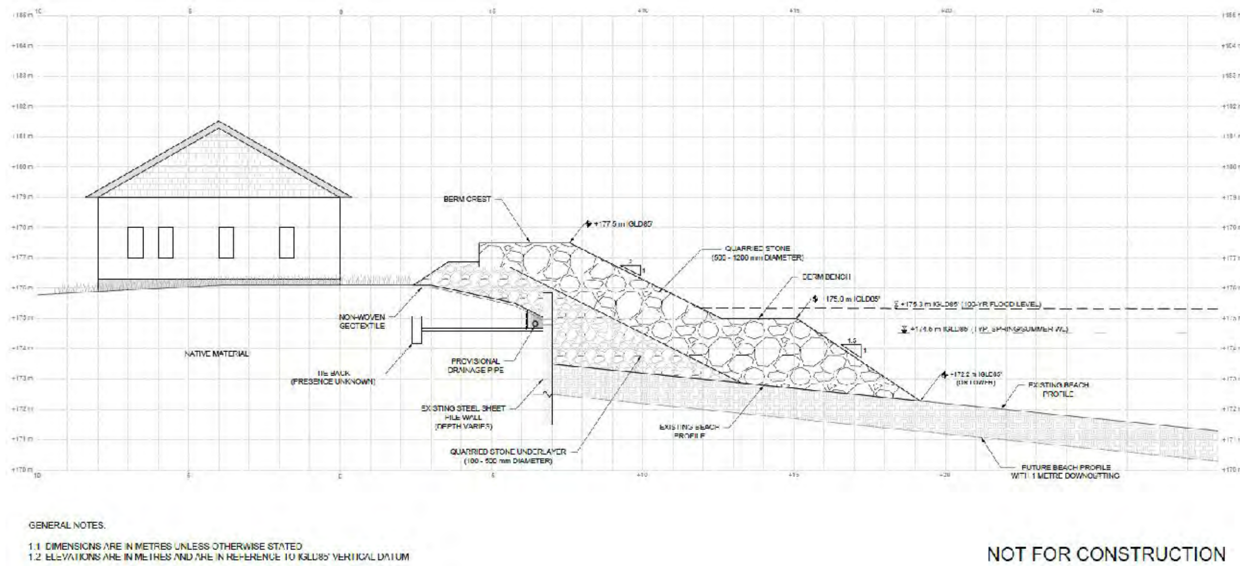



**Figure 6.17 20-Year Planning Horizon Rock Berm Structure for Erie Shore Drive**

#### *6.5.7.3 Option 2-2 Erie Shore Drive Retreat*

In Option 2-2 a retreat program is developed and implemented for the lakefront properties south of the dike consisting of: 1) a buyout strategy assuming upper level of government support exists, or 2) the relocation of homes to an alternative site, or 3) a combination there of. The 2019 assessed value of the properties was approximately $20 million. It is beyond the scope of this report to establish the details and costs of such a retreat program.

#### *6.5.7.4 Option 2-3 Upgrade the Dike for Flood and Erosion Protection*

This Option assumes a retreat program for the properties south of the dike was implemented (Option 2-2). With the buildings removed and the road closed, significant dike upgrades are still required to protect the interior agricultural land from a dike breach and ensure the emergency access for the community of Erieau is not lost along Erieau Road.

In Option 2-3, the dike crest elevation is raised to 177.0 m within the existing footprint of the dike (old road base), as noted in Figure 6.18a. Repairs to the north slope of the dike would be completed and the drainage ditch would be cleaned/maintained.

The shoreline would be naturalized with a combination of grey and green infrastructure. The majority of the existing riparian shore protection would be left in place and augmented with a modified berm cross section, as seen in Figure 6.18b. Since the tolerance for wave overtopping increases with a naturalized shoreline, the crest elevation of the protection is decreased to 176.5 m. The grades along the former residential area are raised and sloped towards the lake. A dune ecosystem is restored, and backshore vegetation is planted to stabilize the shoreline with native plants. A multi-use trail could be constructed between the restored dunes and raised dike crest (not shown on Figure 6.18b or included in the cost estimate).

With the road closed, dike upgraded and shoreline protected with the hybrid grey-green solution, agriculture activities can safely continue in the Burk Drainage scheme and Erieau Road would provide safe ingress and egress to the Village of Erieau under emergency conditions. Erie Beach would have east-west access along Bisnett Line and Erieau Road. Refer to Figure 6.18c. The cost to upgrade the dike and protect the shoreline with a hybrid natural solution is $22.5 to $31.7 million (not including the costs to relocate or remove the existing homes).

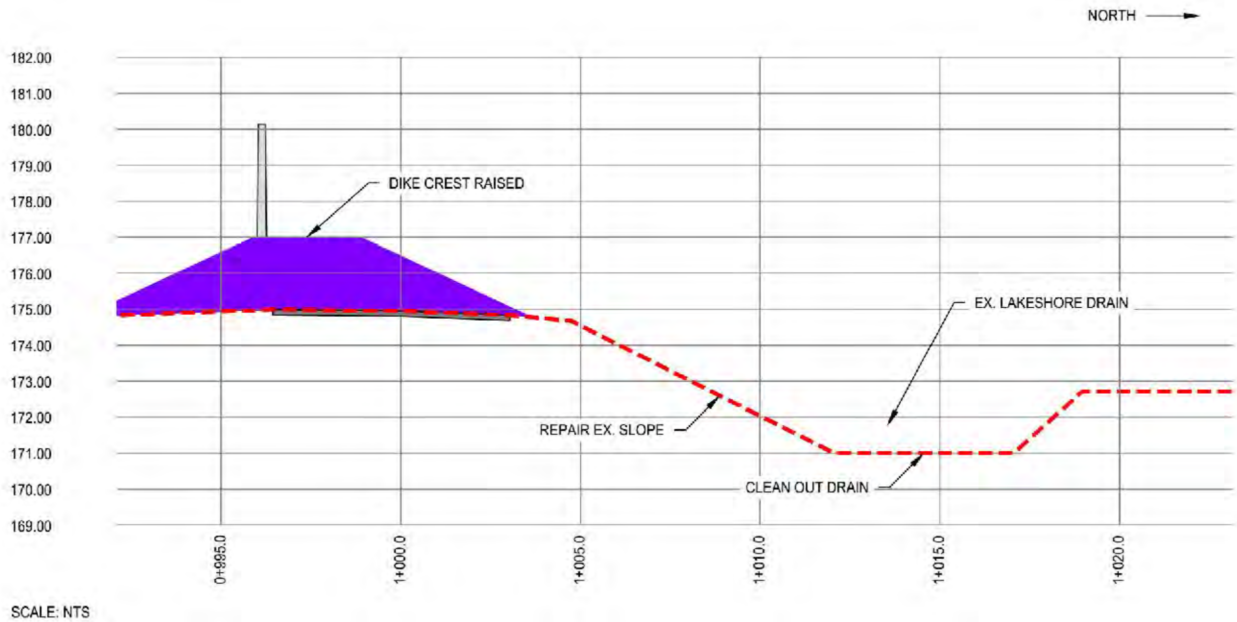



**Figure 6.18a Existing Dike Elevation Raised, Slope Repairs, and Ditch Cleanout (section from Municipality of Chatham-Kent)**

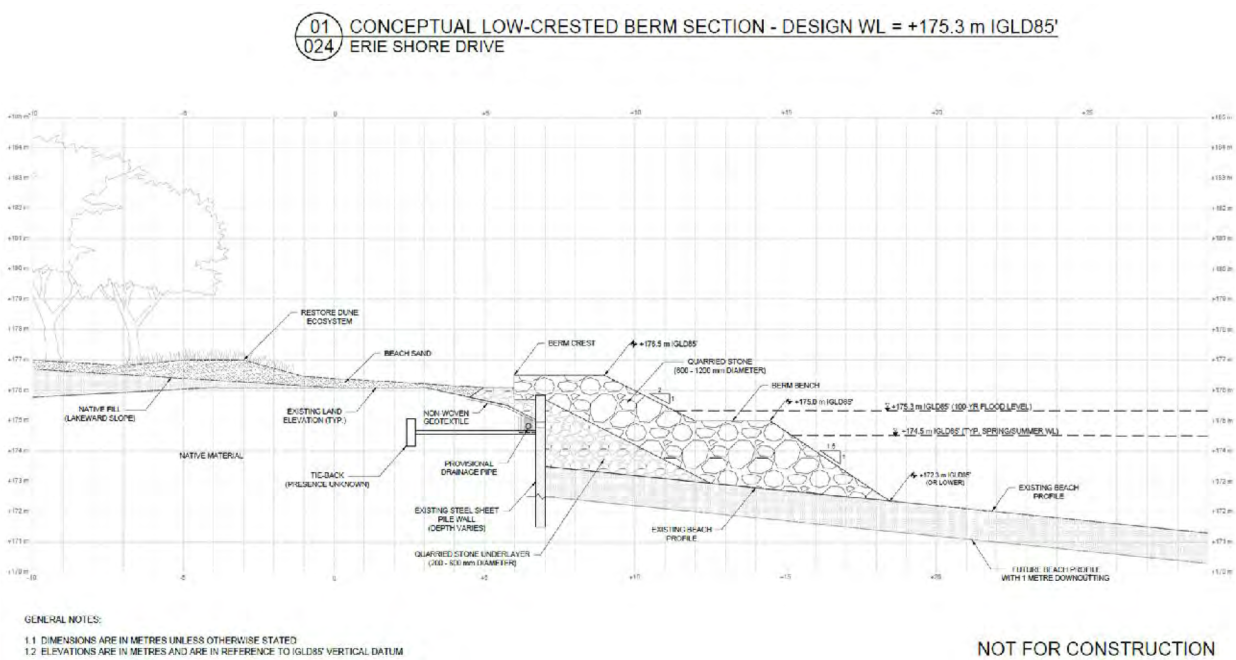



**Figure 6.18b Shoreline Protected with Modified Berm and Nature (dunes/vegetation)**


**Figure 6.18c  Plan View of Option 2-3**

### *6.5.7.5 Option 2-4 Nature-based Adaptation*

The nature-based adaptation concept in Option 2-4 assumes that a retreat program has been completed for the properties along Erie Shore Drive. The dike is protected with a reduced version of the rock berm in Option 2-1c, as it is necessary to protect the shoreline from erosion, yet wave overtopping is not a concern.

The interior lands are restored with a variety of wetland habitat from open water, to meadow, to swamp and upland forest. A hydraulic connection to Lake Erie is constructed. The elevations for the upland forest would require imported fill to ensure lake flooding would not impact Erieau Road (e.g., the elevation of the upland forest would be raised above the 100-year climate change lake level). Refer to Figure 6.19 for a plan view map of Option 2-4.

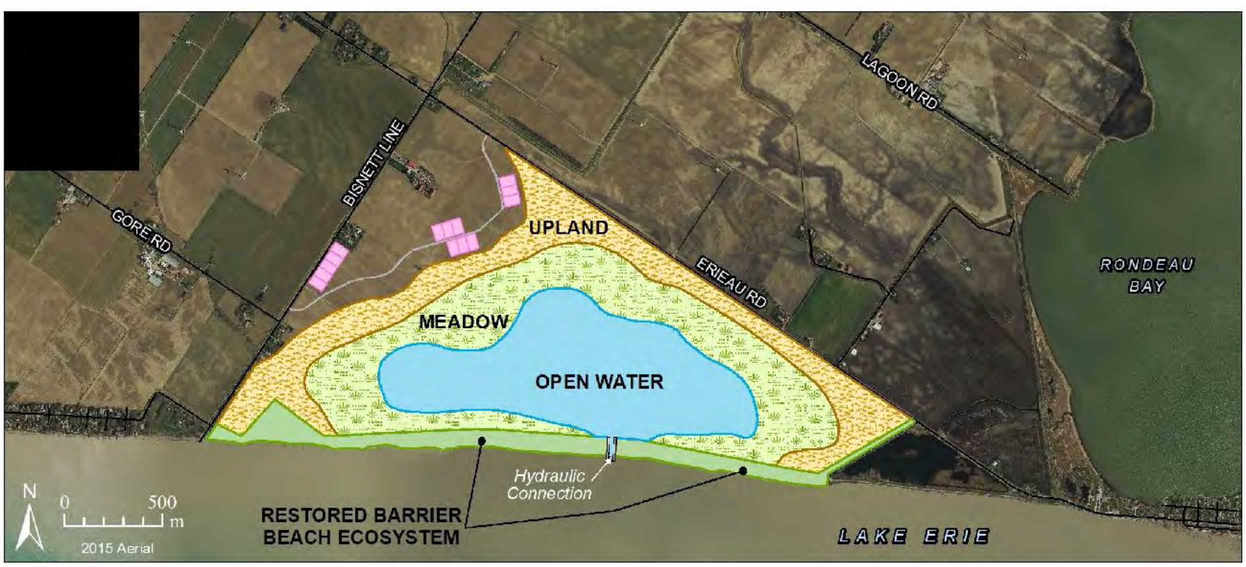



**Figure 6.19  Nature-based Adaptation for Erie Shore Drive and Burk Drain**

It should be noted that the current agricultural lands located above the 100-year lake level in Figure 6.19, near the intersection of Erieau Road and Bisnett Line, are not naturalized in Figure 6.19. This area is approximately 150 acres in size and could be rezoned for residential lots that could help fund the restoration. At this time, the potential revenue for converting these agricultural lands to residential lots has not been integrated into the Option 2-4 opinion of cost.

The cost estimate to acquire the agricultural land south of Erieau Road in the Burk Drainage Scheme and restore the agricultural lands to a coastal wetland that includes a hydraulic connection to Lake Erie ranges from $33.1 to $47.4 million.

### 6.5.8 Region 3A – Village of Erieau

The results of the flood vulnerability assessment for the Village of Erieau were summarized in Section 4.3.5. For the historical 100-year lake level, $13 million in primary and secondary buildings are vulnerable, primarily along the lower bay shoreline. When the climate change 100-year lake level was evaluated, the potential for damages increases dramatically. A total of 357 primary and secondary buildings are within the floodplain and their combined assessed value is $46 million. Given the low land elevations in Erieau and the high density of the development, it features more at-risk development for the climate change 100-year lake level than any other region in the study area. The following sections summarize the general adaptation options for Erieau and two specific options to address emergency access.

#### *6.5.8.1 Region 3A General Adaptation Options*

The following general adaptation options were selected for the Village of Erieau to deal with flood vulnerability, including:

- *Option A Higher Regulatory Standards (Avoid)*: Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate.
- *Option C Maintain Existing Shore Protection Structures (Protect)*: Complete regular maintenance following accepted coastal engineering design principles.
- *Option E – Raise Foundations and Grades (Accommodate)*: Increase elevations around existing buildings and recreational areas above the 100-year flood level or a new standard, to decrease flood risk and improve overland drainage. Site grading plans at the local scale may be required. Septic tile beds may also require updating.
- *Option I – Update Private Septic Systems (Accommodate)*: Existing private septic systems, including weeping beds, are replaced with a proper elevated design, an alternative system, or a community-wide municipal system (i.e., sanitary sewers and treatment).
- *Option J – Raise Road Elevations (Accommodate)*: Elevate road grades above the climate change 100-year flood level

While these options were developed for localized or lot-by-lot vulnerability, given the elevated risk profile for the climate change 100-year lake level, several of these options (raise foundations and road elevations) will be required on a community scale to increase resilience to future climate change water level extremes. Refer to Appendix B for additional details and examples of the options.

#### *6.5.8.2 Accommodate Option 3-1 Construct Secondary Ingress/Egress Route for Erieau*

The vulnerability of the only emergency route to and from Erieau was highlighted in Figure 4.11. If the Erie Shore Drive dike breaches and the Burk Drain floods during the 100-year lake level, Erieau Road will be covered by more than 1.5 m of water and impassable for emergency vehicles. In response, Option 3-1 was developed and includes the construction of a secondary ingress and egress route for the Village of Erieau. Refer to Figure 6.21. Bayview Road would be extended west along the edge of the bay to the existing dike protecting the Rondeau Bay drainage scheme (old rail line). A bridge would be required over the Third Concession Drain (canal). The emergency route would then continue northwest along Lagoon Road. Given the engineering complexities with this Option 3-1 and very high costs relative to Option 3-2, an opinion of cost was not generated.


**Figure 6.21 New Emergency Road from Bayview Avenue**

### *6.5.8.3 Protect Option 3-2 Armour Stone Revetment for Erieau Road*

The old railway embankment entering the Village of Erieau opposite St. Anne's Church is currently protected with ad-hoc armour stone and concrete rubble. Option 3-2 replaces the existing structure with an armour stone revetment for a 50-year planning horizon. The spatial extent of the proposed revetment, which is 425 m in length, is presented in Figure 6.22. Due to ongoing beach erosion, the structure may need to extend further to the east. The conceptual cross-section is presented in Figure 6.23. The toe of the structure is excavated 1 m below the current lake bottom. The crest elevation of 178.0 m was selected to reduce wave overtopping during the climate change 100-year lake level to a level that will not damage the structure or flood the road. The road elevation is raised to 175.8 m to ensure safe access for vehicles during the climate change 100-year flood scenario. The cost range for Option 3-2 is $4.6 to $6.4 million, which includes the structure and road upgrades.


**Figure 6.22 Extent of Armour Stone Revetment for Option 3-2**

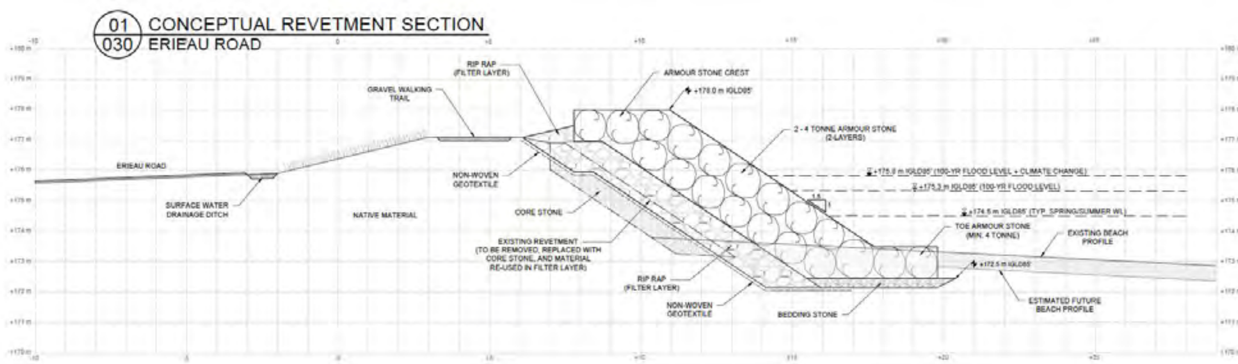



**Figure 6.23 Option 3-2 Cross-section (raised road elevation not shown)**

### 6.5.9 Region 3B – Communities of Rondeau Bay

Region 3B includes the bay communities of Shrewsbury, Rondeau Bay Estates, The Summer Place and Wildwood Line. Historically, these developments have been sheltered from Lake Erie storms and thus not exposed to the wave forces that impact Erie Shore Drive, for example. However, with the current breach in the Rondeau Barrier Beach, potential changes in the hazard exposure of these communities is possible if an adaptation solution is not implemented, as outlined in Section 4.8. The recommended adaptation concepts assume the breach is repaired.

Future planning and design of the Rondeau Bay options will need to consider the ecologically sensitive habitat in the bay and the Ontario Endangered Species Act.

### *6.5.9.1 Region 3B General Adaptation Options*

Eight of the ten adaptation options generated for the study area were selected for the Region 3B, which has significant vulnerability to flooding, especially when the climate change 100-year lake level is considered. The options include:

- *Option A Higher Regulatory Standards (Avoid)*: Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate.
- *Option B Evaluate Existing Land Use Policies and Zoning Regulations (Avoid)*: Re-evaluate existing land-use policies, zoning regulations, septic system requirements, and building standards along eroding and flood prone shorelines to avoid future challenges with development and coastal hazards.
- *Option C – Maintain Existing Shoreline Protection Structures (Protect)*: Complete regular maintenance following accepted coastal engineering design principles. Consider changing failing vertical walls to sloped armour stone revetments.
- *Option D – Construct New Shore Protection (Protect)*: Complete engineering design study and build new shoreline protection. Sloping armour stone revetments are the recommended alternative, not vertical walls.
- *Option E – Raise Foundations and Grades (Accommodate)*: Increase elevations around existing buildings and recreational areas above the 100-year flood level or a new standard, to decrease flood risk and improve overland drainage. Site grading plans at the local scale may be required. Septic tile beds may also require updating.
- *Option F – Relocate Buildings Inland (Retreat)*: Relocate existing buildings to the furthest inland location on a lot or to a new lot.
- *Option I – Update Private Septic Systems (Accommodate)*: Existing private septic systems, including weeping beds, are replaced with a proper elevated design, an alternative system, or a community-wide municipal system (i.e., sanitary sewers and treatment).
- *Option J – Raise Road Elevations (Accommodate)*: Elevate road grades above the climate change 100-year flood level

### *6.5.9.2 Shrewsbury and The Summer Place*

Shrewsbury and The Summer Place have very high vulnerability to coastal flooding, even for the historical 100-year lake level. The value of the primary and secondary buildings in the floodplain for the climate change 100-year lake level increases dramatically (e.g., from $9.4 to $22.0 million in Shrewsbury).

Raising grades (Option E) for The Summer Place is a feasible option, especially given most of the trailers are moveable. The approach to Shrewsbury, which was built on the edge of the Rondeau Bay Marsh, requires further planning that considers land and building elevations, municipal infrastructure such as roads and water, private septic systems versus a municipal collection and treatment system, and the local ecosystem.

### 6.5.10 Region 4 – Federal Navigation Channel and Barrier Beach

The Federal navigation channel and Rondeau Bay Barrier Beach have reached a tipping point and without significant intervention, permanent changes in the physical system will occur with significant impacts to the operation of the channel, the natural flood protection provided by the barrier, and the bay ecosystem. The ongoing sedimentation issues in the navigation channel were summarized in Section 4.7. Erosion of the barrier beach was documented in Section 3.3.2 and the associated loss of wetland habitat was outlined in Section 4.5. The barrier beach has been reduced to a washover terrace for more than 1 km. Without mitigation and restoration, the sedimentation in the navigation channel will get worse, the exposure of the fuel dock and fishing fleet to lake waves will worsen, and the barrier beach may not recover even if low water levels return. With this context, the adaptation options for Region 4 are summarized in the following sections.

#### *6.5.10.1 Accommodate Option 4-1 Raise the Elevation of the Fuel Dock*

The fuel dock in Erieau was submerged by high lake levels throughout the summer of 2019, as seen in Figure 6.24. With the projected higher lake levels due to climate change, this may not be a one-off problem. Therefore, a long-term structural solution is required that raises the elevation of the fuel tanks and pumps, plus the docking infrastructure for the boats. In the spring of 2020 the elevation of the concrete dock was raised, however, the specific details are unknow.

Figure 6.25 highlights an example of an adjustable fuel dock at the Belle River Marina, which is adaptable to fluctuating lake levels and thus has high resilience. Given the exposure of this site to waves, an adjustable dock is not likely feasible, but it provides a good example of an adaptation to fluctuating lake levels.

**Figure 6.24 Submerged Fuel Dock in Erieau, May 7, 2019**

**Figure 6.25  Adjustable Fuel Dock, Belle River Marina (2019)**

### *6.5.10.2 Accommodate Option 4-2 Raise the Elevation of the Fishing Fleet Breakwater*

Option 4.2 was developed to address the increased wave exposure for the commercial fishing fleet dock in Erieau. Refer to Figure 6.26, which was taken in May 2019 when the crest of the breakwater was almost submerged under non-storm conditions. The standard approach to repair this breakwater would be adding rock to expand the base and raise the crest elevation. However, if Option 4-3 was implemented, this adaptation would not be required.

**Figure 6.26  Crest of the Fishing Fleet Breakwater in May 2019 (crest almost submerged)**

### *6.5.10.3 Option 4-3 Phase 1 and 2 for the Barrier Beach Restoration*

Option 4.3 is a two-part transformative adaptation concept that includes the construction of a new armour stone breakwater to re-connect the east jetty to Seagull Island. Once the gap is closed, the west side of Seagull Island is dredged hydraulically, and the sand is used to re-build the beach lakeward (southeast) of the breakwater. Once the construction is complete, the dune is re-vegetated with native marram grass to stabilize the dredged sand and encourage additional sedimentation. See Figure 6.27. The cost range for Phase 1 is \$3.1 to \$4.6 million.

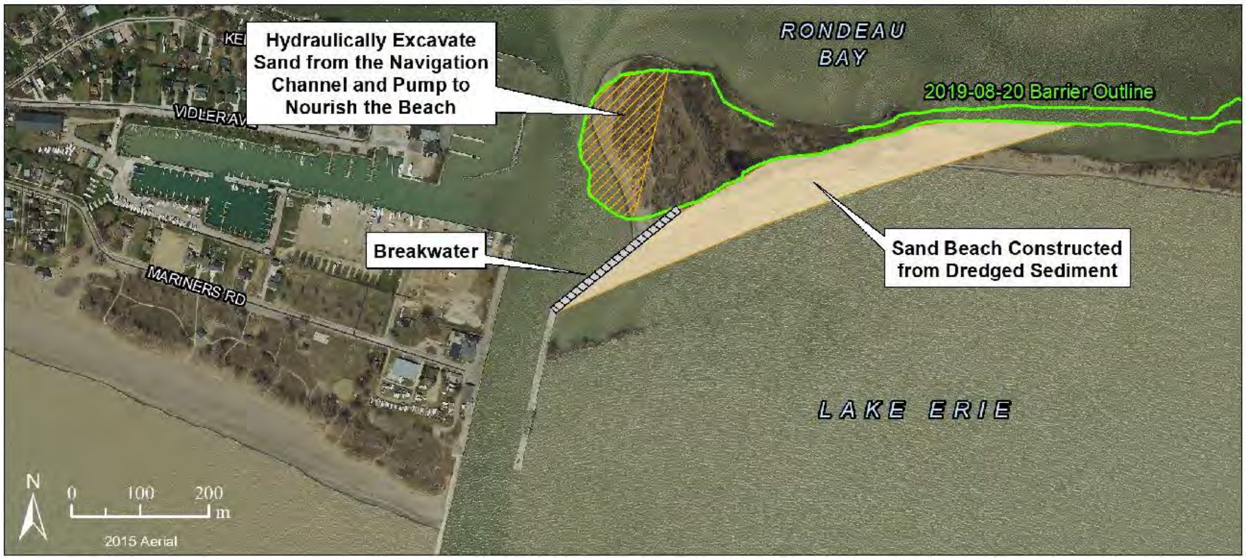



**Figure 6.27 Part 1 Option 4-3 East Jetty Breakwater Extension and Nourishment**

In Part 2 of Option 4-3, a rock berm is constructed at the back of the current barrier beach to stabilize the feature and protect against further inland migration of the beach. Sand is dredged hydraulically from the fillet beach west of the west jetty and pumped to the lakeward side of the rock berm. Refer to Figure 6.28. The cost range for Phase 2 is $7.1 to $10.5 million. The combined cost range for Option 4-3 is $10.2 to $15.2 million.

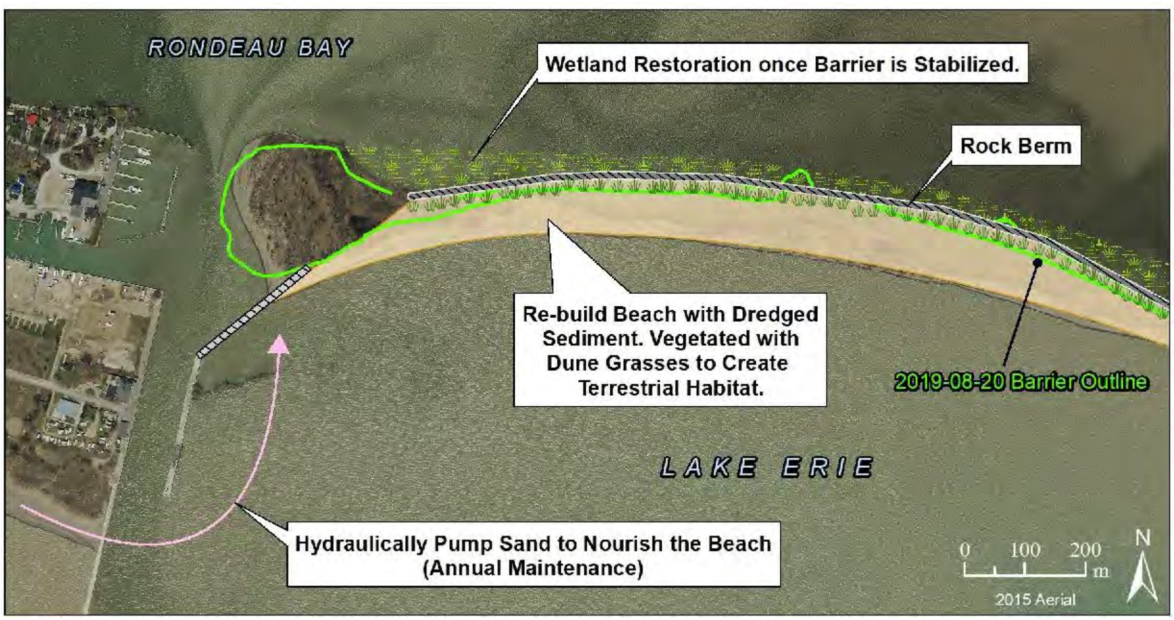



**Figure 6.28 Part 2 Option 3-3 Barrier Beach Berm and Nourishment with Hydraulic Dredging**

# 7.0 CONCLUSIONS

The Chatham-Kent Lake Erie shoreline is approximately 120 km in length. The high lake levels from 2017 to present have exposed the very low resilience of this shoreline to fluctuating water levels and coastal hazards. Decades of building on eroding shorelines and in the coastal floodplain has produced problems that neither the landowners nor the Municipality can afford to address without significant funding support. The changing risk profile due to climate change, including higher high lake levels and higher future erosion rates due to reduced ice cover, make it imperative the community continues to work together and take action on the most vulnerable areas.

Developing a path forward for Erie Shore Drive should be the top priority. A secondary group of priority actions includes: 1) protecting the dike along Erieau Road opposite St. Anne's Church, 2) selecting and implementing an approach for the closed section of Rose Beach Line, 3) developing and implementing a long-term plan for the Talbot Trail west of Erie Beach, and 4) restoring the Rondeau barrier beach and protecting the navigation channel. Medium-term actions are needed for the flood-prone communities of Rondeau Bay and the Village of Erieau, especially given the elevated risk with the climate change 100-year lake level. The long-term planning study for the Wheatley Provincial Park area is also a medium-term priority.

To address these concerns, a series of community-scale adaptation options were developed that represent a broad spectrum of options including avoid, accommodate, retreat, and protect. These concepts were refined for the sub-regions where appropriate and presented in Section 6.0. Concept-level opinions of cost were generated to put the magnitude of the financial investment to increase community resilience in perspective. Based on the legislative responsibilities of the Municipality and Conservation Authority, plus the criteria developed by the community, long-term recommendations for the 10 sub-regions are provided.

## 7.1 Recommendations by Region and Sub-region

The recommendations for the ten regions and sub-regions are provided in the following report sections.

### 7.1.1 Region 1A – Wheatley, Detroit Line, and Pier Road

Most of the Region 1A shoreline, except for Wheatley Provincial Park, is fully developed and armoured. Therefore, one of the most effective long-term adaptation strategies will be regular maintenance of existing shoreline protection structures (Option C). Sloping rock revetment structures are recommended over vertical walls. Site re-grading and raising building foundations may be an effective accommodate strategy in some locations (Option E).

The rapid erosion of the Wheatley Provincial Park shoreline, and implications for adjacent lands was identified throughout the study. Without further information on the planned approach of Ontario Parks for this asset, it is not possible to develop long-term effective adaptation strategies for this area/challenge. Therefore, a future long-term planning study is recommended with participation from Ontario Parks, Wheatley Provincial Park, the Municipality of Chatham-Kent, the Lower Thames Valley Conservation Authority, and local landowners.

### 7.1.2 Region 1B – High Bluffs East of Wheatley Provincial Park to Erie Beach

The vulnerability assessment identified 439 primary and secondary buildings threatened by erosion in the next 50-years, but likely sooner due to climate change, with a combined assessed value of $59.7 million. There is a major road closure along the Talbot Trail near Coatsworth Road that is causing significant traffic disruptions in the community. However, the vulnerability assessment identified a total of eleven sites where a combined 5.9 km of the coastal roads will be threatened by bluff erosion in the next 50-years, or sooner. Clearly, a long-term community-scale adaptation strategy is needed for Region 1B.

For Option 1-2, 40 km of bluff shoreline from the east boundary of Wheatley Provincial Park to Erie Beach is fully protected with an armour stone revetment designed for a 50-year planning horizon. The range of capital costs for this option is $596 to $892 million. While Option 1-2 theoretically protects the eroding bluffs, buildings, and road for the 50-year planning horizon, which address three important community criteria (protect property, permanence/durability, and protect human health), it is likely not affordable for private landowners or the Municipality of Chatham-Kent. The impacts to shoreline health and coastal ecosystems would be significant. Finally, based on preliminary discussions with regulatory agencies, it may not even be possible to secure permits for Option 1-2. Therefore, Option 1-2 is not recommended for further consideration.

The preferred alternative is Option 1-3, which involves the relocation of Talbot Trail further inland with buildings moved when threatened by erosion to protect the structures and human health. The concept level opinion of cost for Option 1-3 is $68 to $96.6 million, which is about 10% of the Option 1-2 (revetment) costs and addresses the affordability criteria. The natural sediment supply to Erieau and Point Pelee is maintained, which protects shoreline ecosystems. While the shoreline property south of Talbot Trail would eventually be lost to erosion, the cost estimate includes the purchase of new lots further inland and building re-location costs. For reference, the building relocation costs are significant and represent 49% to 64% of the cost estimate for the low and high range respectively.

### 7.1.3 Region 1C – Bates Line Drive and Rose Beach Line to Mckinlay Road

Region 1C has low vulnerability to coastal hazards. Moving forward, the adoption of higher regulatory standards (Option A) should be considered, including a 100-year lake level that considers climate change and protection of the beach/dune ecosystem. Where present, existing shoreline protection should be maintained (Option C) and building foundations and grades can be raised to provide flood relief (Option E). If shoreline erosion threatens buildings, they should be located to the furthest and highest location on the lot or to a new location.

### 7.1.4 Region 1D – Mckinlay Road to Hill Road

The focus of Region 1D is the existing road closure of Rose Beach Line. Two community scale alternatives were developed. The Protect Option 1-4 includes a 2 km rock revetment and Retreat Option 1-5 includes decommissioning Rose Beach Line and upgrading New Scotland Line. The retreat option (1-5) is 34 to 45% cheaper than armouring the shoreline (Option 1-4) and eliminates the need for future maintenance of the shoreline protection to keep the current alignment of Rose Beach Line. Option 1-5 is the community-scale adaptation preferred for

Region 1D.  Further planning and zoning are recommended to avoid further conversion of agricultural land to residential building lots in Region 1D.

### 7.1.5 Region 1E – Hill Road to East Study Boundary

The hazard profile in Region 1E contrasts sharply with the bluff shoreline west of Erie Beach, in that the Talbot Trail is located much further inland and development along the bluff crest is limited to a few smaller communities.  Therefore, the vulnerability of Region 1E to coastal hazards is very low, especially when compared to other flood- and erosion-prone areas within the study.  Consequently, no community-scale adaptation options are recommended for Region 1E. Several of the general adaptation options are applicable, including Options A (higher regulatory standards) and Option B (evaluate existing land use policies and zoning regulations to limit new lot creation) to avoid creating more hazards in the future.  If development is located landward of the regulated area designated by the Conservation Authority, buildings should be constructed with moveable foundations (Option G).

### 7.1.6 Region 2A – Erie Beach

The site conditions and hazard profile in Erie Beach contrast sharply with the neighbouring Erie Shore Drive.  Vulnerability to coastal hazards is low and no community-scale adaptations are required at this time.  Several of the general adaptation strategies may be required in the future to address lot-by-lot issues, such as shoreline protection maintenance (Option C) or the construction of new protection (Option D).

### 7.1.7 Region 2B – Erie Shore Drive

The vulnerability of the Erie Shore Drive community to coastal hazards is very high.  Once the barrier beach was developed and eventually armoured in the 1940s, the nearshore lake bottom began to erode and now features very deep conditions.  With the record high lake levels, there is no nearshore to dissipate incoming wave energy, leading to seawalls that are regularly overtopped during storm conditions and damaged, building flooding, road closures, and impacts to the structural stability of the dike.

There have been past attempts at building community-scale shoreline protection for the dike and homes along Erie Shore Drive, including the study led by Todgham & Case (1998).  As noted in the coastal engineering study that supported the dike assessment (Baird, 1998), as time passes without a solution the complexity and costs continue to increase.  The most expensive shore protection option in the 1998 report cost $4,000/m.  The preliminary opinion of cost for the Erie Shore Drive revetment alternative generated for this study (Option 2-1a), that accounts for climate change impacts on the 100-year lake level and additional lowering of the lake bottom, ranged from $14,000 to $21,000/m.  The community was encouraged to reach a consensus on a regional shore protection alternative in 1998 and implement a solution.  Unfortunately, nothing was done.

The adaptation concepts for Region 2B Erie Shore Drive are summarized in Table 7.1.  The Protect Option 2-1a which accounts for climate change and was developed for a 50-year planning horizon addresses three of the top five adaptation concept criteria (e.g., protect property, permanence and durability, and protect human health).  The affordability of this concept for lakeshore residents, landowners in the Burk Drainage Scheme, and the Municipality is unknown. The Provincial Drainage Act could be used to evaluate the alternatives, identify the benefiting parties, and recommend the allocation of the costs accordingly.

If the community-scale shoreline protection concepts (Option 2-1a to 2-1c) are not desirable or affordable for the benefiting parties along Erie Shore Drive, then a retreat program should be pursued (Option 2-2). The dike would still require repairs to protect the agricultural land and Erieau Road from a breach and interior flood, as outlined in Option 2-3.

Based on feedback received during consultations with senior levels of government, funding is not available for private shoreline protection. However, there is an emerging emphasis on nature-based climate solutions that generate co-benefits for communities and increase resilience, which is consistent with Option 2-4. By removing buildings, eliminating the agricultural land, and protecting Erieau Road from flooding, coastal risks are eliminated, emergency access to the Village of Erieau is protected, and more than 400 acres of new coastal wetlands are created. Option 2-4 is consistent with best-practice for disaster mitigation and nature-based adaptation.

**Table 7.1 Summary of Adaptation Options for Erie Shore Drive (Region 2B)**

| Adaptation Approach | Option No. | Description of Adaptation Option | Cost (millions) |
|---|---|---|---|
| Protect | 2-1a | Revetment for 50-year planning horizon, building flood proofing, upgraded septic systems, and dike/road repairs | \$59.2 to \$84.4 |
| Protect | 2-1b | Revetment for 25-year planning horizon, building flood proofing, upgraded septic systems, and dike/road repairs | \$45.7 to \$64.3 |
| Protect | 2-1c | Armour stone berm for 20-year planning horizon, building flood proofing, upgraded septic systems, and dike/road repairs | \$36.8 to \$50.7 |
| Retreat | 2-2 | Erie Shore Drive retreat and buyout/relocate homes. The assessed value of the property was approximately \$20.0 million in 2019 | Unknown |
| Upgrade Dike for Flood Protection | 2-3 | The dike is upgraded to provide flood protection for the agricultural land and Erieau Road *(note: assumes Option 2-2 is implemented)* | \$22.5 to \$31.7 plus Option 2-2 cost |
| Nature-based Adaptation | 2-4 | Purchase property in the Burk Drain south of Erieau Road, protect the shoreline, naturalize the dike, and restore coastal wetland and upland forest habitat on the former agricultural lands *(note: assumes Option 2-2 is implemented)* | \$33.1 to \$47.4 plus Option 2-2 cost |

### 7.1.8 Region 3A – Village of Erieau

There are several serious challenges for the Village of Erieau. First, during the 100-year flood level based on historical extremes, the only ingress/egress route for emergency vehicles could be covered in 1.0 m to 1.5 m of water if the dikes breach. The preferred approach to ensure safe emergency access is to protect the road at St. Anne's Church ($4.6 to $6.4 million) and upgrade Erieau Road to ensure it provides access during the 100-year flood level. If Erie Shore Drive is protected, it may not be necessary to raise the elevation of Erieau Road.

The second major challenge for the Village of Erieau is the flood-prone development along the bay shoreline. A total of $13 million in primary and secondary buildings are in the historical 100-year floodplain. The value of the buildings threatened by the climate change 100-year lake level increases by a factor of 3.5 to $46 million. The general adaptation options can address many of these challenges, including raising building foundations, constructing new private septic systems, and raising road elevations. However, given the magnitude of the risk, these general options need to be developed into a community-scale plan in the medium-term for Erieau.

### 7.1.9 Region 3B – Communities of Rondeau Bay

The flood vulnerability of buildings, roads, and private septic systems for the communities of Rondeau Bay is high. Recommendations are provided by geographic region:

- Shrewsbury: a community-scale adaptation plan is required for Shrewsbury that raises building elevations and grades to facilitate site drainage, ensure functional private septic systems, and safe road access during emergencies.

- Rondeau Bay Estates: this relatively new community was constructed at appropriate elevations to mitigate the historical 100-year flood level. However, vulnerability increases dramatically with the climate change 100-year flood level, since the community was not designed to this standard. Higher regulatory standards are recommended for new development and existing buildings should be flood proofed as required.

- The Summer Place: the entire trailer park needs to be elevated with appropriate upgrades to the shoreline protection along the bay.

### 7.1.10 Region 4 – Federal Navigation Channel and Barrier Beach

The navigation channel in Erieau is a fundamental artery of the community, facilitating lake access for the commercial fishing fleet, the marinas, and the residents of Rondeau Bay. Yet the functionality of the channel and the connectivity with the barrier beach to the east have been in slow decline for decades. As highlighted throughout this report, this physical system is on the verge of a tipping point, especially if the current period of high lake levels continues.

Following the completion of this study, we recommend the formation of a collaborative involving local landowners and stakeholder groups from the community to secure funding, complete a design for the restoration, and implement the infrastructure and nature-based adaptation approaches in Option 4-3. Membership in the collaborative should include but not be limited to representatives from the Lower Thames Valley Conservation Authority, the

Municipality of Chatham-Kent, Small Craft Harbours, Environment and Climate Change Canada, Department of Fisheries and Oceans, Natural Resources Canada, local marina representatives, Ontario Parks, Rondeau Provincial Park, the Ministry of the Environment, Conservation, and Parks, and the Ministry of Natural Resources and Forestry.

## 7.2 Next Steps

For the first time in Ontario, the projected impacts of climate change on coastal storms, future ice cover, wave energy, and lake levels were evaluated in a comprehensive coastal risk assessment. Vulnerability to flooding and erosion along the Lake Erie shoreline in Chatham-Kent varied spatially but was generally very high, especially when the higher lake levels projected due to climate change scenarios were integrated. The preferred adaptation options that have been costed in this report range from $131.7 to $217.2 million. In some cases, the adaptation options exceed the value of the assets they are attempting to protect. The path forward is unknown and complex, but priorities must be established, and solutions implemented. Also, the community must learn from the long history of inaction along Erie Shore Drive. Coastal hazards do not go away, they just get more severe over time and more expensive to mitigate. And climate change is making everything more complicated and more expensive.

The following steps are recommended:

1. Prioritize the most vulnerable areas and proceed with planning and engineering studies to implement the selected adaptation option(s), including nature-based solutions. The top priority areas include:

    a. Region 2B: develop and implement a long-term plan for Erie Shore Drive.

    b. Region 3A: protect the dike along Erieau Road opposite St. Anne's Church.

    c. Region 1B: complete the Environmental Assessment for the Talbot Trail realignment and implement a solution.

    d. Region 1D: complete the Environmental Assessment for Rose Beach Line realignment and implement a solution.

    e. Protect the navigation channel, commercial fishing fleet, fuel dock, and marina by restoring the Rondeau barrier beach.

2. Reach consensus on the approaches for the remaining Regions and Sub-regions.

3. Modify the Lower Thames Valley Conservation Authority board-approved policies as required based on the study findings.

4. Update Lower Thames Valley Conservation Authority hazard mapping (erosion and flooding) based on the study findings.

5. Update the Municipal Official Plan, Zoning By-laws, and Development and Building Standards based on the technical findings and recommendations from this study.

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# APPENDIX A

## Materials from the Community Meetings

# Dynamic Lake Erie Shoreline Processes Viewed From Space


INFORMATION:

CHATHAM-KENT
LAKE ERIE
SHORELINE STUDY

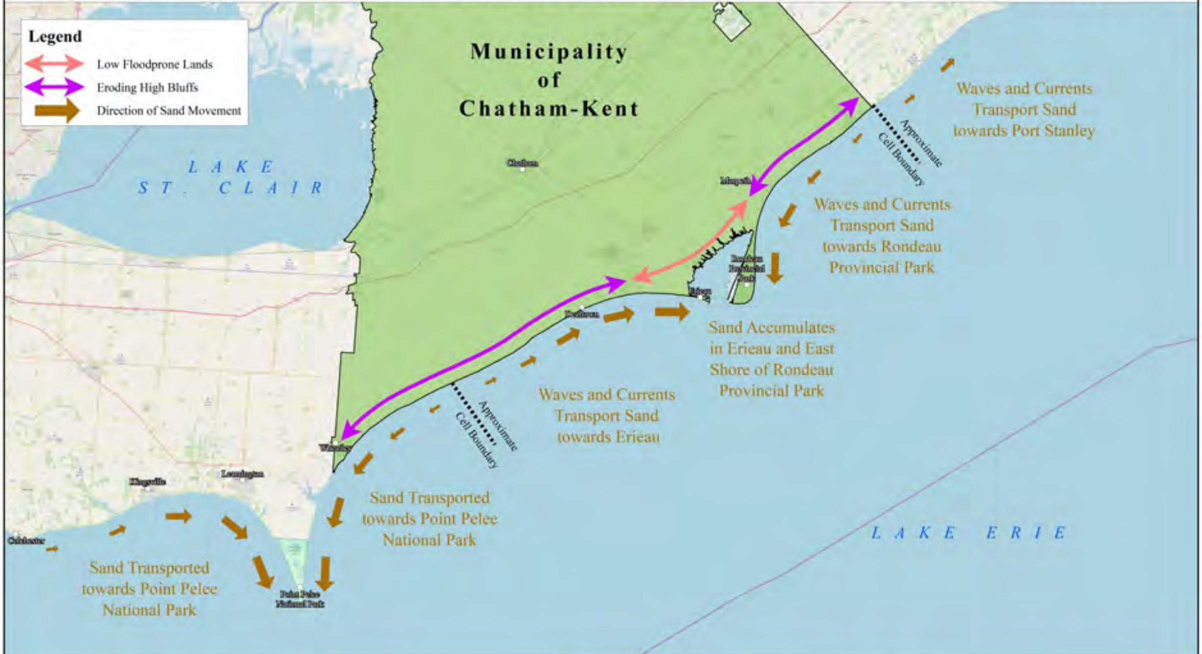
DEVELOPED FOR: Chatham-Kent — Cultivating Growth, Shore to Shore; Lower Thames Conservation

DEVELOPED BY: Zuzek inc.

0 20 40 km

Map Date: April 8, 2019

# SHORELINE HAZARDS AND DIRECTION OF SAND MOVEMENT IN THE LAKE




INFORMATION:

CHATHAM-KENT
LAKE ERIE
SHORELINE STUDY

DEVELOPED FOR: Chatham-Kent — Cultivating Growth, Shore to Shore

Lower Thames Conservation

DEVELOPED BY: Zuzek Inc.

0 5 10 15
km

Map Date: April 8, 2019

# HISTORY OF COASTAL HAZARDS DURING HIGH LAKE LEVELS IN ERIEAU

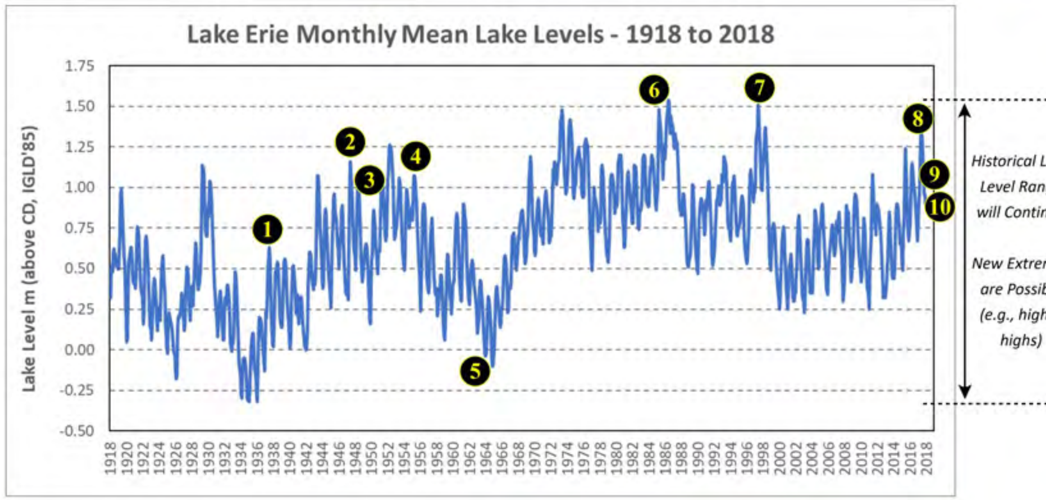

③ 1951 Rondeau Flood


④ 1955 Ice Storm


⑥ 1985 Flood


⑧ 2017 May Flood

② 1948 Flooded Crops in Erieau





⑨ 2018 April Flood

① 1937 Sand Bagging In Erieau


⑤ 1963 Erie Shore Drive Beach


⑦ 1997 January Ice Storm


⑩ 2019 January Ice Storm

INFORMATION:

CHATHAM-KENT LAKE ERIE SHORELINE STUDY

DEVELOPED FOR: Chatham-Kent — Cultivating Growth, Shore to Shore; Lower Thames Conservation

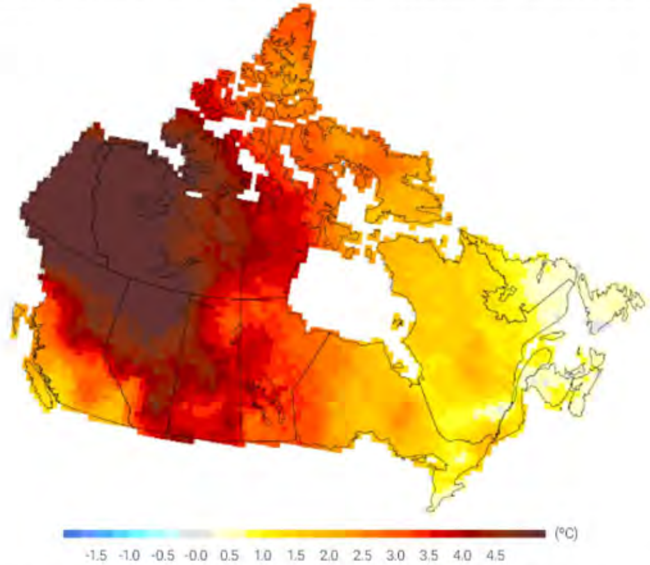
DEVELOPED BY: Zuzek inc. — ONE WORLD

Historical images provided by the Chatham-Kent Municipal Museum. Recent images provided by the Lower Thames Valley Conservation Authority.

Map Date: April 8, 2019

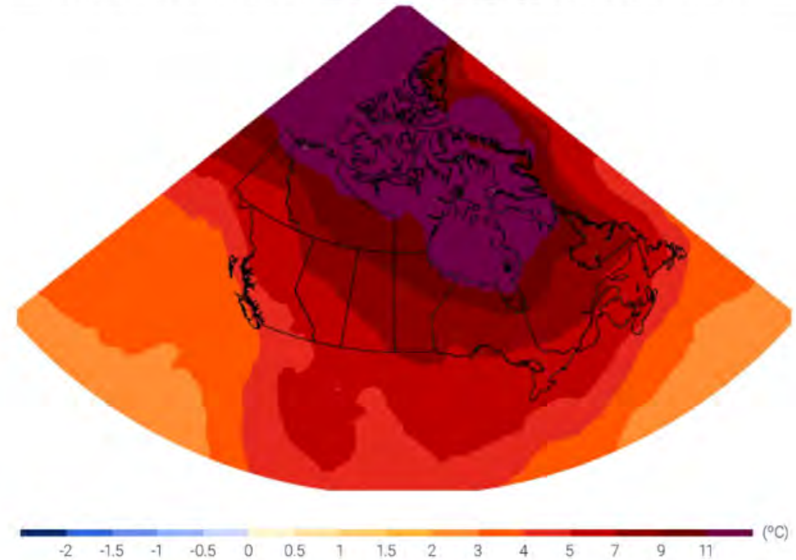
# WARMER AIR AND WATER TEMPERATURES WILL LEAD TO LESS LAKE ICE

## 1948 to 2012 Winter Air Temperature Increase




*Source: Vincent et al, 2015. In 'Zhang, X., Flato, G., Kirchmeier-Young, M., Vincent, L., Wan, H., Wang, X., Rong, R., Fyfe, J., Li, G., Kharin, V.V. (2019): Changes in Temperature and Precipitation Across Canada; Chapter 4 in Bush, E. and Lemmen, D.S. (Eds.) Canada's Changing Climate Report. Government of Canada, Ottawa, Ontario, pp 112-193'.*

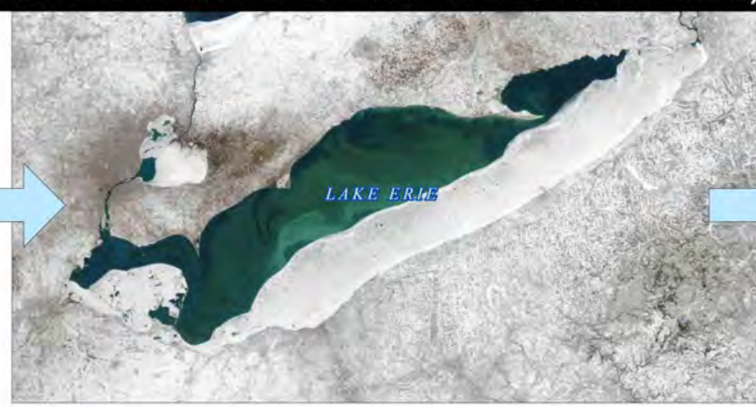
## 2081-2100 Winter Warming Projection for RCP8.5




*Source: Climate Research Division, Environment and Climate Change Canada. In 'Zhang, X., Flato, G., Kirchmeier-Young, M., Vincent, L., Wan, H., Wang, X., Rong, R., Fyfe, J., Li, G., Kharin, V.V. (2019): Changes in Temperature and Precipitation Across Canada; Chapter 4 in Bush, E. and Lemmen, D.S. (Eds.) Canada's Changing Climate Report. Government of Canada, Ottawa, Ontario, pp 112-193'.*

## Warming has already decreased the extent and duration of Lake Erie ice cover. In the future, the lake could be ice-free in the winter.


Lake Ice Cover Near 100%




Partial Ice Cover on the Lake


Ice Cover Limited to the Eastern Basin

INFORMATION:

CHATHAM-KENT
LAKE ERIE
SHORELINE STUDY


DEVELOPED FOR: Chatham-Kent — Cultivating Growth, Shore to Shore; Lower Thames Conservation

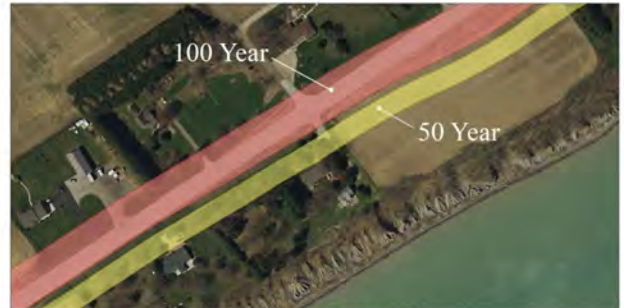
DEVELOPED BY: Zuzek inc. — ONE WORLD

Map Date: April 8, 2019

# FLOODING AND EROSION HAZARDS WILL INCREASE DUE TO CLIMATE CHANGE


Erosion rates will increase.

Road closures will be more frequent.




More infrastructure at risk.

Wave Impacts on buildings will be more frequent.

More upper slope failures due to increased rainfall.


Shoreline protection will fail.

The number of flooding events will increase.

Flanking erosion of shore protection.

Ineffective shoreline protection.

INFORMATION:

CHATHAM-KENT
LAKE ERIE
SHORELINE STUDY


DEVELOPED FOR:

Chatham-Kent
Cultivating Growth, Shore to Shore

Lower Thames Conservation

DEVELOPED BY:

Zuzek inc.
ONE WORLD

Recent images provided by the Lower Thames Valley Conservation Authority and Zuzek Inc.

Map Date: April 8, 2019

# EXIT SURVEY

## Chatham-Kent Lake Erie Shoreline Study Meeting #1 (April 10, 2019)

**I attended: ☐ 2pm meeting OR ☐ 6pm meeting**

**A. Could you tell us what is of concern to you?**

A1. To what extent is coastal flooding and/or erosion a concern for you and your family/organization:

☐ Low
☐ Medium
☐ High

A2. To what extent is climate change a concern for you and your family/organization:

☐ Low
☐ Medium
☐ High

**B. Could you please give us some feedback on how we did with the meeting today?**

B1. Is there any topic that you would like covered in the next Chatham-Kent Lake Erie Shoreline Study Meeting?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

B2. The information in the presentations was easy to understand.

☐ Strongly Agree
☐ Agree
☐ Undecided
☐ Disagree
☐ Strongly Disagree

B3. The logistics (location, time) of the Meeting were suitable:

☐ Strongly Agree
☐ Agree
☐ Undecided
☐ Disagree
☐ Strongly Disagree

See following page

B4. The length of the Meeting was:

☐ Much too short
☐ Too short
☐ Just right
☐ Too long
☐ Much too long

B5. I will participate in other Chatham-Kent Lake Erie Shoreline Study Meetings:

☐ Strongly Agree
☐ Agree
☐ Undecided
☐ Disagree
☐ Strongly Disagree

**C. Do you have any other comments?**

C1. I have a question(s) that I would like to ask the experts.

Name:

__________________________________________________________________

Email: _____________________________________________________________

Address: ___________________________________________________________

Telephone: _________________________________________________________

Question(s):

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

C2. Do you have any final comments?

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________


June 19, 2010, 1:30 pm Session:  Location of erosion and flooding issues


June 19, 2010, 6:00 pm Session:  Location of erosion and flooding issues


June 20, 2010, 9:30 am Session: Location of erosion and flooding issues


June 20, 2010, 1:30 pm Session: Location of erosion and flooding issues

## Meeting break-out questions [~45 minutes allotted]:

1. **A goal of adaptation solutions is to increase community resilience to shoreline flooding and erosion now and in the future. Resilience generally means "*building capacity to bounce back, and to learn, adapt, and improve so the community is better prepared for future climate change impacts*". From your perspective, what does COMMUNITY RESILIENCE mean? How <u>could your</u> community become resilient**?[10 minutes]

[**Facilitator Prompts**:

**Flooding**: If you were to experience a flooding event, what does resilience mean to you? - <u>Does it mean no flooding at all or I get flooded regularly and can cope with a certain level of flooding</u>?

**Erosion:** If you experience erosion event, what does resilience mean to you? <u>If a major access road to my property fails, I would use gravel roads or a farmer's field access road?</u>

<u>If erosion affects my property, I would have the ability to move my house etc. away from the hazard?</u>

What attributes should be present to achieve community resilience? How would you experience community resilience?]

2. **When making community decisions to deal with shoreline flooding and erosion, potential solutions can be ranked based on a range of criteria. Can you provide some examples of criteria that you think should be used?** [15 minutes]

[**Facilitator Prompts/Aids**: Initial list of evaluation criteria same as the exit survey (can present some to the group if it is struggling but want to expand and get a sense of priority):

- __ Protect human health and safety
- __ Preserve and enhance coastal habitat and ecosystems
- __ Maintain and enhance public access to the lakefront
- __ Number of properties, businesses, and individuals benefiting
- __ Affordability for affected landowners
- __ Affordability for the Municipality (i.e. tax implications)
- __ Reduce vulnerability of public infrastructure to coastal hazards
- __ Permanence and durability of the solution
- __ Protect property
- __ Maintain natural shoreline processes and shoreline health]

3. **We presented 4 general types of adaptation solutions - accommodate, avoid, protect, and retreat - for addressing erosion and flooding.**

    a) **Think about three areas:**

    - **Flooding/erosion in low-lying areas**
    - **Erosion along high bluff areas**
    - **Erosion of the Rondeau Barrier Beach and exposure of the navigation channel, commercial fishing fleet, fuel dock, wetland habitat, and Rondeau Bay communities to coastal storms**

    b) **what actions could be done in short-term and long-term?** [20 minutes?]

[**Facilitator prompt**:

People can select the area to talk about.

Small map(s) on table and Vulnerability map on wall in room to help participants if needed.

In your experience, do you have examples of what has worked and/or not worked; initiate brief conversation on managed RETREAT]

**At the table:**

- Facilitator - Printed list of questions to discuss
- Note paper
- Map (small page size) of C-K coastline

# Exit Survey #2

## Chatham-Kent Shoreline Study Meeting #2, June 19 and 20, 2019

**I attended:**

June 19: ☐ 1:30pm meeting or ☐ 6:00pm meeting

June 20: ☐ 9:30am meeting or ☐ 1:30pm meeting

**I attended the April 10, 2019 meeting: ☐ YES or ☐ NO**

### A. Could you tell us a bit about yourself? (Pick all that apply)

☐ I live, farm or work or operate a business in the Municipality of Chatham-Kent **directly abutting** the Lake Erie shoreline

☐ I live, farm or work or operate a business in the Municipality of Chatham-Kent **not directly abutting, but within 1 km** of the Lake Erie shoreline

☐ I live, farm or work or operate a business in the Municipality of Chatham-Kent **greater than 1 km from** the Lake Erie shoreline

☐ I enjoy recreational activities (e.g. boating, camping) in the Chatham-Kent Lake Erie Shoreline Study Area

☐ None of the above

### B. Could you please give us your opinion?

B1. When making community decisions about how to deal with shoreline flooding and erosion, solutions can be evaluated based on some criteria. From the list below, place a √ beside your **top three** criteria.

__ Protect human health and safety

__ Preserve and enhance coastal habitat and ecosystems

__ Maintain and enhance public access to the lakefront

__ Number of properties, businesses, and individuals benefiting

__ Affordability for affected landowners

__ Affordability for the Municipality (i.e. tax implications)

__ Reduce vulnerability of public infrastructure to coastal hazards

__ Permanence and durability of the solution

__ Protect property

__ Maintain natural shoreline processes and shoreline health

__ Other______________________________________________________

See following page …

**C. Could you please give us some feedback on how we did with the meeting?**

C1. Is there any topic that you would like covered in the next Chatham-Kent Shoreline Study Meeting? ____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

C2. The information in the presentation was easy to understand.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Undecided
- ☐ Disagree
- ☐ Strongly Disagree

C3. The Breakout discussion was useful in getting our input.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Undecided
- ☐ Disagree
- ☐ Strongly Disagree

C4. I will participate in other Chatham-Kent Shoreline Study Meetings.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Undecided
- ☐ Disagree
- ☐ Strongly Disagree

**D. Do you have any final comments (name, and contact information not required)?**

Name: ____________________________________________________________

Email: ____________________________________________________________

Address: ____________________________________________________________

Telephone: ____________________________________________________________

Comments: ____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

## Chatham-Kent Lake Erie Shoreline Study – Community Input

### *Evaluation Criteria Worksheet – Breakout Group Resource*

As you review and discuss the Draft Adaptation Options, please use this list of evaluation criteria as a tool to assess the "performance" of the Options. For each column associated with an adaptation option, review the criteria and place a √ beside the statement that reflects your best judgement.

My region is: ________________________________________

| CRITERIA | DRAFT ADAPTATION OPTIONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ID NUMBER OF DRAFT ADAPTATION OPTION →→→→** | | | | | | | | |
| **B2-1. Protection of Public Safety:** | | | | | | | | |
| The draft adaptation option provides a high degree of public safety | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| The draft adaptation option provides a moderate degree of public safety | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| The draft adaptation option provides a low degree of public safety | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **B2-2. Permanence and Durability:** | | | | | | | | |
| The draft adaptation option is a short-term solution (0 to 25 years) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| The draft adaptation option is a medium-term solution (26 to 50 years) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| The draft adaptation option is a long-term solution (more than 50 years) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **B2-3. Affordability of Implementation:** | | | | | | | | |
| I would not be willing to pay any one-time costs to implement this draft adaptation option on my property | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would be willing to pay one-time costs up to $50,000 to implement this draft adaptation option on my property | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would be willing to pay one-time costs of $50,000-$100,000 to implement this draft adaptation option on my property | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would be willing to pay one-time costs of $100,000-250,000 to implement this draft adaptation option on my property | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would be willing to pay one-time costs of more than $250,000 to implement this draft adaptation option on my property | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **B2-4. Affordability of Long-term Maintenance:** | | | | | | | | |
| I would not be willing to pay any maintenance costs for this draft adaption option on my property | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would be willing to pay maintenance costs of up to $5000 per year for this draft adaption option on my property | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would be willing to pay maintenance costs greater than $5000 per year for this draft adaption option on my property | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **B2-5. Impacts to Adjacent Properties and Downdrift Shoreline (maintains natural water currents and movement of sand along coastline):** | | | | | | | | |
| There will be no impacts to neigbouring properties or the downdrift shoreline | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| There will be some impacts to neigbouring properties and/or the downdrift shoreline | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| There will be significant impacts to neigbouring properties and/or the downdrift shoreline | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **B2-6. Protection and Enhancement of Coastal Ecosystems (habitat, species, water quality):** | | | | | | | | |
| The draft adaptation option protects and enhances coastal ecosystems | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| The draft adaptation option provides some protection or enhancement of coastal ecosystems | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| The draft adaptation option does not protect or enhance coastal ecosystems | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **B2-7. Contributes to Community-wide Resilience (interconnected, long-term benefits to people, places, the environment and culture)** | | | | | | | | |
| Implementation of the draft adaptation option improves community resilience | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Implementation of the draft adaptation option maintains the status quo community resilience | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Implementation of the draft adaptation option detracts from community resilience | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

# Exit Survey #3 – Please hand in before leaving

## Chatham-Kent Shoreline Study Meeting #3, November 26, 2019

I attended November 26, 2019 meeting: ☐ **1:00pm or** ☐ **6:00pm**

I attended a June 19 or 20, 2019 meeting: ☐ **YES or** ☐ **NO**

I attended an April 10, 2019 meeting: ☐ **YES or** ☐ **NO**

## A. Could you tell us a bit about yourself?

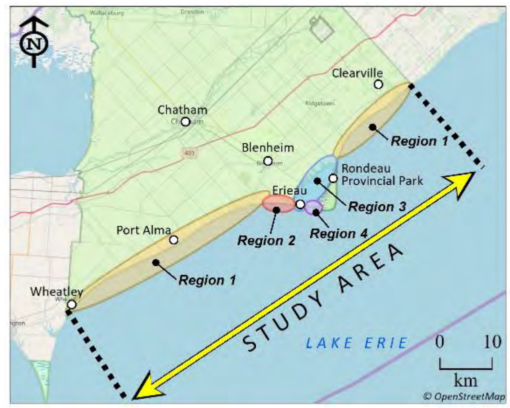
I chose to participate in the following region for breakout group discussions**:**

☐ **Region 1 -** High Bluff Areas

☐ **Region 2 -** Erie Beach, Erie Shore Drive, and the Dyked Farmland

☐ **Region 3 -** Flood-prone Communities around Rondeau Bay

☐ **Region 4-** Federal Navigation Channel and Rondeau Barrier Beach




## B. Could you please give us your opinion?

**B1. In your breakout group you evaluated draft adaptation options. For your region, what was your preferred option?**

Adaptation option number: ___________Option title: ______________________________________________

**B2. Using your best judgment, please evaluate your preferred draft adaptation option in satisfying the community-based criteria (put a √ beside your choice):**

**B2-1. Protection of Public Safety**:

☐ The draft adaptation option provides a high degree of public safety
☐ The draft adaptation option provides a moderate degree of public safety
☐ The draft adaptation option provides a low degree of public safety

**B2-2. Permanence and Durability:**

☐ The draft adaptation option is a short-term solution (0 to 25 years)
☐ The draft adaptation option is a medium-term solution (26 to 50 years)
☐ The draft adaptation option is a long-term solution (more than 50 years)

**B2-3. Affordability of Implementation:**

☐ I would not be willing to pay any one-time costs to implement this draft adaptation option on my property
☐ I would be willing to pay one-time costs up to $50,000 to implement this draft adaptation option on my property
☐ I would be willing to pay one-time costs of $50,000-$100,000 to implement this draft adaptation option on my property
☐ I would be willing to pay one-time costs of $100,000-250,000 to implement this draft adaptation option on my property
☐ I would be willing to pay one-time costs of more than $250,000 to implement this draft adaptation option on my property

See following page …

**B2-4. Affordability of Long-term Maintenance (ongoing costs):**

- ☐ I would not be willing to pay any maintenance costs for this draft adaption option on my property
- ☐ I would be willing to pay maintenance costs of up to $5,000 per year for this draft adaption option on my property
- ☐ I would be willing to pay maintenance costs greater than $5,000 per year for this draft adaption option on my property

**B2-5. Impacts to Adjacent Properties and Downdrift Shoreline (maintains natural water currents and movement of sand along coastline):**

- ☐ There will be no impacts to adjacent neighbouring properties or the downdrift shoreline
- ☐ There will be some impacts to neighbouring properties and/or the downdrift shoreline
- ☐ There will be significant impacts to neighbouring properties and/or the downdrift shoreline

**B2-6. Protection and Enhancement of Coastal Ecosystems (habitat, species, water quality):**

- ☐ The draft adaptation option protects and enhances coastal ecosystems
- ☐ The draft adaptation option provides some protection or enhancement of coastal ecosystems
- ☐ The draft adaptation option does not protect or enhance coastal ecosystems

**B2-7. Contributes to Community-wide Resilience (interconnected, long-term benefits to people, places, the environment, and culture)**

- ☐ Implementation of the draft adaptation option improves community resilience
- ☐ Implementation of the draft adaptation option maintains the status quo community resilience
- ☐ Implementation of the draft adaptation option detracts from community resilience

**B3. What do you like about the draft adaptation options presented today**?

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

**B4. What suggestions do you have to improve the draft adaptation options presented today?**

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

## C. Do you have any final comments (name and contact information is optional)

Name: ____________________________________________________________

Email: ___________________________ Telephone:_________________________

Comments: ______________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

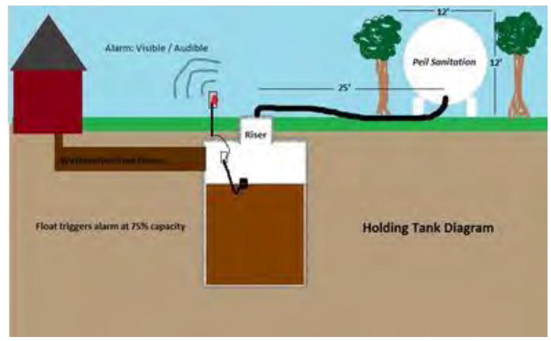
______________________________________________________________________________

# APPENDIX B

## Climate Change Adaptation Options

| GENERIC ADAPTATION OPTION | SAMPLE PHOTOGRAPH OR GRAPHIC |
| --- | --- |
| ***Note:*** *these are general guidelines and options. The LTVCA and Municipality of Chatham-Kent should be consulted to evaluate appropriate zoning, regulations, and permit requirements before taking any action. There may be additional Provincial and Federal Acts and Legislation that are also applicable.* | |
| **Option A - Higher Regulatory Standards (Avoid):** Implement regulatory standards higher than the 100-year flood level and the 100-year erosion rate |  |
| **Option B - Evaluate Existing Land Use Policies and Zoning Regulations (Avoid):** Re-evaluate existing land-use policies, zoning regulations, septic system requirements, and building standards along the eroding bluffs to avoid future challenges with development and erosion hazards |  |
| **Option C – Maintain Existing Shoreline Protection Structures (Protect)**: Complete regular maintenance following accepted coastal engineering design principles. Consider changing failing vertical walls to sloped armour stone revetments |  |

| | |
|---|---|
| **Option D – Construct New Shore Protection (Protect)**: Complete engineering design study and build new shoreline protection. Sloping armour stone revetments are the recommended alternative, not vertical walls |  |
| **Option E – Raise Grades and/or Foundations (Accommodate):** Increase elevations around existing buildings and recreational areas above the 100-year flood level or a new standard, to decrease flood risk and improve overland drainage. Site grading plans at the local scale may be required. Septic tile beds may also require updating |  |
| **Option F – Relocate Buildings Inland:** Relocate existing buildings to the furthest inland location on a lot or to a new lot |   |
| **Option G - Construct Moveable Buildings:** Construct all future development with appropriate structural support to facilitate future re-location when at risk to erosion and flooding hazards (e.g., structural support such as I-beams included in the foundation design) |  |

| | |
|---|---|
| **Option H - Emergency Shore Protection:** If existing shoreline protection structures fail, the Lower Thames Valley Conservation Authority and Ministry of Natural Resources and Forestry are currently approving emergency repairs using like for like (e.g., a failed steel sheet pile wall can be replaced with another steel sheet pile wall) |  |
| **Option I - Update Septic Systems:** Existing private septic systems including weeping beds are replaced with a proper elevated design, an alternative system, or a community wide municipal system (i.e., sanitary sewers and treatment). |   |
| **Option J - Raise Road Elevations:** Elevate road grades above the climate change 100-year flood level | |

# APPENDIX C

# COSTS FOR ADAPTATION OPTIONS

## TALBOT TRAIL OPTIONS

**OPTION 1-2 Armour Stone Revetment**

| Option Component | $/unit | Metres | Total |
|---|---|---|---|
| **Armour Stone Revetment, Slope Regrading and Drainage** | | | |
| Low (includes engineering, permitting, construction, indexing) | $14,900 | 40000 | $596,000,000 |
| High (includes engineering, permitting, construction, indexing) | $22,300 | 40000 | $892,000,000 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Revetment Unit Cost:*

**OPTION 1-3 Relocate Talbot Trail and Buildlings Inland**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Primary Buildings | $100,000 | 235 | $23,500,000 |
| Secondary Buildings | $25,000 | 204 | $5,100,000 |
| New 0.5 Acre Parcel | $20,000 | 235 | $4,700,000 |
| Construct New Road (km) | $1,960,800 | 7.5 | $14,706,000 |
| Upgrade Existing Rural Road (km) | $737,352 | 27.1 | $19,982,239 |
| **High Cost Range** | | | |
| Primary Buildings | $200,000 | 235 | $47,000,000 |
| Secondary Buildings | $50,000 | 204 | $10,200,000 |
| New 0.5 Acre Parcel | $20,000 | 235 | $4,700,000 |
| Construct New Road (km) | $1,960,800 | 7.5 | $14,706,000 |
| Upgrade Existing Rural Road (km) | $737,352 | 27.1 | $19,982,239 |
| **Low Opinion of Cost** | | | $67,988,239 |
| **High Opinion of Cost** | | | $96,588,239 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Road Costs*

## ROSE BEACH LINE OPTIONS

**OPTION 1-4 Rose Beach Line Armour Stone Revetment**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range for Revetment** | | | |
| Armour Stone Revetment (2,000 m) | $8,471 | 2000 | $16,942,000 |
| Road Resurfacing (2 km) | $646,800 | 2 | $1,293,600 |
| **High Cost Range for Revetment** | | | |
| Armour Stone Revetment (2,000 m) | $12,706 | 2000 | $25,412,000 |
| Road Resurfacing (2 km) | $646,800 | 2 | $1,293,600 |
| **Low Opinion of Cost** | | | $18,235,600 |
| **High Opinion of Cost** | | | $26,705,600 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Revetment Unit Cost:*

**OPTION 1-5 Decommission Rose Beach Line and Upgrade New Scotland Line**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| Upgrade New Scotland Line | $646,800 | 4.57 | $2,955,876 |
| New Scotland Line Bridge Replacements (lump sum) | | | $3,000,000 |
| Utility relocations | | | $2,000,000 |
| Buy Land, 1.15km*30m (6.6 acres) | $20,000 | 8.5 | $170,000 |
| new road connects lakeside residences to Mckinley/Antrim | $1,720,000 | 0.5 | $860,000 |
| new road for three residences to Antrim | $1,720,000 | 0.23 | $395,600 |
| new road from Trailer Park to New Scotland | $1,720,000 | 0.42 | $722,400 |
| Decommision Rose Beach Line | | | $500,000 |
| **Sub-total** | | | $10,603,876 |
| **10% for Engineering, Permitting, Tender, Construction Observation** | | | $11,664,264 |
| **4% for Indexing** | | | $12,130,834 |
| **Low Opinion of Cost** | | | $12,130,834 |
| **High Opinion of Cost (plus 20%)** | | | $14,557,001 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Revetment Unit Cost:*

# ERIE SHORE DRIVE OPTIONS

**OPTION 2-1a 50-year Armour Stone Revetment and Dike Repairs**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Armour Stone Revetment | $14,000 | 3300 | $46,200,000 |
| Dike Upgrades, Lakeshore Drain, and Road (lump sum) | | | $10,000,000 |
| Floodproof Buildings (assume half/60) | $25,000 | 60 | $1,500,000 |
| New Private Septic System (assume half/60) | $25,000 | 60 | $1,500,000 |
| **High Cost Range** | | | |
| Armour Stone Revetment | $21,000 | 3300 | $69,300,000 |
| Dike Upgrades, Lakeshore Drain, and Road (lump sum) | | | $10,000,000 |
| Floodproof Buildings (assume half/60) | $50,000 | 60 | $3,000,000 |
| New Private Septic System (assume half/60) | $35,000 | 60 | $2,100,000 |
| **Low Opinion of Cost** | | | $59,200,000 |
| **High Opinion of Cost** | | | $84,400,000 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Revetment Unit Costs*

**OPTION 2-1b 25-year Armour Stone Revetment and Dike Repairs**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Armour Stone Revetment | $9,900 | 3300 | $32,670,000 |
| Dike Upgrades, Lakeshore Drain, and Road (lump sum) | | | $10,000,000 |
| Floodproof Buildings (assume half/60) | $25,000 | 60 | $1,500,000 |
| New Private Septic System (assume half/60) | $25,000 | 60 | $1,500,000 |
| **High Cost Range** | | | |
| Armour Stone Revetment | $14,900 | 3300 | $49,170,000 |
| Dike Upgrades, Lakeshore Drain, and Road (lump sum) | | | $10,000,000 |
| Floodproof Buildings (assume half/60) | $50,000 | 60 | $3,000,000 |
| New Private Septic System (assume half/60) | $35,000 | 60 | $2,100,000 |
| **Low Opinion of Cost** | | | $45,670,000 |
| **High Opinion of Cost** | | | $64,270,000 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Revetment Unit Costs*

## ERIE SHORE DRIVE OPTIONS (continued)

### OPTION 2-1c 20-year Rock Berm and Dike Repairs

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Rock Berm | $7,200 | 3300 | $23,760,000 |
| Dike Upgrades, Lakeshore Drain, and Road (lump sum) | | | $10,000,000 |
| Floodproof Buildings (assume half/60) | $25,000 | 60 | $1,500,000 |
| New Private Septic System (assume half/60) | $25,000 | 60 | $1,500,000 |
| **High Cost Range** | | | |
| Rock Berm | $10,800 | 3300 | $35,640,000 |
| Dike Upgrades, Lakeshore Drain, and Road (lump sum) | | | $10,000,000 |
| Floodproof Buildings (assume half/60) | $50,000 | 60 | $3,000,000 |
| New Private Septic System (assume half/60) | $35,000 | 60 | $2,100,000 |
| **Low Opinion of Cost** | | | $36,760,000 |
| **High Opinion of Cost** | | | $50,740,000 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Rock Berm Unit Costs*

### OPTION 2-2 Erie Shore Drive Retreat

| Option/Component | | Total |
|---|---|---|
| Purchase Lakefront Property | *approxiately* | $20,000,000 |
| Remove and/or Relocate Homes | | *unknown* |

*Note: Actual cost to purchase property would be determined in the future*

## ERIE SHORE DRIVE OPTIONS (continued)

**OPTION 2-3 Upgrade the Dike for Flood and Erosion Protection**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Rock Berm for Shore Protection | $5,600 | 3300 | $18,480,000 |
| Increase Crest Elevation of Existing Dike | lump sum | 2100 | $2,000,000 |
| Repair North Slope of Dike and Lakeshore Drain | lump sum | | $500,000 |
| Naturalize Shoreline (raise/slope to lake, vegetation) | lump sum | | $1,527,000 |
| **High Cost Range** | | | |
| Rock Berm for Shore Protection | $8,400 | 3300 | $27,720,000 |
| Increase Crest Elevation of Existing Dike | lump sum | 2100 | $2,000,000 |
| Repair North Slope of Dike and Lakeshore Drain | lump sum | | $500,000 |
| Naturalize Shoreline (raise/slope to lake, vegetation) | lump sum | | $1,527,000 |
| **Low Opinion of Cost** | | | $22,507,000 |
| **High Opinion of Cost** | | | $31,747,000 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Rock Berm Unit Costs*

**OPTION 2-4 Nature-based Adaptation**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Purchase Agricultural Land (1107 acres) | | | $17,200,000 |
| Protect Shoreline with Rock Berm | $2,880 | 3300 | $9,504,000 |
| Restore Upland and Marsh Habitat (418 acres) | $9,500 | 418 | $3,971,000 |
| Barrier Beach Restoration (30 acres) | $15,000 | 30 | $450,000 |
| Hydraulic Connection to Lake Erie | lump sum | | $2,000,000 |
| **High Cost Range** | | | |
| Purchase Agricultural Land (1107 acres) | | | $17,200,000 |
| Protect Shoreline with Rock Berm | $6,480 | 3300 | $21,384,000 |
| Restore Upland and Marsh Habitat (418 acres) | $12,650 | 418 | $5,287,700 |
| Barrier Beach Restoration | lump sum | | $1,527,000 |
| Hydraulic Connection to Lake Erie | lump sum | | $2,000,000 |
| **Low Opinion of Cost** | | | $33,125,000 |
| **High Opinion of Cost** | | | $47,398,700 |

*Notes:*
*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Rock Berm Unit Costs*
*Actual cost to purchase land would be determined in the future*

## ERIEAU ROAD (opposite St. Anne's Church)

**OPTION 3-2 Armour Stone Revetment for Erieau Road**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Armour Stone Revetment | $8,471 | 425 | $3,599,986 |
| Raise Road Elevation to 175.8 m | lump sum | | $1,000,000 |
| **High Cost Range** | | | |
| Armour Stone Revetment | $12,706 | 425 | $5,399,979 |
| Raise Road Elevation to 175.8 m | lump sum | | $1,000,000 |
| **Low Opinion of Cost** | | | $4,599,986 |
| **High Opinion of Cost** | | | $6,399,979 |

*Note: 5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Revetment Unit Costs*

**OPTION 4-3 Phase 1 of Barrier Beach Restoration**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Armour Stone Breakwater | lump sum | | $2,344,500 |
| Beach Excavation and Nourishment | lump sum | | $751,500 |
| **High Cost Range** | | | |
| Armour Stone Breakwater | lump sum | | $3,516,700 |
| Beach Excavation and Nourishment | lump sum | | $1,127,300 |
| **Low Opinion of Cost** | | | $3,096,000 |
| **High Opinion of Cost** | | | $4,644,000 |

*Notes:*
*5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Breakwater Unit Costs*
*Added 5% for Mobilization/Demobilization for the Hydraulic Dredging*

**OPTION 4-3 Phase 2 of Barrier Beach Restoration**

| Option/Component | $/unit | Units | Total |
|---|---|---|---|
| **Low Cost Range** | | | |
| Armour Stone Breakwater | $2,900 | 1700 | $4,930,000 |
| West Beach Excavation and Nourishment | $1,300 | 1700 | $2,210,000 |
| **High Cost Range** | | | |
| Armour Stone Breakwater | $4,300 | 1700 | $7,310,000 |
| West Beach Excavation and Nourishment | $1,900 | 1700 | $3,230,000 |
| **Low Opinion of Cost** | | | $7,140,000 |
| **High Opinion of Cost** | | | $10,540,000 |

*Notes:*
*5% for Engineering, 5% (Permitting, Tender, Construction), and 4% Indexing included in Breakwater Unit Costs*
*Added 5% for Mobilization/Demobilization to the Hydraulic Dredging*

# APPENDIX D

## CV for P. Zuzek

# Peter J. Zuzek, MES, CFM, P.Geo.
## President

## QUALIFICATIONS

| | |
|---|---|
| **PROFILE** | Peter Zuzek is the founder and President of Zuzek Inc., a professional services company dedicated to increasing the health and resilience of the world's coastal ecosystems. He has 30 years of experience managing complex multi-disciplinary coastal investigations throughout North America and internationally. Services include coastal erosion and flooding studies, risk assessments, coastal zone planning, shoreline management plan development, water quality investigations, habitat protection and restoration, living shorelines, climate studies, and development of climate change adaptation strategies. |
| **EDUCATION** | Master of Environmental Studies, University of Waterloo<br>Bachelor of Environmental Studies, University of Waterloo |
| **ASSOCIATIONS** | Professional Geoscientist, Association of Geoscientists of Ontario<br>Certified Floodplain Manager, Association of State Floodplain Managers<br>President, Coastal Zone Canada Association |
| **EMPLOYMENT HISTORY** | Zuzek Inc. 2016 - present, President<br>Baird & Associates 1994 - 2016, Project Manager |

## SHORELINE PLANNING AND MANAGEMENT

### Chatham-Kent Lake Erie Shoreline Study

*Client: Municipality of Chatham-Kent and the Lower Thames Valley Conservation Authority*

Project Manager and Technical Lead for the shoreline study covering the Lake Erie jurisdiction of the Municipality of Chatham-Kent. The technical studies and planning engaged a broad spectrum of stakeholders and regulators with jurisdiction along Lake Erie to evaluate hazards, map vulnerability, calculation risks, and develop community-scale climate change adaptation plans.

### Southeast Leamington Hazard Identification and Risk Assessment (HIRA)

*Client: Municipality of Leamington*

Completed a comprehensive hazard identification and risk assessment (HIRA) for the community of Southeast Leamington, which is exposed to severe erosion and flooding threats. The report focused on hazards, change over time due to shoreline and lake bottom erosion, a risk assessment, and recommendations for monitoring. Updated floodplain mapping was recommended.

### Long Point and Walsingham Forest Priority Place Cloud Mapping Application

*Client: Long Point World Biosphere Reserve Foundation*

Zuzek Inc. was retained by the Long Point World Biosphere Reserve to develop a cloud-based mapping application to store and visualize geo-spatial data for the Priority Place.

### Lower Trent Shoreline Management Plan Update

*Client: Lower Trend Conservation Authority*

Zuzek Inc. was retained by the Lower Trent Conservation Authority to complete a shoreline management plan update. The shoreline was sub-divided into reaches based on geomorphic conditions of the shoreline and updated flood and erosion hazard setback mapping was prepared.

### Central Lake Ontario Shoreline Management Plan Update

*Client: Central Lake Ontario Conservation Authority*

Project manager for an update of the 1990's shoreline management plan for CLOCA. The study included oblique aerial photographs, comprehensive field observations, numerical modeling, and updated hazard mapping.

### Ganaraska Region Shoreline Management Plan Update

*Client: Ganaraska Region Conservation Authority*

The Ganaraska Region shoreline was the focus of a recent shoreline management plan update by Zuzek Inc. Detailed field observations and drone photography was collected, followed by updated extreme value analysis and numerical modeling. New mapping for the hazardous lands along Lake Ontario was generated.

### Adapting to the Future Storm and Ice Regime in the Great Lakes

*Financial Support: Natural Resources Canada*

Project Manager for the first ever climate change investigation in the Great Lakes dedicated solely to evaluating the impacts of future coastal storm extremes and trends in ice cover. In Stream 1, the influence of our future climate on extreme wave heights and storm surges will be quantified and compared to historical conditions. In Stream 2, this new information will be mainstreamed into four adaptation case studies to increase the resilience of coastal communities and improve our planning and hazard regulations. Stream 2 solutions will be co-developed with Municipalities, Conservation Authorities, and local partners.

### Fortress of Louisbourg Sea Level Rise Adaptation Plan

*Client: Parks Canada Agency*

Project Manager for the Fortress of Louisbourg sea level rise adaptation plan. The park is in Cape Breton, Nova Scotia and the Fort was originally built in the early 1700's. The site faces numerous natural hazards, including sea level rise, crustal subsidence, and exposure to severe storms from the North Atlantic. Consequently, the Fort and cultural resources are threatened by flooding and erosion hazards. A series of mitigation plans were developed for the Grand Etang barrier beach and seawall.

### Elgin County Shoreline Management Plan (SMP)

*Client: Elgin County and Four CA's (Lower Thames, Kettle, Catfish and Long Point Region)*

Project Manager for the Elgin County SMP update. Technical studies included a detailed field reconnaissance of 90 km of shoreline, measurement of historical shoreline erosion rates, and flood risk assessment for low lying lands. Various shoreline management options were developed based on the technical findings and policy guidance. A joint SMP was written for the four CAs.

### Victoria Beach Integrated Shoreline Management Plan

*Client: Rural Municipality of Victoria Beach*

The coastal community of Victoria Beach is located on narrow peninsula in the southern basin of Lake Winnipeg. Pete managed a three-part study that culminated in the development of the Shoreline

Management Plan to help the community address coastal hazards and maintain beach access. The technical work included a governance review, technical studies, and public engagement to develop the SMP.

### Shoreline Restoration and Management Plan, Indiana Dunes National Lakeshore

*Client: US National Parks Service*

Contributed to a multi-disciplinary investigation to development a shoreline restoration and management plan for the Indian Dunes National Lakeshore. The coastal dune habitat features some of the most ecological diverse habitat in the Great Lakes Region and, yet, is threatened by coastal development, park visitors, harbours that disrupt littoral drift, and invasive species. A comprehensive management plan was developed following the technical investigation that included enhanced regional sediment management.

### Regional Programme for the Sustainable Management of Coastal Erosion and Sea Level Rise in the Seas of East Asia

*Client: United Nations Environmental Programme*

Retained by the UNEP to develop a strategic policy document on coastal erosion and sea level rise for the Coordinating Body of the Seas of East Asia (COBSEA). Phase 1 focused on country consultations and the framework development. In Phase 2, a one-week workshop was held in Thailand with the 10 member countries to refine the approach and finalize the document which was published by the UN.

### Southeast Leamington Sustainable Management Strategy

*Client: Essex Region Conservation Authority*

Managed a complex multi-disciplinary investigation that included coastal process modelling, water quality studies, erosion and flooding assessments, dyke geotechnical analysis, biodiversity assessments, and tourism economics. A benefit-cost analysis was used to evaluate alternative land use scenarios for the region, culminating in the selection of the preferred sustainable alternative.

### Colchester to Southeast Shoal Littoral Cell Study

*Client: Conservation Authority, Municipal Governments, and Industry*

Led a comprehensive study on erosion and sedimentation processes for a littoral cell on Lake Erie extending from the Detroit River to the shoal off the tip of Point Pelee National Park (PPNP). The investigation looked at historical sediment supply rates from erosion, sediment sinks, and depositional areas. The findings were used to highlight the negative impact of shoreline armouring and sedimentation at the harbours, which in turn negatively impact shoreline erosion rates and habitat loss within PPNP.

### Regional Sediment Management Plan for Michigan City Harbor

*Client: US Army Corps of Engineers, Detroit District*

Managed a comprehensive study into sediment bypassing at Michigan City. A long-term sediment budget was used to quantify sediment sources, transport pathways, and sinks along the coastline. The findings were used to develop a multi-agency regional sediment management plan to optimize the harbor dredging, minimize costs, and maximize downdrift benefits for the dredged sediment.

### Ministry of Natural Resources Integrated Coastal Zone Management Review

*Client: Ministry of Natural Resources and Forestry*

In cooperation with Dr. Larry Hildebrand and Dr. Peter Ricketts, Pete managed a study for the Ministry of Natural Resources and Forestry on options to apply Integrated Coastal Zone Management principles in the Great Lakes Region. The report reviewed existing legislation, actions in other jurisdictions, and International case studies. Options for better integration and collaboration among government agencies and the steps required to achieve the stated goals were outlined.

### Climate Change Impacts on Lake Ontario Coastal Processes

*Client: Department of Fisheries and Oceans (DFO)*

Retained to investigate the potential impacts of climate change on Lake Ontario coastal processes. Hourly wave conditions were predicted for the historical 1971 to 2000 over-water winds and the estimated future 2041 to 2070 over-water winds from the Canadian Regional Climate Model. In addition to evaluating the intensity and frequency of future storms versus historical conditions, the hourly waves from both scenarios were used in an erosion model to quantify recession rates and the availability of new sediment for beach building. The results were used to assess potential impacts to fish habitat by DFO.

### Climate Change and Policy Workshop

*Client: Ministry of Natural Resources and Forestry & Environment and Climate Change Canada*

Coordinated a large two-day coastal policy forum to review the status of existing regulations and investigate the degree to which climate change considerations were presently integrated. Recommendations were provided on required technical studies and the need for a White Paper on integrating climate change risk into the existing planning and regulatory framework.

### Climate Change Risk Assessment for Coastal Infrastructure in Nova Scotia

*Client: Nova Scotia Department of Transportation and Infrastructure Renewal*

Managed a preliminary coastal risk assessment for several highway and bridge sites in Nova Scotia exposed to coastal hazards during storms. Event based hazards such as storm surge, erosion, and flooding were investigated, along with long-term processes such as sea level rise and crustal subsidence. Management alternatives were developed to reduce risks and future maintenance of the infrastructure.

## EROSION AND SEDIMENTATION PROJECTS

### Synopsis of Point Pelee National Park Erosion and Mitigation Options

*Client: Parks Canada*

Prepared a synopsis of shoreline erosion processes and rates within Point Pelee National Park spanning the last 100 years. Updated mapping of recent erosion rates was also generated along with forecasts of future shoreline position to assess infrastructure risks and potential habitat loss. A variety of erosion mitigation strategies were highlighted, include beach nourishment options that work with natural processes.

### Lac Seul Erosion Investigation

*Client: Aboriginal Affairs and Northern Development Canada*

Principal investigator and project manager for the Lac Seul erosion investigation. A comprehensive field program, literature review, and computer modelling were completed to generate multiple lines of evidence on the pre and post-dam erosion rate on Lac Seul. Expert witness testimony provided in the Supreme Court of Canada.

### Lake Winnipeg Water Level Regulation Review

*Client: Manitoba Clean Environment Commission*

Prepared an expert report on the impacts of Lake Winnipeg water level regulation on shoreline erosion and accretion processes. The critical factors controlling erosion were reviewed, along with the influence of fluctuating water levels (both natural and regulated). Presented findings at a hearing in Winnipeg and provided recommendations for future technical studies.

### Ochiichagwe'Babigo'Ining Ojibway Nation Erosion Study

*Client: Ochiichagwe'Babigo'Ining First Nation*

Project Manager for two technical studies for the Ochiichagwe'Babigo'Ining Ojibway Nation. The first investigation focused on the linkages between water level regulation, flooding, and erosion associated with the Lake Woods water management regime. The second investigation developed conceptual design alternatives to protect critical infrastructure at risk to erosion and flooding.

### Mitaanjigamiing First Nation Erosion Study

*Client: Mitaanjigamiing First Nation*

Project Manager for a two-part investigation for the Mitaanjigamiing First Nation on Rainy Lake. Part one included detailed site reconnaissance of the shoreline to identify potential erosion sites and critical infrastructure at risk to erosion and flooding hazards. Part two included the generation of design alternatives to protect critical infrastructure at risk to flooding for the upper portion of the easement and ensure the waterfront and boat launch were functional for the anticipated range of future lake levels.

### Lac Des Mille Lacs Erosion Study

*Client: Lac Des Mille Lacs First Nation*

A multi-day field data collection mission was completed on Lac Des Mille Lacs. The information, along with desktop studies, were used to evaluate the impact of water level regulation on shoreline erosion within the Reserve. Recommendations were also provided for a flooding easement and critical infrastructure was identified that was vulnerable to flooding. Engineering designs were prepared to protect at risk buildings.

### Whitesand First Nation Erosion Peer Review

*Client: Ontario Power Generation*

Retained by Ontario Power Generation to complete a peer review of documented erosion procession on the north shore of Lake Nipigon, within the limits of the Whitesand First Nation. The study included a review of the water level regulation on the lake and the influence on erosion processes. Detailed erosion measurements were completed to assess risks and make recommendations for erosion protection.

### Lake St. Joseph Erosion and Flooding Assessment

*Client: Attorney General of Canada and Ontario Power Generation*

Served as an expert witness in the legal proceedings between the Mishkeegoggamang Ojibway First Nation and the Attorney General / Ontario Power Generation. A detailed field investigation was completed to collect erosion and sedimentation data. These data, along with historical references, shoreline change measurements, numerical modelling and expert judgement were used to formulate an opinion on the role of the lake flooding on erosion processes. Testimony was provided in the Ontario Provincial Court.

### Gull Lake Wave Database

*Client: Manitoba Hydro*

Project Manager for a numerical modelling investigation on Gull Lake, in northern Manitoba. An hourly wave database was generated for the planned reservoir at full supply to support wave erosion modelling. The wave database was delivered in an interactive ArcReader GIS application.

### Lake Diefenbaker Erosion Assessment

*Client: Environment Canada*

As Project Manager for the study, Pete was responsible for supervising the calculation of historical erosion rates, wave modelling, and shoreline erosion modelling with COSMOS. The COSMOS tool was used to investigate historical erosion rates and evaluate future water level management scenarios.

## East Harbor State Park Erosion Investigation, Lake Erie

*Client: Ohio Department of Natural Resources (DNR)*

Retained by the Ohio DNR to evaluate erosion issues within the State Park and recommend remedial options to improve the swimming beach conditions. Technical studies included literature review, site surveys, aerial photograph analysis of historical shoreline change rates, sediment transport calculations, and a regional sediment budget. The preferred alternative included a series of low crested offshore breakwaters and beach nourishment.

## Erie Shore Drive Flood and Erosion Study, Lake Erie

*Client: Municipality of Chatham-Kent*

Managed the investigation of coastal hazards for the community of Erie Shore Drive. The study included field work, modelling of coastal processes, erosion and flooding assessment, and the development of remedial options. A preferred option to protect the homes and dyke was developed.

## Investigation into Downdrift Erosion Impacts, Shade Beaches, PA

*Client: Harborcreek Township, Pennsylvania*

Managed the investigation into potential downdrift impacts of a proposed harbor development on Lake Erie. The work included field reconnaissance, geology and erosion assessment, longshore sediment transport calculation, and a harbor bypassing analysis.

## NIPSCO Bailly Station Intake Sand Transport Investigation, Indiana

*Client: NIPSCO*

Led the coastal investigation into sedimentation processes at the NIPSCO Bailly Station water intake. Numerical tools and GIS were used to quantify rates of sediment transport and accretion around the intake. The study recommended remedial measures to reduce sedimentation and dredging in the future.

## Minnesota Point Section 111 Erosion Study Report

*Client: US Army Corps of Engineers*

Managed the investigation into erosion and sedimentation processes at Minnesota Point, Lake Superior, which features two jetted navigation channels and a long barrier beach system. Numerical modelling of waves and sediment transport in combination with shoreline change measurements, sedimentation records, and dredging history were used quantify erosion processes. Recommendations included relocating future dredged sediment to mitigate the ongoing shore erosion and nourish the beaches.

## Toronto Islands Erosion Study

*Client: Toronto and Region Conservation Authority*

Led the coastal investigation into erosion processes at the Toronto Island. The technical studies included a review of historical aerial photographs, quantification of historical bathymetric changes, and numerical modelling of waves, currents and sediment transport to develop a detailed sediment budget. The sediment budget was used to quantify historical and modern sediment sources, transport pathways, and sinks. Long-term management recommendations were developed to reduce future shore erosion.

## Keltic Lodge Coastal Erosion Study, Cape Breton, Nova Scotia

*Client: Nova Scotia Department of Transportation and Infrastructure Renewal*

Principal investigator in the study of coastal erosion hazards at the Keltic Lodge site, located on the narrow Middle Head Peninsula in Cape Breton. Erosion of the weak sea cliffs was threatening buildings and the transportation network. Remedial options were developed based on the geologic assessment, groundwater processes, wave climate, and sea level rise considerations.

## FLOODING PROJECTS

### FEMA Guidelines and Specifications for Coastal Floodplain Mapping

*Client: Federal Emergency Management Agency (FEMA)*

FEMA generates and updates graduated floodplain risk maps for all the rivers and coastal areas of the United States. Pete participated in a multi-team initiative to update the Guidelines and Specifications used to produce the mapping. The technical studies included the evaluation of the latest wave runup and overtopping procedures, wave and storm surge modelling capabilities, and overland wave propagation.

### FEMA DFIRM Production for Kandiyohi and Eaton Counties

*Client: FEMA Region V*

Managed the technical studies and generation of digital flood insurance rate maps (DFIRMS) for two riverine counties in the State of Michigan. More than 100 standardized map tiles were generated to map the spatial extent of the 1% and 0.2% chance flood risks. The final products were delivered in a GIS Geodatabase and as PDF maps.

### FEMA DFIRM Production in Wayne and Monroe Counties

*Client: FEMA Region II*

Managed all activities related to the coastal analysis and generation of floodplain work maps for Wayne and Monroe Counties, Lake Ontario. The coastal analysis utilized the new response base approach to map the graduated risk zones for flooding hazards.

## WATER QUALITY AND WATER QUANTITY PROJECTS

### Great Lakes Integrated Nearshore Framework

*Client: Environment and Climate Change Canada*

Project Manager for a three-year contract with Environment and Climate Change Canada to assist with the development of the Integrated Nearshore Framework and the Baseline Habitat Survey. Collectively these two components of the Great Lakes Water Quality Agreement will be used to establish a baseline assessment of nearshore water quality and habitat, upon which future improvements will be measured. The findings will be used to enhance protection of high-quality habitat and prioritize restoration activities. Community collaborations will also be supported to engage stakeholders for restoration work.

### Southern Georgian Bay Beta Habitat Units

*Client: Environment and Climate Change Canada*

The Baseline Survey approach developed for the Habitat and Species Annex of the Great Lakes Water Quality Agreement was applied by Pete for Southern Georgian Bay. The study relied on existing lakewide geo-spatial data and the generation of new information, such as detailed wave modelling. The findings were used to map Regional Habitat Areas and nested Habitat Units.

### Barbados Water Quality Study, Coastal Risk Assessment and Management Program

*Client: Coastal Zone Management Unit, Government of Barbados*

Project Manager for a comprehensive water quality investigation for the nearshore zone of Barbados. The study included a review of historical data, instrument deployment for new data collection, water chemistry assessment, and a detailed algae stable isotope analysis (over 500 samples) to determine the source(s) and fate of nitrogen pollution. These data were also used to develop an island wide 2D circulation model and a detailed 3D water quality model; both used to evaluate remedial alternatives to improve local water quality.

## Lake Ontario – St. Lawrence River Water Level Regulation Study

*Client: International Joint Commission, USACE, ECCC*

Project Manager for a multi-year investigation on the impacts associated with water level regulation on Lake Ontario and the St. Lawrence River. Studies quantified the impacts on shore erosion, flooding, maintenance of existing shoreline protection structures, and supported the assessment of beach impacts and coastal dunes protecting wetlands. Economic damages were calculated with time series water levels for 3,000 km of shoreline represented by more than 20,000 individual property parcels.

## International Upper Great Lakes Study

*Client: ECCC, USACE, and the IJC*

Managed several investigations for the Upper Great Lakes Study, including a review of available geo-spatial data, the sensitivity of the Flood and Erosion Prediction System (FEPS) to alternative regulation plans, evaluation of potential study sites, and investigation of flooding impacts associated with alternative regulation plans for historical supplies and climate change induced water supplies. The studies were used to evaluate alternative Regulation Plans for the water releases from Lake Superior.

## Rainy Lake Excel Flood Tool

*Client: International Joint Commission*

Managed the development of a custom Excel based open source flooding tool to evaluate alternative water level regulation scenarios for the Rainy Lake system and the associated impacts on riparian property. The tool utilized time series water levels and historical storms to estimate flooding damages to existing buildings and calculate economic damages.

## Preliminary Study of Structural Compensation Options for the St. Clair River

*Client: International Joint Commission*

Project Manager for a study into engineering options to remediate past dredging of the St. Clair River, which has increased the conveyance of the river. Conventional flow remediation structures, such as sills and weirs were considered, along with options that would enable adaptive management of flow regulation, such as gated structures and submerged hydroelectric turbines.

# RESTORATION PROJECTS

## Lighthouse Beach Restoration, Pictou, Nova Scotia

*Client: Nova Scotia Department of Transportation and Infrastructure Renewal*

Project Manager for a multi-year investigation into the breach of the Lighthouse Beach sand spit and the development of a remedial solution. Technical studies included the review of historical sand mining activities, shoreline change measurements, wave and current modelling, storm surge assessment, beach erosion simulations, and engineering design. The breach in the 1.4 km long sand spit was filled with a rock dyke and beach nourishment was used to restore the beach and dune habitat.

## Ecosystem Based Adaptation Pilot Study for Reef Restoration

*Client: Coastal Zone Management Unit, Government of Barbados*

Managed a pilot project to restore the fringing reefs of Barbados. These shallow ecosystems protect the island beaches from storm damage and produce the carbonate sediment needed to maintain healthy beaches but have declined in response to climatic stressors and pollution. The study assessed reef health, identified coral donor colonies, and constructed an aquaculture laboratory to grow small coral in a controlled environment. Once the corals reached a sufficient size, they were transplanted to the reefs and monitored.

### Keta Lagoon Causeway and Sea Defense, Ghana, West Africa

*Client: Government of Ghana*

Led the coastal process investigation to support the design of sea defences along a 7 km eroding barrier beach in Ghana. The long-term erosion rate ranged from 5 to 10 m/yr. Technical analysis included historical shoreline change measurements, review of geologic conditions, and littoral sediment budget calculations. The findings were used to support the remedial design, which included 10 million cubic metres of beach nourishment, a new coastal highway, land reclamation and habitat restoration.

## INTERNATIONAL PROJECTS

### Barbados Shoreline Change Study, Coastal Risk and Management Program

*Client: Coastal Zone Management Unit, Government of Barbados*

Project Manager for a shoreline change study for the island of Barbados. The investigation included the review and analysis of four decades of beach profile data to assess erosion and accretion patterns. Recommendations were provided to enhance the program with new data collection tools. Shoreline change was also analyzed with historical aerial photographs dating back to the 1950s. Detailed rates of change were calculated for the beach and cliff environments. The results were used to develop a coastal classification that characterizes the long-term shoreline trend for natural and engineering shorelines.

### Development of a Hurricane Erosion Vulnerability System, Elbow Cay, Bahamas

*Client: Government of The Bahamas*

Lead coastal scientist for the assessment of hurricane erosion vulnerability at Elbow Cay, which was extensively damaged by Hurricane Floyd in the Fall of 1999. A custom system was developed that integrated GIS technology and numerical models to assess potential storm damage and resilience of the islands beaches to future hurricanes. The erosion prediction tools were also used to evaluate the feasibility of several remedial alternatives to strengthen the protection provided by the beaches of Elbow Cay.

### Evaluation of Hurricane Impacts for a Deep-Water Outfall

*Client: Government of Dominica*

Investigated hurricane storm damages at the location of a proposed deep-water outfall on the Island of Dominica. The geologic properties of the site were evaluated, along with modelling estimates of beach and seabed erosion for future hurricanes. The modelling results were also used to develop the engineering aspects for the outfall, including the anchoring system and burial depth.

### Simandou Port Construction Feasibility Study, Guinea

*Client: Rio Tinto*

Led the field investigations into the feasibility of a new port construction in a large tidal estuary in southern Guinea. The field work included instrument deployment, sediment coring and characterization within the estuary and on the delta, and a geomorphic assessment of the river shoreline and coast. The findings were used to assess navigation channel location and dredging requirements for the proposed port.

### Analysis of Beach Erosion and Channel Sedimentation, Herzliya Marina

*Client: Government of Herzliya*

Lead coastal investigator for a beach erosion and sedimentation study at the Herzliya Marina, north of Tel Aviv. Aerial photograph comparisons, seabed change measurements, and numerical modelling were used to quantify sediment sources, rates of sediment transport, and channel sedimentation. Remedial options were developed to reduce future maintenance costs and maintain safe navigation into the marina basin.

## TECHNICAL PAPERS AND CONFERENCE PRESENTATIONS

Zuzek, P.J. (2019). Flood and Erosion Vulnerability Studies in Southwestern Ontario. Southwestern Ontario Shoreline Roundtable Information Meeting, London, Ontario

Zuzek, P.J. (2019). Chatham-Kent Lake Erie Shoreline Study and Planning Implications. 2019 Ontario West Planners Forum, London, Ontario.

Zuzek, P.J. (2019). Climate Change Impacts on Coastal Storms and Ice Cover for Lakes Erie and Ontario. Provincial Flood Forecasting and Warning Workshop, Toronto, Ontario.

Zuzek, P.J. (2018). Collaborative Shoreline Management Planning and Climate Change Adaptation Planning on Lake Erie. Latornell Conservation Symposium, Alliston, Ontario.

Zuzek, P.J. and Mortsch, L. (2018). Adapting to the Future Storm and Ice Regime in the Great Lakes. Coastal Zone Canada Association Conference, St. John's, Newfoundland.

Zuzek, P.J., Anderson, J., McKenna, J., and Hatcher, J. (2018). Application of the Nearshore Framework Assessment for Lake Erie and the Huron-Erie Corridor in Canada. International Association of Great Lakes Research Conference, Toronto, Ontario.

Zuzek, P.J. (2017). Overview of Coastal Hazard Management in the Great Lakes. Eight Annual National Roundtable on Disaster Risk Reduction, Halifax, Nova Scotia.

Zuzek, P.J. (2016). Elgin County Shoreline Management Plan. Proceedings of the 2016 Coastal Zone Canada Conference, Toronto, Ontario.

Degia, K. and Zuzek, P.J. (2016). Coral Reef Restoration as a Climate Change Adaptation Approach. Proceedings of the 2016 Coastal Zone Canada Conference, Toronto, Ontario.

Zuzek, P.J. (2015). Development of a Joint Shoreline Management Plan for Elgin County. Proceedings of the 2015 Latornell Conservation Symposium, Alliston, Ontario.

Zuzek, P.J. (2014). Development of an Integrated Nearshore Framework for the Great Lakes. Proceedings of the Coastal Zone Canada 2014 Conference, Halifax, Nova Scotia.

Zuzek, P.J. (2013). Stakeholder Engagement and Initial Development of the Great Lakes Nearshore Framework. Proceedings of the Latornell Conservation Symposium, Alliston, Ontario.

Zuzek, P.J. (2012). Developing a Long-term Shoreline Management Plan for Victoria Beach Using a Stakeholder Centric Framework. Coastal Zone Canada Conference 2012, Rimouski, Quebec.

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# APPENDIX C

## Credit Valley Conservation Watershed and Nearshore Water Quality Modelling

# Credit Valley Conservation Watershed and Nearshore Water Quality Modelling

Prepared for:

**Zuzek Inc.**

July 6, 2020

Prepared by:

**Prepared By:**
Amanjot Singh, Ph.D., P.Eng., CVC
Ray Dewey, Modeling Surface Water Ltd.

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## List of Figures

# 1.0 INTRODUCTION

The Credit Valley Conservation (CVC) watershed is located at the western end of Lake Ontario. Refer to Figure 1.1 for a map of the watershed and sub-watershed boundaries.

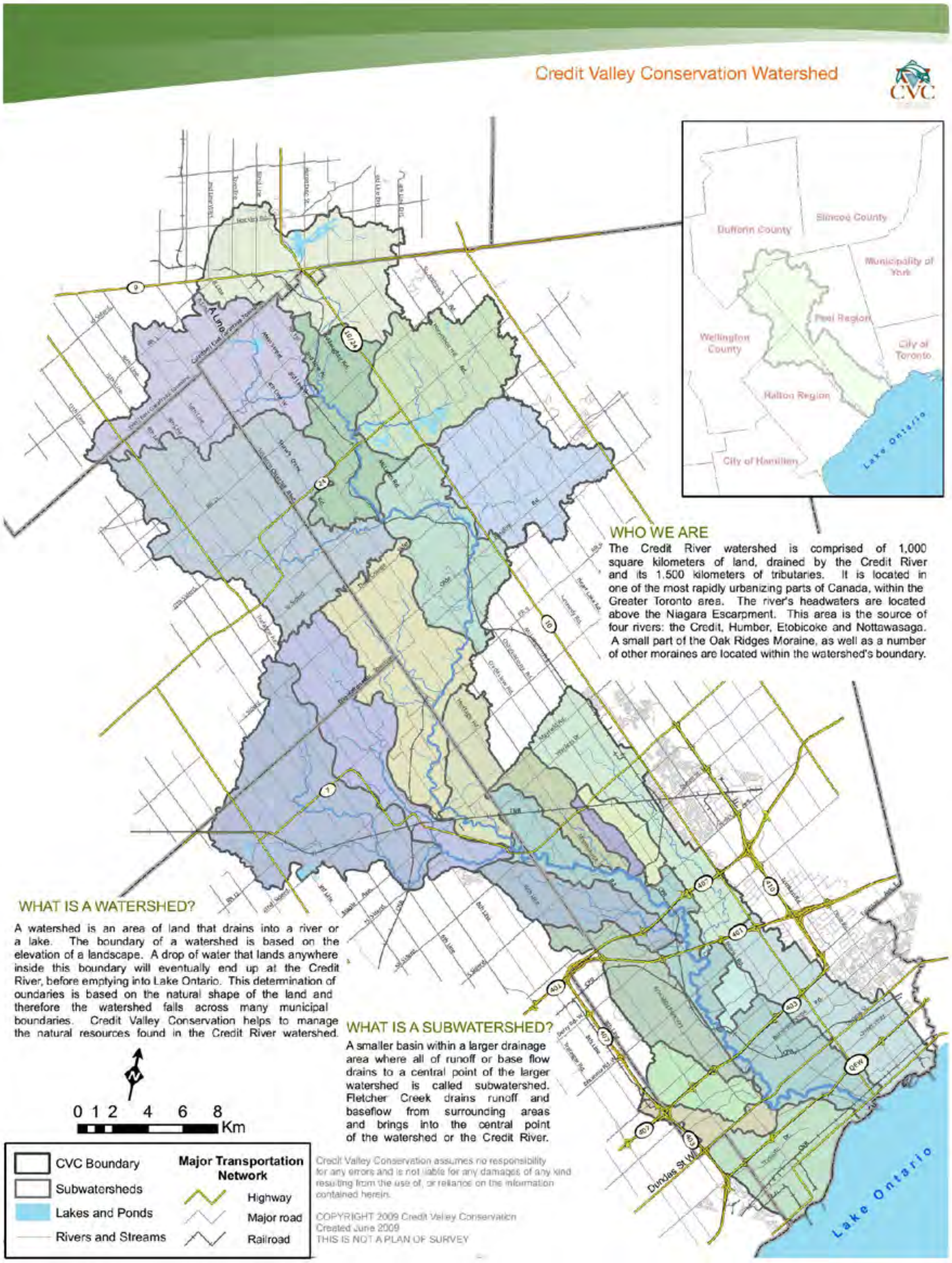


**Figure 1.1 CVC Watershed (map published by the CVC)**

This report provides a general overview of an ongoing numerical modeling study of nearshore water quality, including the potential impacts of climate change.

## 1.1 Linkages to the NRCan Supported Climate Change Study

Zuzek Inc. received financial support from NRCan and other project partners to complete the study entitled Adapting to the Future Storm and Ice Regime in the Great Lakes (Zuzek Inc. 2019). Stream 1 focused on the impacts of climate change on future lake levels, ice cover, and coastal storms. Stream 2 featured four case study, including the CVC nearshore water quality study described in this report, a strategic review of potential impacts of climate change for the Burlington Beach Master Plan (Zuzek Inc, 2020a), a White Paper prepared with feedback from the Conservation Authority Coastal Working Group (Mortsch and Zuzek, 2020), and the Chatham-Kent Lake Erie Shoreline Study (Zuzek Inc., 2020b).

## 1.2 Relevant Technical Findings from the NRCan Climate Change Study

The Stream 1 technical studies featured investigations by RWDI (2020) into future storm frequency and intensity in the Great Lakes Basin, and detailed numerical modeling of wave heights and storm surge on Lake Ontario and Lake Erie (Baird, 2019). Key findings include:

- Winter temperatures are projected to be 5 to 7 degrees warmer in Southern Ontario by late century for RCP8.5 (Bush and Lemmen, 2019).
- Based on output from five global climate models, no change in synoptic weather patterns (storm types and region of origin) are expected for the Great Lakes (RWDI. 2020).
- No statistically significant changes in sea-level pressure gradients were observed for synoptic scale storms in the future climate model output, suggesting storm extremes such as peak wave heights and maximum storm surge will not increase in the future (RWDI, 2020).
- Average lake levels are projected to be higher for all of the Great Lakes in the future (note: modelling not completed for Lake Ontario) and wet periods will result in even higher lake levels (ECCC Open File, 2020).
- On average, wave heights and storm surges are not projected to be higher in the future for the RCP8.5 emission scenario (Baird, 2019).
- Air and water temperature increases will result in reductions in winter ice cover, potentially leading to ice-free lakes by late century for RCP8.5 (RWDI, 2020; ECCC Open File, 2020).
- Ice-free lakes in the winter will increase the amount of wave energy reaching the shorelines of Lake Ontario and Lake Erie by up to 100% in some regions (Baird, 2019).
- The hazards associated with winter flooding and erosion events will increase in the future (Zuzek Inc., 2020a; Zuzek Inc., 2020b).

# 2.0 CVC Water Quality Modeling

The MIKE-3 (three dimensional hydrodynamic and water quality model) software was used to evaluate the water quality scenarios in the nearshore region of Lake Ontario under Credit Valley Conservation (CVC) jurisdiction. The scenarios under consideration include:

- Nearshore pollutant dynamics under existing condition.
- Nearshore pollutant dynamics under lakefill options.
- Impact of road salt and snow melt on the water quality in the nearshore.
- Impact of climate change on pollutant transport from watershed to the nearshore.

Figure 2.1 presents the shoreline for existing conditions, with the model boundary for the proposed lakefill scenario presented in Figure 2.2.

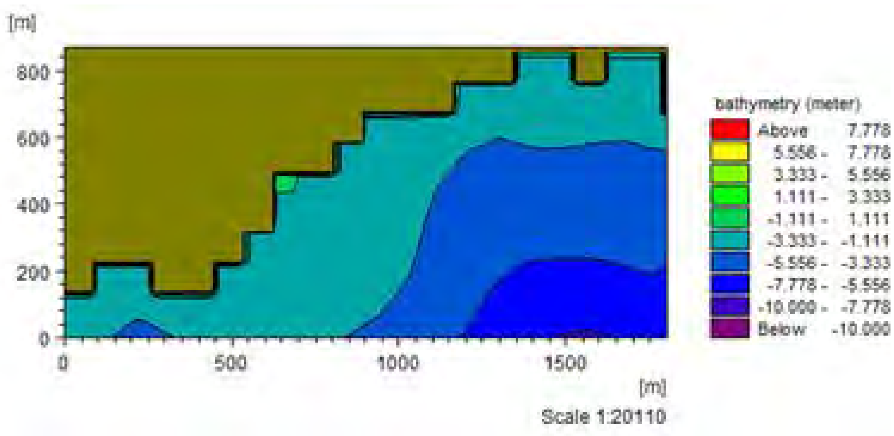


**Figure 2.1 CVC Model Boundary East of Lakeview TGS Pier (Etobicoke Creek is in the top right corner of the model grid)**

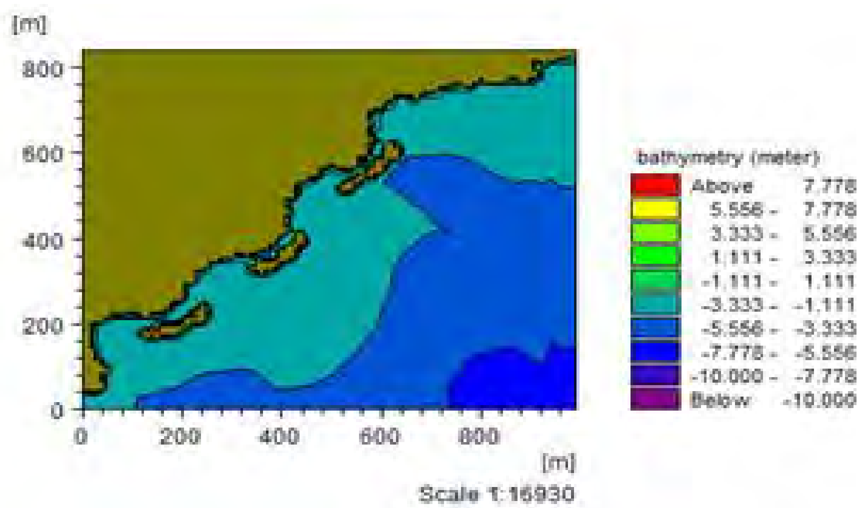


**Figure 2.2 CVC Model with Lakefill at Jim Tovey Park**

## 2.1 Modeling Total Suspended Solids (TSS)

The model domain also includes the Clark Water Treat Plant (WTP) intake. The TSS information from May to August 2008 was simulated at different depths for the existing conditions (Figure 2.3) and proposed future lakefill at Jim Tovey Park (Figure 2.4).

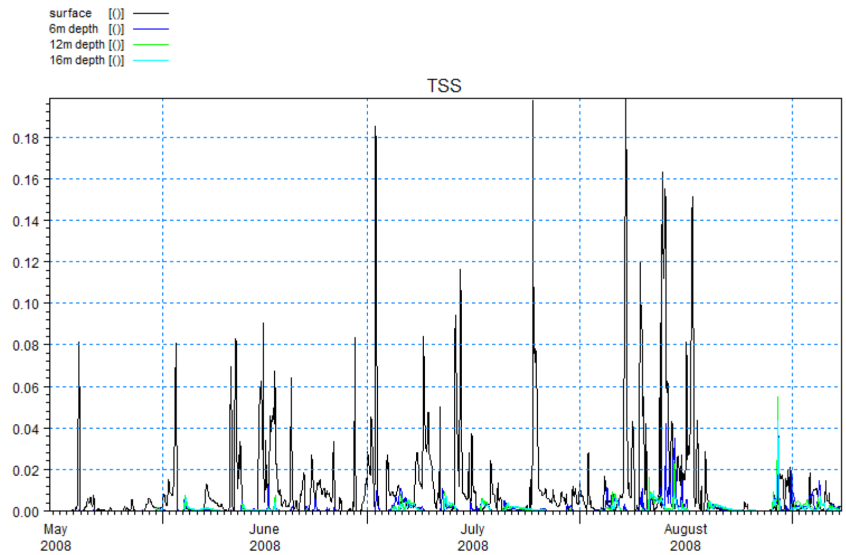


**Figure 2.3 Modelled TSS Levels at Clark WTP Intake for the Existing Shoreline**

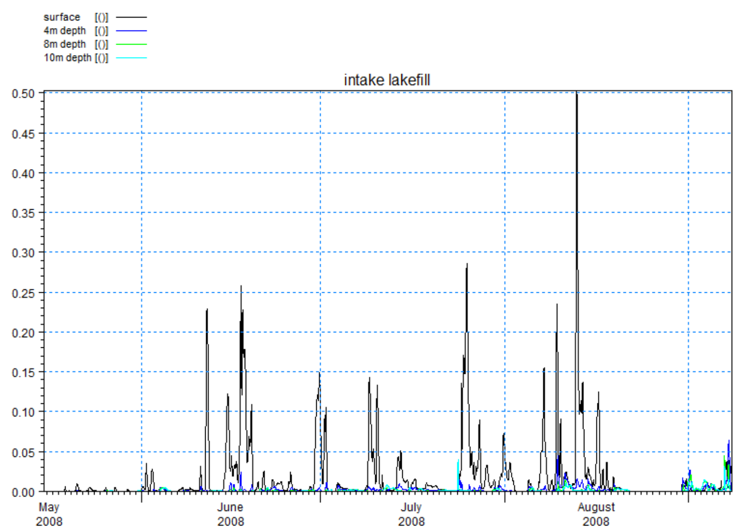


**Figure 2.4 TSS Concentrations at Clark WTP Intake with Lakefill at Jim Tovey Park**

## 2.2 Road Salt Impacts from Snowmelt Events

Snowmelt events in urban regions produce high salinity levels in roadway melt water that eventually reaches the tributaries and Lake Ontario. A set of simulations were made with elevated levels of practical salinity units (PSU) to determine what the impacts could be on the Clark WTP intake. The elevated PSU was set constant over the simulation period. A separate project will utilize an updated watershed model to provide updated PSU levels in the tributaries during snowmelt conditions. The existing conditions simulation is shown in Figure 2.5 and the lakefill condition in Figure 2.6.

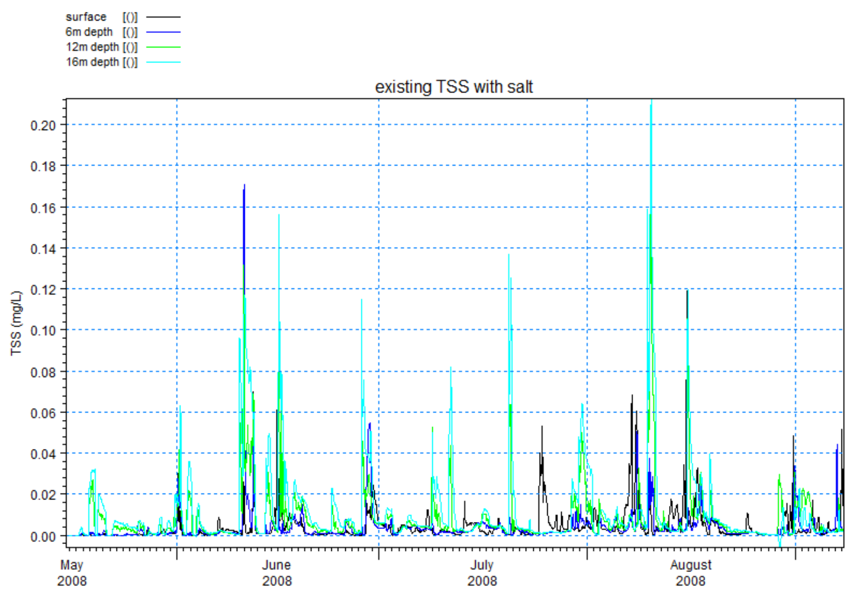


**Figure 2.5 TSS Levels at the Clark WTP for the Existing Shoreline Conditions (high PSU results in elevated levels of TSS at the depth of the intake)**

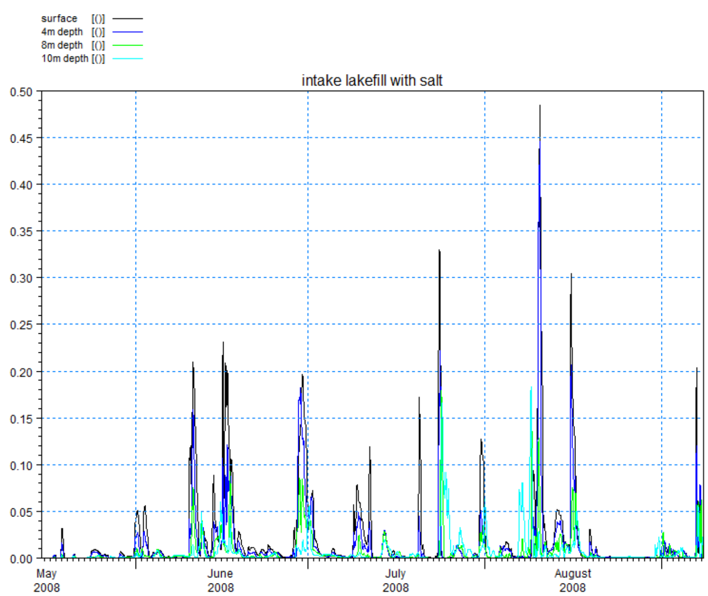


**Figure 2.6 TSS Levels at the Clark WTP for the Proposed Lakefill due to Road Salt and Snow Melt**

## 2.3 TSS Plume Modeling

Another form of graphical output is plume delineation of TSS concentrations. With the MIKE3 model, the contours of TSS can be displayed at different depth layers to show the path of the plume from various sources. Figure 2.7 simulates a scenario for the existing shoreline and the plumes from the two small tributaries and Etobicoke Creek, which is the dominant source in this area.

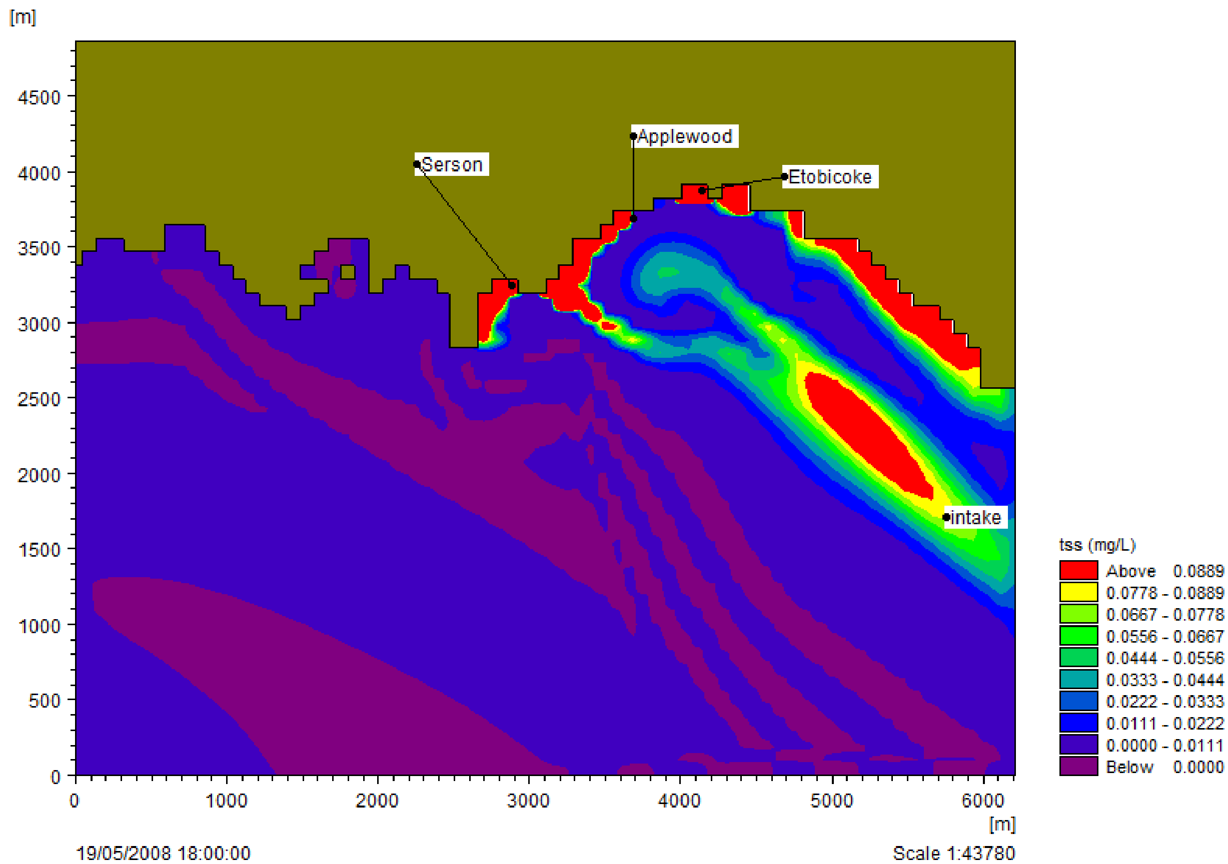


**Figure 2.7 TSS Plume Delineation from Local Tributaries in Proximity to the Clark WTP Intake**

# 3.0 MODELING CLIMATE CHANGE IMPACTS

In future phases of the project, the scenario evaluation will continue with the MIKE3 model to investigate the potential impacts of climate change on TSS concentrations in the nearshore for the existing shoreline and planned lakefill. The Stream 1 findings (Zuzek Inc. 2019) will inform the selection of appropriate climate scenarios and storm extremes.

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# APPENDIX D

## Screening Level Assessment of Climate Change Impacts on the Burlington Beach Master Plan

# Screening Level Assessment of Climate Change Impacts on the Burlington Beach Master Plan

Prepared for:

Region of Halton

June 8, 2020

Prepared by:


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Zuzek inc.
ONE WORLD

*Beach Closure Sign, June 23, 2019*


**Disclaimer:**

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# EXECUTIVE SUMMARY

The Burlington Beach and canal to Hamilton Harbour has been managed and altered for more than 200 years dating back to the first stabilization of the canal in the early 1800s when the area was known as Wellington Square (Weeks-Mifflin and Mifflin; 1989). The present Federal Navigation Channel is protected with concrete and steel jetties and provides access to the deep-water Port of Hamilton.

The beach is a popular regional destination and features numerous existing amenities including a waterfront trail, beach access, a food and washroom pavilion, sailing club, and launch for non-motorized boats. It was also significantly damaged during the prolonged high-water events in 2017 and 2019. Resilience to coastal storms and high lake levels is low, as evidenced by the site observations documented in this report.

Climate Change is making the implementation of the Master Plan even more challenging. Lake levels are projected to be even higher than the peak reached in June 2019, and warmer air and lake temperatures in the future will lead to less protective ice-cover. The relatively mild and ice-free conditions in 2019/2020 are a prelude to future conditions.

A significant beach and dune restoration project is required for the entire length of the beach to reduce flood risks and protect the existing and planned infrastructure upgrades from erosion. Some elements of the existing plan will require re-design, even with a fully restored beach and dune, such as the gas fire circle located on the beach in The Strand.

Regular and comprehensive monitoring is required to document the post-construction conditions of the rebuilt dune and monitor the success of the restoration project. Moving forward, the monitoring and additional improvements to the site should be completed within the framework of an adaptive management strategy. Increasing the resilience of the beach and dune in an uncertain future due to climate change will require a continuous management commitment.

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# 1.0 INTRODUCTION

Burlington Beach is located at the western end of Lake Ontario and is part of a narrow isthmus that separates the lake from Hamilton Harbour. Refer to Figure 1.1 for a map. In 2015, Halton Regional Council approved a comprehensive master plan to expand and upgrade Burlington Beach. A map of the plan is presented in Figure 1.2. Acquisition of additional lands from willing sellers continues to expand the park inland and re-align Lakeshore Road. A brief overview of the beach history is provided, along with the scope of this climate change screening level assessment, which is one case study of the overall investigation entitled Adapting to the Future Storm and Ice Regime in the Great Lakes (Zuzek Inc, 2020).

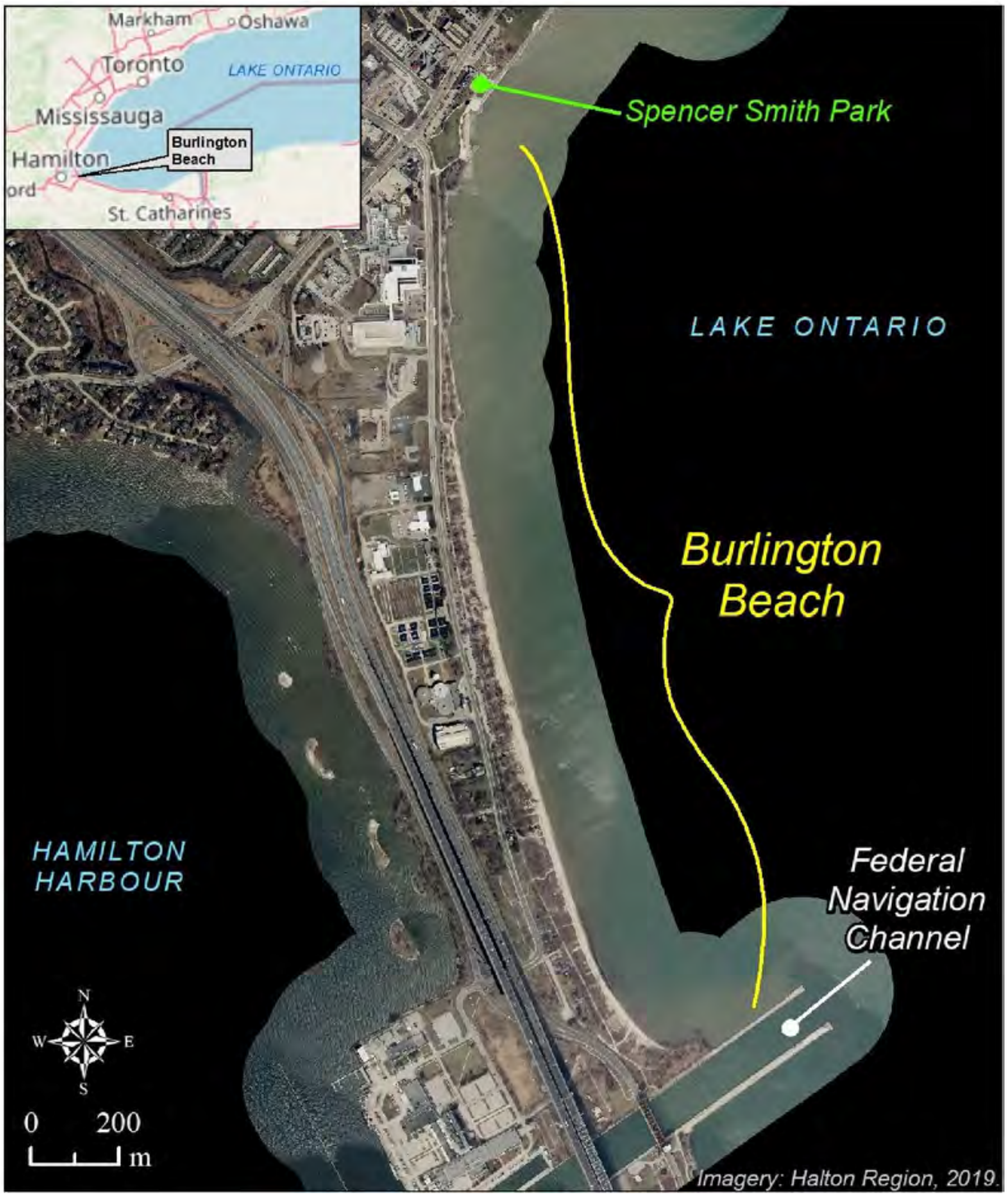


**Figure 1.1 Burlington Beach Location Map**


**Figure 1.2 Burlington Beach Master Plan (Approved in 2015)**

## 1.1 Overview of Beach and Canal History

The Burlington Beach site features more than 200 years of history. In the 1811 Map of Burlington (then Wellington Square) presented in Figure 1.3, the early beginnings of the community are captured, including the alignment of Plains Road (Road to York) and Brant Street (Weeks-Mifflin and Mifflin; 1989). At the time, Burlington Beach was a wayward sand spit with a natural channel into Burlington Bay. A swing bridge provided access across the canal in 1811 and was later replaced with a ferry. The British Military maintained a fort on the south bank of the canal.

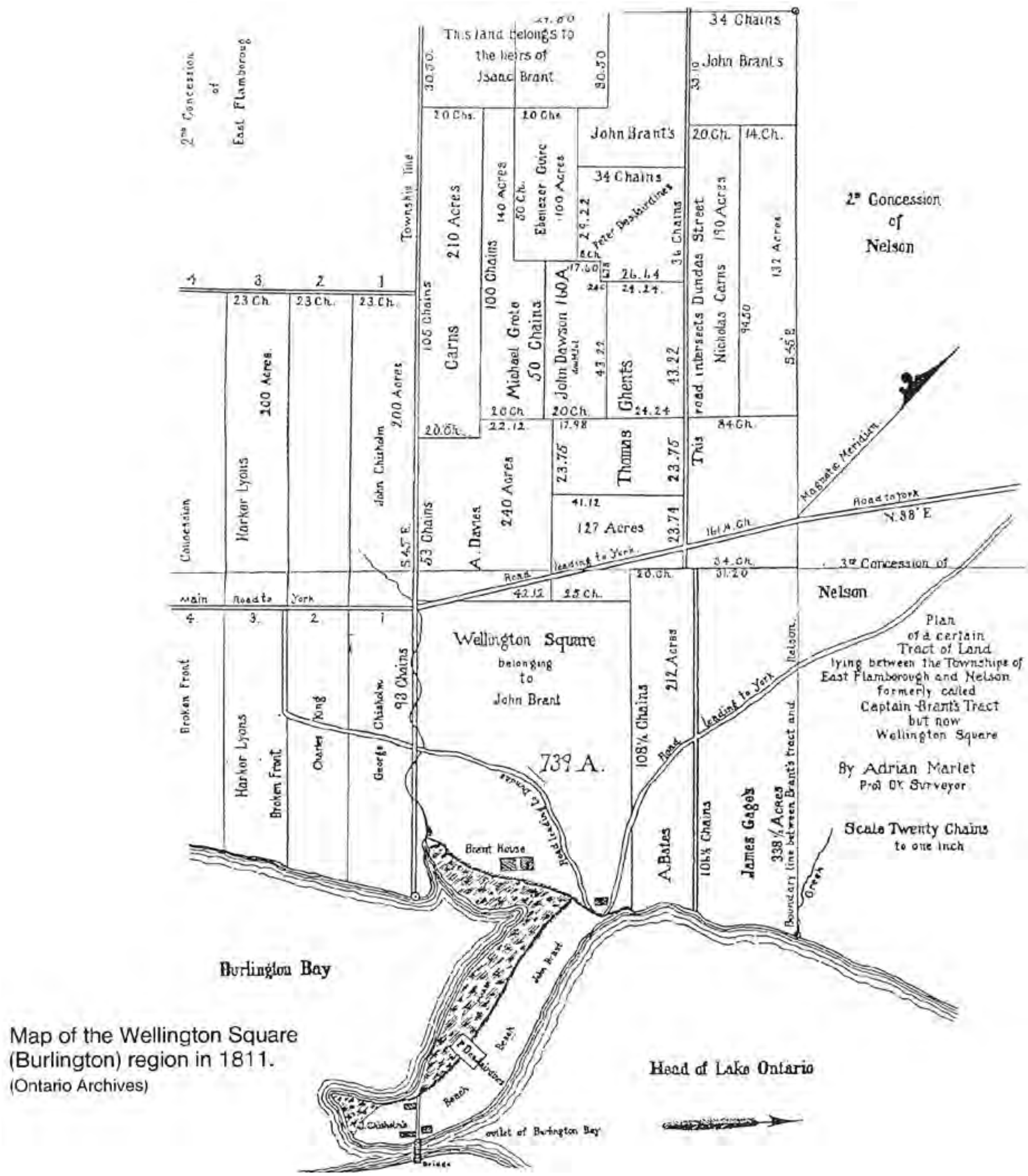


**Figure 1.3 1811 Map of Wellington Square (Burlington)**

The first formal canal was stabilized with rock filled timber cribs, was 72 feet wide, and featured a navigation depth of 10 feet. The project was finished in 1826. In 1837, a lighthouse was added and by 1844 the canal had been widened to 180 feet (Weeks-Mifflin and Mifflin, 1989). The canal provided safe refuge for the Schooners of the day and was an important aspect of the marine economy.

Photographs of the Burlington Beach strip in 1900, looking north and south respectively, are presented in Figure 1.4 and Figure 1.5. At the north end of the beach, the present-day Spencer Smith Park adjacent to the beach had not been constructed and the shoreline consisted of the native shale bluffs. A rail line linked Burlington with the communities of Hamilton and Niagara, as seen in both photographs. At the south end of the beach, near the canal, a series of cottages/homes are located between the rail line and beach (Figure 1.5).

**Figure 1.4 Burlington Beach in 1900 Looking North towards present-day Spencer Smith Park**

**Figure 1.5 Burlington Beach in 1900 Looking South towards the Canal**

## 1.2 Existing Conditions

A map of the current condition is provided in Figure 1.6. The present canal is almost 300 feet wide and facilitates access to the deep-water Port of Hamilton. Three bridges span the canal to facilitate vehicle traffic and the former beach is now home to a waste water treatment facility, a Ministry of Transportation maintenance yard, and Joseph Brant Hospital.

The beach has been subdivided into three principal zones in the Master Plan, with the natural Wind Beach adjacent to the Federal navigation channel. The Strand features a sandy beach and will be a key public access area for users to the waters edge. The Living Shoreline at the north features two trail connections to Spencer Smith Park and will be restored with natural vegetation and beach nourishment.


**Figure 1.6 Burlington Beach and Three Master Plan Areas**

## 1.3 Scope of Investigation

The components of this screening level assessment of the Burlington Beach Master Plan include:

- Meetings with Halton Region, the City of Burlington, and Conservation Halton staff.
- Screening level assessment of climate change impacts on the Master Plan elements.
- Report summarizing the findings and recommendations.

## 1.4 Recent Lake Ontario Water Level Trends

Regulation of Lake Ontario water levels began in 1960, with the operation of the Moses-Saunders Power Dam in Cornwall, Ontario. Prior to 2017, the record all-time high monthly mean lake level of 75.76 m was recorded in June 1952. From 1953 to 2016, summer water levels only peaked above 75.5 m IGLD'85 on four occassions over a 65 year period.

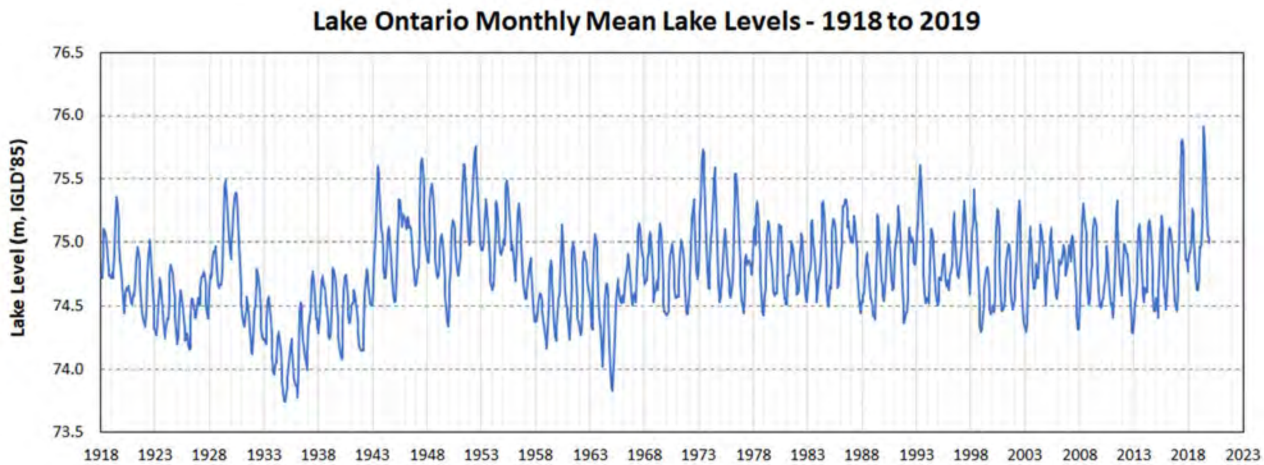


**Figure 1.7 Monthly Mean Water Level on Lake Ontario**

Then, in June 2017, Lake Ontario water levels established a new record all-time high water level of 75.81 m. The water levels in 2018 were close to the long-term average condition. In June 2019, Lake Ontario established a new record all-time high lake level of 75.91 m.

# 2.0 FIELD OBSERVATIONS AND DATA

Recent field observations and data sources are summarized in Section 2.0.

## 2.1 Recent Shoreline Observations

Recent observations from Burlington Beach are summarized from 2017 to 2020.

### 2.1.1 May 11, 2017 Burlington Beach

In June 2017, Lake Ontario set a new record all-time high monthly mean lake level of 75.81 m. The beach was fully submerged by the high lake levels and erosion occurred along the banks and dune at the back of the beach throughout the site. Refer to Figure 2.1 which captures the conditions during a mild wind event on May 11, 2017. One year later, the trail was re-aligned further inland and the shoreline was hardened with quarried rip rap, as seen in Figure 2.2.

**Figure 2.1 Erosion of Trail during 2017 High Lake Level Conditions**


**Figure 2.2 Re-alignment of the Trail and Shoreline Armouring in 2018**

### 2.1.2 April 15, 2018 Ice Storm and Post-storm Conditions

One year later, the western end of Lake Ontario was impacted by a large, slow-moving low-pressure system that tracked east to west along the long axis of Lake Ontario known as the 2018 ice-storm. Burlington Beach and Spencer Smith Park were severely impacted as seen in Figure 2.3 and Figure 2.4.

**Figure 2.3 Ice-covered Seawall at Spencer Smith Park**

**Figure 2.4 Wave Overtopping at Spencer Smith Park**

The post storm conditions at Burlington Beach were observed on April 22, 2018. Wave overtopping of the low-lying beach and dunes resulted in large volumes of woody debris throughout the grassed areas and trails of the park, as seen in Figure 2.5. There was also considerable erosion of the small dunes in the central part of the beach near the pumphouse and pavilion (Figure 2.6). At the north end of the beach, where the shoreline transitions to a cobble shingle beach, the root systems of large trees were exposed (Figure 2.7). The erosion damage on April 22, 2018 was a combination of the prolonged high lake levels in 2017 and the magnitude of the April 2018 ice-storm.


**Figure 2.5 Debris Washed Over Dune/Bank into the Park**


**Figure 2.6 Eroded Dune at Parkette**


**Figure 2.7 Exposed Tree Roots along Cobble/Shingle Beach**

### 2.1.3 June 23, 2019 High Water Observations

The site was observed with staff from Halton Region on March 15, 2019. The winter beach conditions in front of the Pavilion are seen in Figure 2.8. Signs of erosion in the face of the dune are evident but the marram grass has successfully retained beach sediment in front of this important infrastructure.

**Figure 2.8 March 15, 2019 Conditions at the Pavilion**

By June 2019, record volumes of spring rainfall in the Great Lakes and Ottawa River watersheds resulted in a steady rise in Lake Ontario water levels. In June, Lake Ontario had reached a new record all-time monthly mean level of 75.91 m IGLD'85. The beach was again submerged by water, as seen in Figure 2.9, only this time with 10 cm more water than in 2017.

**Figure 2.9 June 23, 2019 Conditions at the Pavilion**

Typical beach conditions are presented in Figure 2.10. The piece of concrete in the foreground had not been observed by the author in more than 20 years. The second year of record high lake levels, in three years, eroded the beach and dune/bank exposing a wide range of old structures, corroded concrete drums, and sandbags that had been buried for many years.

Interestingly, by May 2020, with lower lake levels (May 2020 monthly mean of 75.41 m), much of the former sand beach had recovered and re-buried the old concrete structure, as seen in Figure 2.11.

**Figure 2.10 Inundated Beach in June 2019**

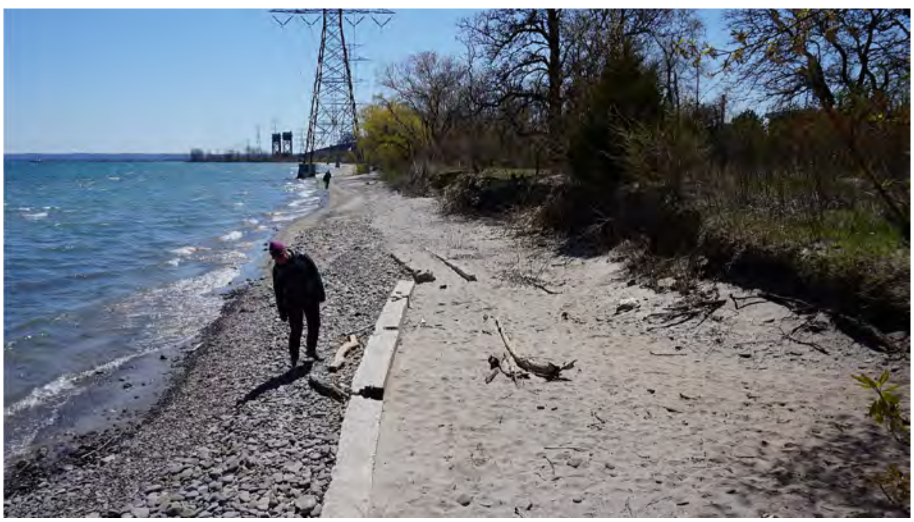

**Figure 2.11 Beach Conditions on May 13, 2020**

Even without a beach, users did not stop visiting this popular regional destination. The various informal trail networks throughout the park were used to gain access to the waters edge. Often climbing right over the sensitive dunes and eroded banks to gain access to the water. Refer to Figure 2.12.

While the Pavilion was closed as an access node to the beach, the photograph in Figure 2.13 shows the restored dune ecosystem and American Beachgrass was still providing some protection from high lake levels.

**Figure 2.12 Beach Access Across Eroding Dune/Bank**


**Figure 2.13 Closed Pavilion with Dune Protection**

### 2.1.4 January 2020 Winter Observations

A final set of site observations was collected in January 2020, following the record setting high lake levels established first in 2017 and then again in 2019. Figure 2.14 is typical of the Wind Beach, which featured the most natural dune conditions within the park. Significant erosion has occurred over the last three years and a steep face or scarp exists along most of the reach.

Similarly, the smaller dunes and sand banks in The Strand showed obvious signs of erosion, as seen in Figure 2.15. Along the Living Shoreline, the former cobble and shingle beaches have eroded and the bank supporting the upper trail has been re-enforced with rip rap in many locations (Figure 2.16).

Figure 2.14 Eroded Dune in the Wind Beach

Figure 2.15 Eroded Dune in The Strand

Figure 2.16 Armoured Slope along the Living Shoreline

## 2.2 Ice Cover at Burlington Beach

Given the depths in the western basin of Lake Ontario and the amount of heat stored in the water, the lake never freezes over completely. A more common phenomenon is shore-fast ice, which accumulates at the waters edge, as seen in Figure 2.17. These ridges of ice can grow in height and width, as winds and currents drive smaller amounts of lake ice against the shoreline. While not extensive in size, shore-fast ice can play an important role in protecting shorelines from winter storms and associated flood and erosion hazards.

**Figure 2.17 Shore-Fast Ice on February 28, 2019**

Figure 2.18 was taken from the same location eleven months later, on January 31, 2020. During the relatively mild winter of 2019/2020, there was no shore-fast ice at Burlington Beach. The beach and dune were fully exposed to coastal storms and erosive waves during winter storms.

**Figure 2.18 Ice-free Conditions on January 31, 2020**

# 3.0 CLIMATE CHANGE SCREENING ASSESSMENT

Section 3.0 of the report summarizes the screening level assessment of potential climate change impacts on the Master Plan for Burlington Beach.

## 3.1 Updated 100-year Lake Level at the Burlington Gauge

The historical time series water levels for the Burlington Gauge were obtained from Environment and Climate Change Canada, along with a synthetic dataset that accounts for Regulation Plan 2014. Our analysis also calculated an updated 100-year static lake level, the 100-year storm surge, and the combined probability of these two independent events.

Table 3.1 summarizes the values for the Burlington gauge from the historical 1989 (MNR) document on water levels. A 100-year static lake level of 75.54 m and a 100-year storm surge of 0.94 m were reported in MNR (1989), along with a combined 100-year lake level of 76.01 m.

**Table 3.1 Historical and Updated 100-year Flood Level in Burlington**

| Reference | 100-year Static Level, (m, IGLD'85) | 100-year Surge (m) | 100-year Combined Lake Level (m, IGLD'85) |
|---|---|---|---|
| MNF, 1989 | 75.54 | 0.94 | 76.01 |
| Update for this study | 75.84 | 0.68 | 76.15 |

When the analysis was updated for this study to account for the prolonged period of high lake levels in 2017 and 2019, the combined 100-year lake level increased to 76.15 m, or an increase of 0.14 m above the MNR (1989) level. The static lake level increased by 0.3 m to 75.84 m.

Interestingly, the 100-year surge level at the Burlington gauge decreased to 0.68 m (SJL, 2020). We believe the 100-year surge level of 0.94 reported by MNR (1989) is an error, since the largest surge on record at the Burlington gauge is 0.75 m and the second largest is 0.60 m. A surge event of 0.94 would be an extreme outlier and is not supported by this updated analysis of the historical data.

It is also important to note that the monthly mean Lake Ontario water level in 2019 reached 75.91 m, which exceeds the old estimate of the 100-year static lake level in MNR (1989) by 0.3 m. In addition, this level represents a return period of greater than 100-years.

From May to July 2019, the maximum storm surge event recorded at the Burlington Gauge was 0.11 m, indicating the region was not impacted by any significant storms. If a storm surge with a return period of 25-years occurred (0.26 m) and had impacted the Burlington Beach in June 2019, the resultant water level (76.17 m) would have exceeded the old published MNR (1989) 100-year water level by 0.16 m and the updated 100-year combined lake level by 0.02 m.

## 3.2 Research on Future Lake Levels and Storm Surge

As part of the International Joint Commissions (IJC) review of Lake Superior water level regulation, research was completed on the potential impacts of climate change on future lake levels in the Great Lakes Basin (IUGLS, 2012). A key finding of this research was the potential for higher highs and lower lows. In other words, lake levels will become more extreme in the future.

This research is currently being updated by Environment and Climate Change Canada (ECCC, Open File 2020) for an assessment of coastal wetland vulnerability to climate change and adaptation capacity in the Great Lakes. At this time, the draft internal results continue to suggest higher highs will be possible in the future due to climate change. This second study re-enforces the importance of considering future lake level extremes due to climate change when managing the coastal zone of the Great Lakes, not simply relying on historical extremes to establish the 100-year combined flood level.

The Stream 1 report by RWDI (2020) investigated the potential impact of climate change on severe storms that generate large surge events in Burlington. Based on the analysis of synoptic weather patterns from five global climate models for Representative Concentration Pathway (RCP8.5) and the late century period (2071-2100), no statistically significant changes in storm frequency or magnitude were identified. A second analysis evaluated future changes or gradients in sea level pressure across the Great Lakes, which is a key driver for large coastal storms, which move from areas of high to low pressure. Again, the analysis found no statistically significant trends that would suggest more storms will occur more frequently or be more severe in the future. Therefore, based on this research, the best available information at this time suggests historical storm surges will be representative of the frequency and magnitude of future storm surges due to influence of climate change.

Translating these findings to the Master Plan for Burlington Beach, the greatest risk to the stability of the beach and resilience to coastal storms will be higher lake levels. Therefore, it would be prudent to consider future lake level extremes higher than the 100-year combined lake level reported in Table 3.1 when designing and implementing the Master Plan.

## 3.3 Warming Trends and Future Ice Cover

The projected winter warming in Canada for RCP2.6 and RCP8.5 future emission scenarios were recently summarized by Bush and Lemmen (2019). Refer to information for 2031-2050 and 2081-2100 in Figure 3.1. Significant winter warming is projected, especially for RCP8.5. By late century, winter temperatures for this scenario are projected to be 5 to 7 degrees Celsius warmer in Southern Ontario.

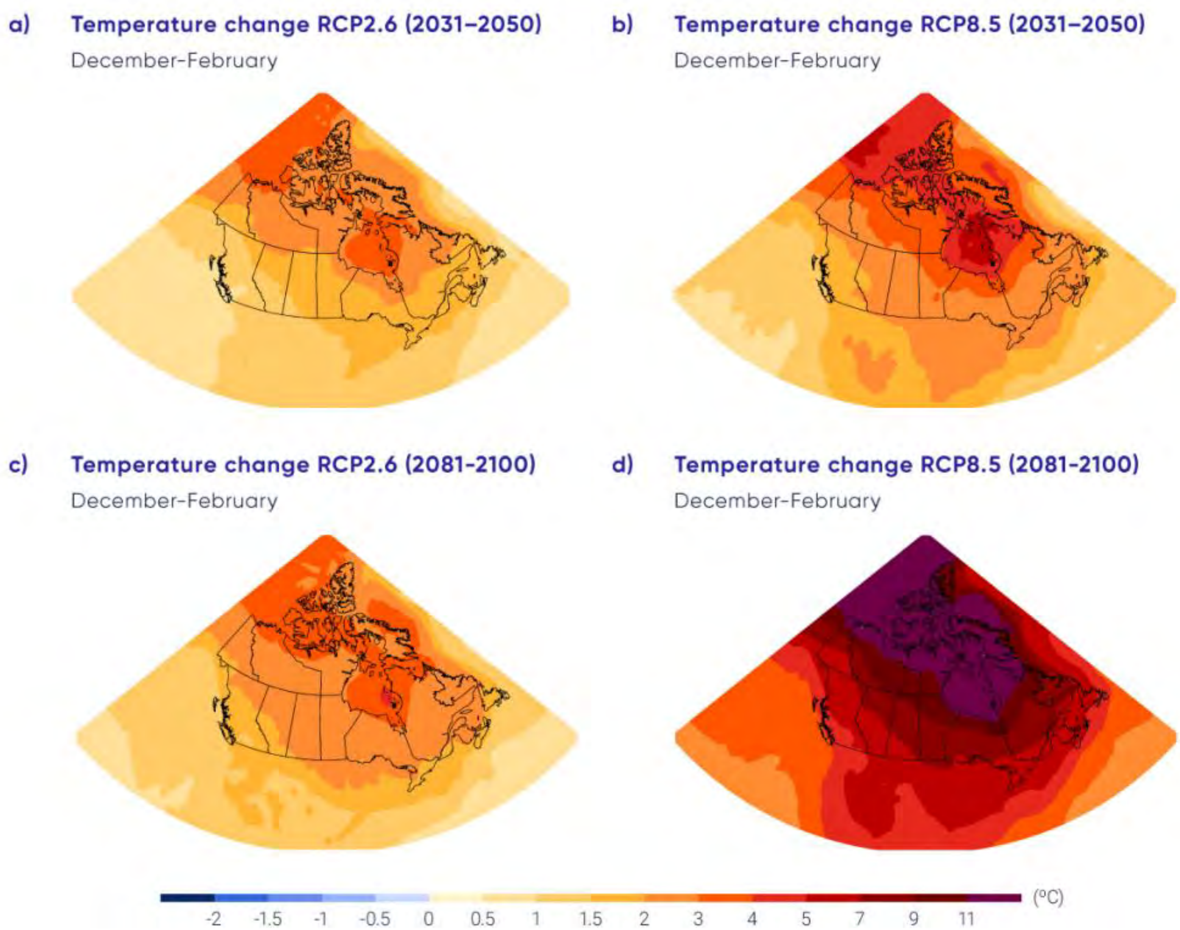


**Figure 3.1 Winter Warming for Mid- and Late-Century (from Bush and Lemmen, 2019)**

Ice cover in the Great Lakes has been decreasing since 1973 (Wang et al., 2012) with similar trends documented across the northern hemisphere (Sharma et al., 2019). The projected winter warming will continue to increase land and lake temperatures, resulting in further reductions in ice cover in the future. Figure 3.2 provides a conceptual diagram of these potential changes with extensive ice cover in the eastern basin (left-hand panel), coverage limited to the Kingston Basin in the middle panel, and no ice coverage in the open lake for the winter image in the right-hand panel. As the winter temperatures continue to warm in Southern Ontario, the duration of ice coverage and shore-fast ice will continue to decrease and could approach zero by late century (e.g., 2080).

Based on future land and lake temperatures extracted from the Weather Research and Forecasting (WRF) model for a late century RCP8.5 scenario, RWDI (2020) reached similar conclusions. Lake Erie and Ontario could be ice-free in the future. This observation was recently validated by an ongoing ECCC study for the Great Lakes (ECCC, Internal File 2020).


**Figure 3.2 Schematic Diagram of Reduced Lake Ontario Ice Coverage**

In the January 31, 2005 MODIS satellite image of the western end of Lake Ontario (Figure 3.3), ice coverage is present along the Niagara and Hamilton shoreline and the majority of Hamilton Harbour is ice covered. If the projected warning continues, the occurrence of large ice sheets and the shore-fast ice noted in Section 2.2 of this report will become less frequent.

**Figure 3.3 January 31, 2005 MODIS Satellite Image of Lake Ontario**

## 3.4 Future Storms and Wave Exposure

As discussed above, the research by RWDI (2020) in Stream 1 used multiple lines of evidence to evaluate potential changes in the frequency or magnitude of future storms. The data on future storms from the Global Climate Models and evaluation of future pressure gradients across the

Great Lakes Region concluded there was no statistically significant evidence to suggest storms will become more frequent or extreme.

The numerical modelling completed by Baird (2019) utilized historical wind fields to simulate nearshore wave heights for the top 15 storm events impacting the western end of Lake Ontario from 2000 to 2013. The peak wave height is summarized in Figure 3.4 (blue bars). The storms were re-simulated for the late-century RCP8.5 emission scenario using gridded wind fields from the Weather Research and Forecasting (WRF) model (Baird, 2019). The peak wave height for these storm simulations were also plotted on Figure 3.4 (grey bars). For Storms 1, 3, 5, 8, 11, and 15, the simulated wave heights were larger for the historical storm. For Storms 9, 12, and 13, wave heights were slightly larger for the storm simulated with the late-century winds.

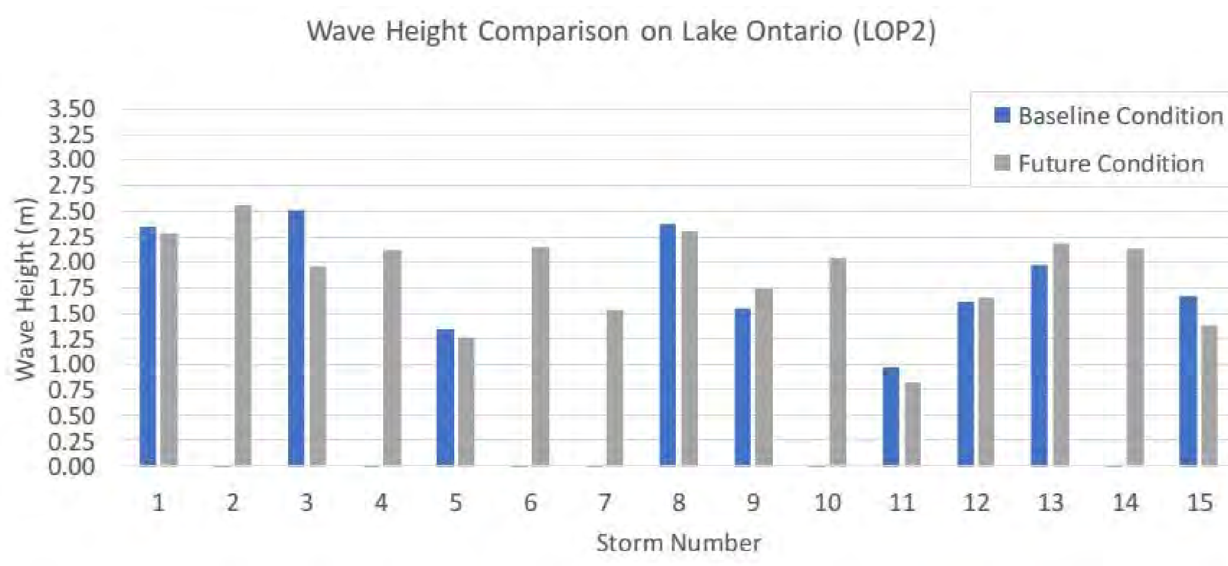


**Figure 3.4 Peak Wave Height for the Top 15 Storms at the Western End of Lake Ontario from 2000 to 2013 with Historical and Climate Change Winds**

Perhaps the most interesting and relevant findings pertain to Storms 2, 4, 6, 7, 10 and 14. Historically, these were non-storms for the shoreline of Burlington Beach due to the presence of ice cover or shore-fast ice along the shoreline. In other words, the ice buffered or protected the beach, dunes and park infrastructure from storm damage. However, for the late century simulation for RCP8.5, the model was run with the assumption of zero ice cover.

These results highlight the significant benefits of the protective ice cover for Burlington Beach and the changing risk profile that warming in Southern Ontario will bring to the site as ice becomes less frequent in the future.

# 4.0 IMPLICATIONS FOR THE MASTER PLAN

The results from this screening level assessment on potential future climate change impacts for the implementation of the Burlington Beach Master Plan are summarized below.

## 4.1 Future Storm Extremes and Coastal Hazards

The key findings on the exposure of Burlington Beach to coastal storms and the associated flooding and erosion hazards based on the Stream 1 findings and other relevant research include:

- Lake levels are projected to be more extreme across the lakes in the future due to climate change (higher net basin supplies to the watershed with more rainfall and snow). Even though Lake Ontario levels are moderated by the operation of the Moses Saunders Power Dam, 2017 and 2019 have shown the lake is not immune to high lake level events. The Master Plan must focus on restoring the beach and dune ecosystem to increase resilience to events such as the prolonged high water conditions in 2017 and 2019, and ideally even higher conditions in the future.

- The occurrence and spatial extent of ice cover will continue to decline in the future and may reach zero by late century for the RCP8.5 scenario.

- Consequently, Burlington Beach will be exposed to more erosion and flooding events in the future.

## 4.2 Master Plan Implementation

The Burlington Beach Master Plan includes significant infrastructure upgrades and many new amenities for park users to enjoy the Lake Ontario shoreline and interior parklands. Based on the results of this screening level assessment of the Master Plan components, the following recommendations are provided for consideration while implementing the project:

- Infrastructure elements located on the beach below the 100-year flood level, such as the gas fire circle in The Strand, should be relocated further inland away from coastal hazards.

- A significant and bold investment is needed to restore the beach and dune ecosystem to increase resilience to future high lake level events and protect the interior infrastructure from flood damages. Also, the restored dune will increase the resilience of the site to future high-water periods, by buffering the park from erosion and providing a reservoir of sand to maintain the beach.

- Controlled access points are required from the interior parklands, over the restored dune, and onto the sand beach. All remaining uncontrolled access points must be eliminated with future landscape plans to ensure the dune restoration is successful.

- Regular monitoring will be required to document the beach and dune restoration, including physical changes in the environment and the restoration of the plant communities. These data and results will allow the park owners to make science-based management decisions and deal with the uncertainty of climate change in the future.

- An adaptive management approach should be adopted for future beach and dune management and monitoring, building on successful approaches and learning from mistakes. Future maintenance of the coastal dune ecosystem must become part of the regular ongoing site maintenance to increase resilience to future storms and high lake level events. Following high-water periods, it may be necessary to re-nourish the beach with external sources of sand.

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