Erosion and Dynamic Beach Hazard Mapping: Supplement to the Essex Region Coastal Flood Hazard Mapping Report

Prepared for:

County of Essex and Essex Region Conservation Authority

June 13, 2024

Prepared by:

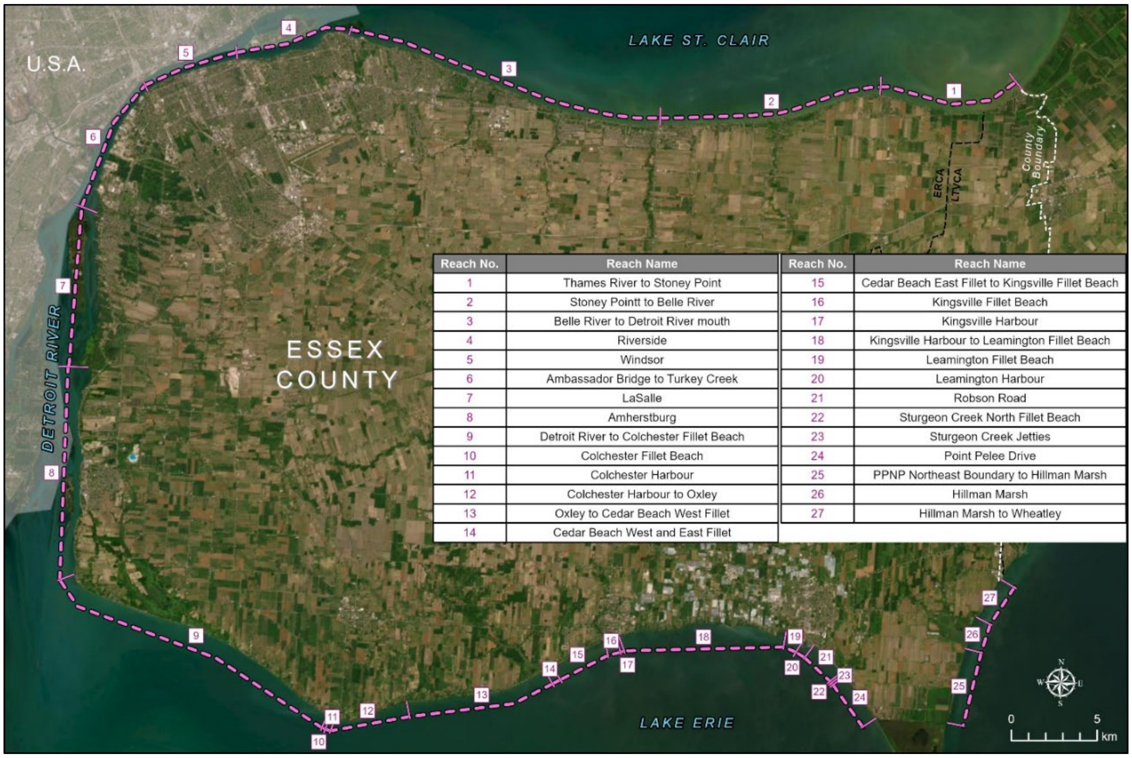
Zuzek inc.
ONE WORLD

In association with:

SJL ENGINEERING

DHI

Map of shoreline reaches for the hazard mapping



Reach No.	Reach Name	Reach No.	Reach Name
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12	Colchester Harbour to Oxley	26	Hillman Marsh
13	Oxley to Cedar Beach West Fillet	27	Hillman Marsh to Wheatley
14	Cedar Beach West and East Fillet		

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Disclaimer:

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1.0 INTRODUCTION

In partnership with the Essex Region Conservation Authority, the County of Essex received funding from the Flood Hazard Identification and Mapping Program (FHIMP), which is part of a national flooding program from Natural Resources Canada (NRCan) and administered in Ontario by the Ministry of Natural Resources and Forestry. Under that program a flooding hazard mapping study was completed, and a report was produced titled 'Essex Region Coastal Flood Hazard Mapping', authored by Zuzek Inc., SJL Engineering, and DHI (Zuzek Inc., 2024a). This supplementary report discusses additional technical studies funded by the County of Essex, the City of Windsor, and the Essex Region Conservation Authority to map the *erosion hazard* and d*ynamic beach hazard*.

1.1 Study Area

The study area shoreline extends from the mouth of the Thames River in the southeast corner of Lake St. Clair, includes the entire Canadian Detroit River shore, and the Lake Erie shoreline in the western basin and the east side of the Pelee Peninsula to Wheatley. Refer to Figure 1.1.

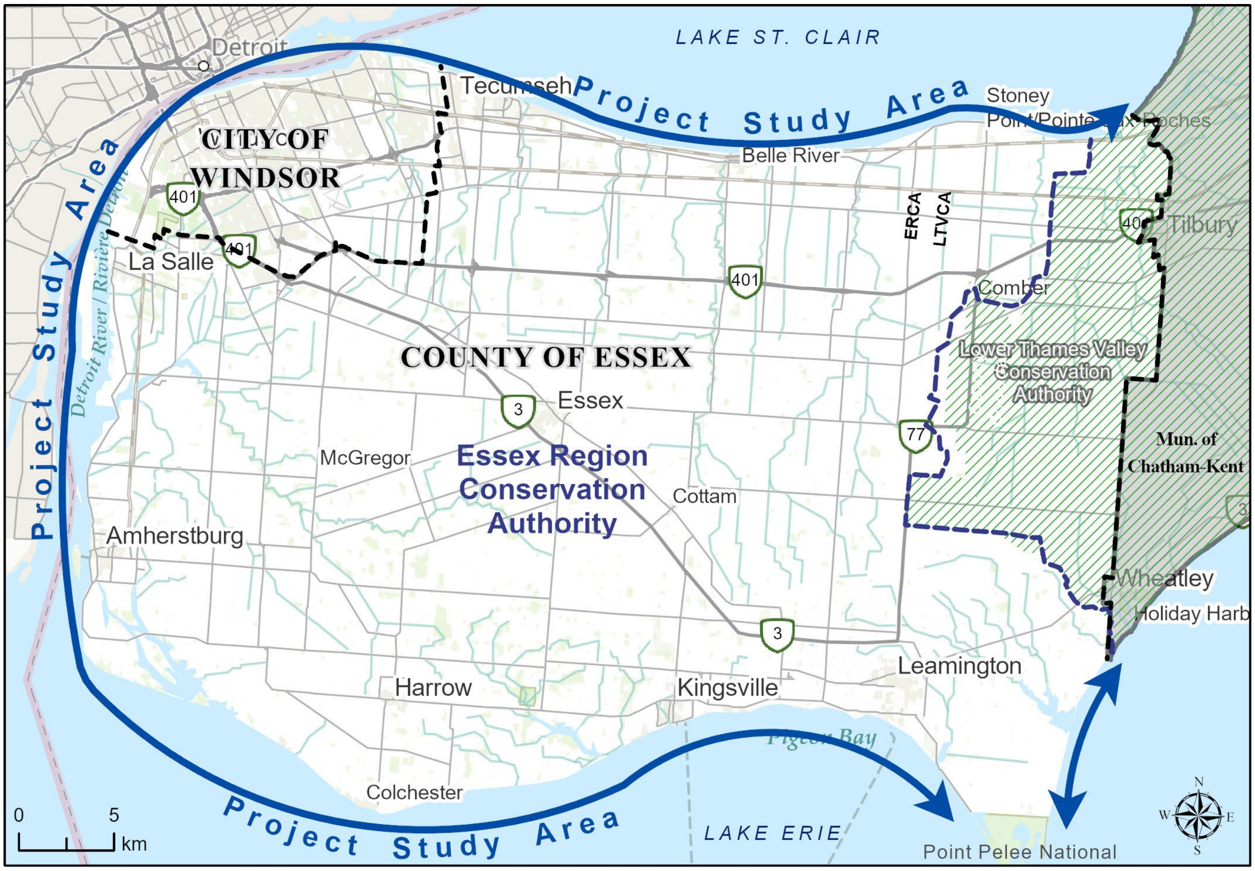


Figure 1.1 Study area

While the City of Windsor is a separate municipal jurisdiction than the County of Essex, they contributed to the study and the hazard mapping was extended to their jurisdiction.

The majority of the study shoreline falls within the jurisdiction of the Essex Region Conservation Authority (ERCA), with the exception of the northeast corner at the mouth of the Thames, where the Lower Thames River Conservation Authority (LTVCA) regulates shoreline development. The jurisdiction of the LTVCA is hatched in Figure 1.1.

1.2 Scope of Supplementary Report

This supplementary report documents the following:

- Historical shoreline change assessment and projections for the future that consider the impacts of a changing climate.

- An inventory of major coastal structures.

- Mapping of the *erosion hazard* and *dynamic beach hazard* for historical conditions and climate change.

2.0 Technical Analysis

The additional technical analysis completed to update the *erosion hazard* and *dynamic beach hazard* maps included a shoreline change analysis and structure inventory.

2.1 Shoreline Change Assessment

The shoreline change assessment, including recent orthophotographs, historical imagery, bluff recession rates, and trends for beach shorelines is summarized.

2.1.1 Recent Orthophotographs

ERCA provided 2022 orthophoto coverage of the entire Essex County coastline, which excludes the City of Windsor. This coverage represents nearly 1,000 digital orthophoto files at a resolution of 10 cm. Using GIS, the files were seamlessly mosaiced together and resampled to a resolution of 20 cm to reduce overall file size, improve re-drawing speed, and improve usability.

For the City of Windsor shoreline, a 2021 orthophoto web image service was used to fill the gap in the 2022 coverage. The 2021 imagery was exported as a series of tiles along the City of Windsor shoreline. Both the 2021 and 2022 imagery datasets are shown in Figure 2.1

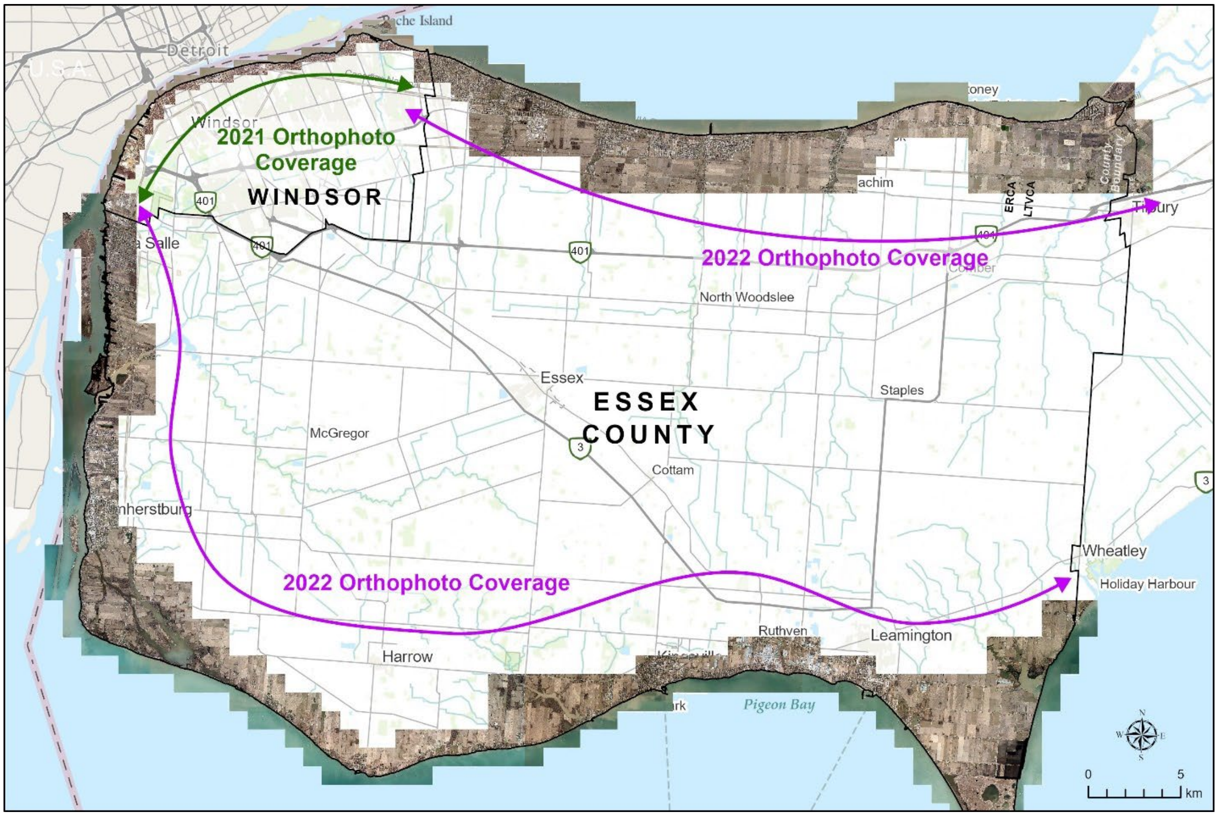


Figure 2.1 Recent orthophoto coverage

2.1.2 Historical Air photos

ERCA provided a series of 1975 digital air photos and one 1967 image for the shoreline change analysis. The scale of the 1975 air photos was 1:5,000 while the scale of the 1967 image was not known. These photos were scanned at a resolution of 600dpi. To compliment these images, a set of 1947 digital scanned air photos was obtained from the National Archives in Ottawa at a scale of 1:15,000. The coverage for all three images was based on selected areas of interest where the shoreline was presently ‘unprotected’ and a historical comparison was possible. The photo coverage is illustrated in Figure 2.2 along with the registered air photos from 1947, 1967, and 1975. Each area of interest is labeled with a colour-coded shape corresponding to beaches, harbours, or eroding banks in Figure 2.2.

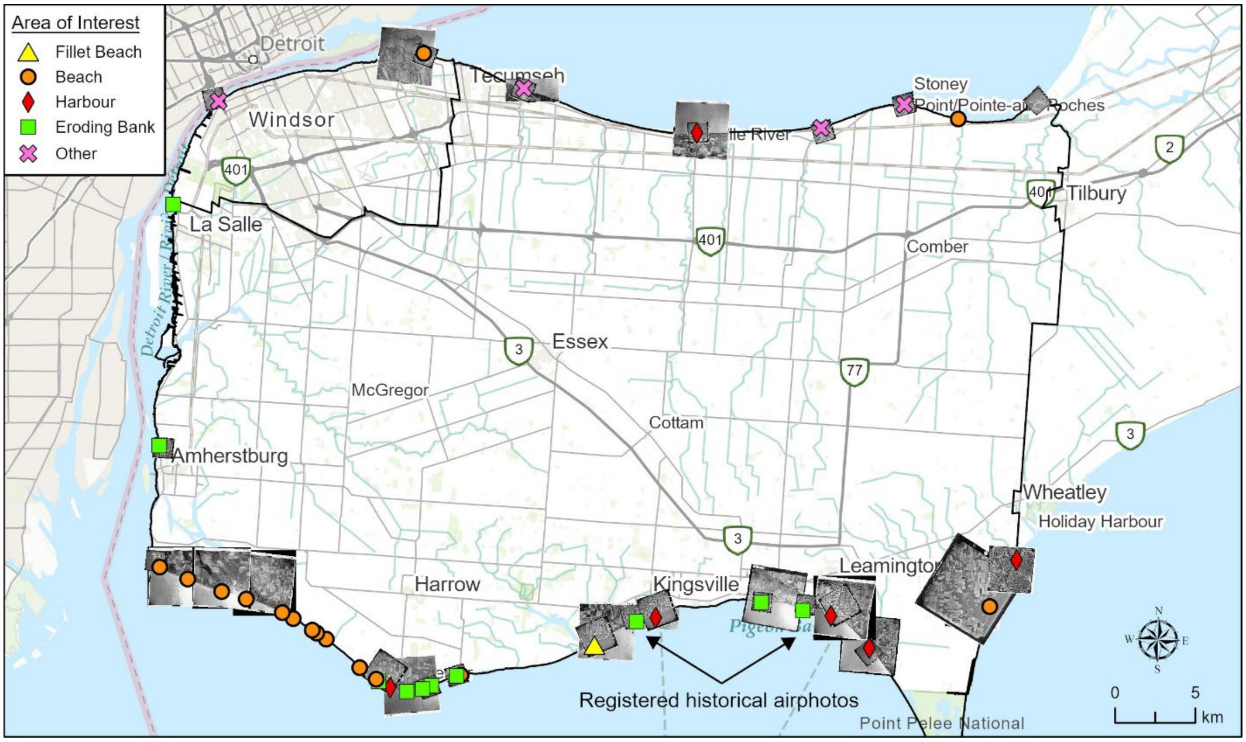


Figure 2.2 Registered historical air photo coverage

The 1947, 1967, and 1975 air photos were geo-referenced with ArcGIS software primarily using 2022 orthophotographs as the base imagery. Provincial orthophoto collections from 2006, 2010, and 2015 were also consulted in some cases. Root Mean Square (RMS) errors were used to quantify a maximum potential horizontal positional error in the geo-referenced photos, which is reported during the geo-referencing process with GIS software. The maximum RMS errors for the historic air photos are listed in Table 2.1. It is important to note that technical studies (Crowell et al, 1991) have shown the actual horizontal error in geo-referenced aerial images and maps is generally much lower than the RMS error (in other words, RMS error is a conservative estimate).

Table 2.1 RMS error for geo-referenced aerial photo datasets

Year	Max. RMS	Avg. RMS	No. Photos
1947	1.72	0.85	13
1967	0.32	0.32	1
1975	1.14	0.62	20

To assess the influence of the potential RMS error, the horizontal error is divided by the temporal period of the shoreline change analysis. For example, the 1.72 m RMS error for the 1947 photo series translates to a potential annualized error of 0.02 m/yr (1.72 / 75 years) when comparing shoreline positions to the 2022 orthophotograph. Provided the rate of change measured from 1947 to 2022 is greater than 0.02 m/yr, there is confidence in the rate. If the RMS error for a specific period, once annualized to a rate of change, was greater than the actual erosion measurement between the photos (e.g., 1947 to 2022), the photograph was not used in the shoreline change analysis.

An example of a historical aerial photo included in the registration process is presented in Figure 2.3. The yellow arrows point to the ground control used, which are the red X's. Ground control represents features that are visible in both the historic aerial and the base imagery. To minimize horizontal positional errors in geo-referenced imagery, ground control points were well distributed across the area of coverage, an appropriate transformation method was applied, and routine visual checks against base imagery were completed.

Georeferencing: A11161_002.tif

Transformation: 2nd Order Polynomial

Controls Points: 9 / 9

Total RMS Errors

Forward: 0.592663

Inverse: 0.001508

Forward-Inverse: 0.000652

Figure 2.3 Example of ground control selection during photo registration

2.1.3 Measured Bluff Recession Rates

Once the historical imagery was geo-referenced, visual checks were completed to identify locations of possible shoreline change when compared to the 2022 orthophotos. When a suitable area was found, a common reference feature such as a top of bluff line was digitized in both the historical photo and either the 2017 topographic LiDAR Digital Terrain Model (DTM) discussed in the main FHIMP report (Zuzek Inc., 2024a), or the 2021/2022 orthos. Using on-screen measuring tools, the change in horizontal position was assessed.

If a change in horizontal position was observed, detailed shoreline change measurements methods were applied. Using semi-automated tools in GIS, transects were drawn between the common reference features at a spacing of 10 m. The individual transect lengths in the population of transects were calculated, then divided by the number of years between historical and recent reference feature to obtain an annualized recession rate. For example, if the transect length between the 1947 photo and 2022 photo was 10 m, then the annualized transect recession rate is 0.13 m (10 / (2022-1947)).

The Average Annual Recession Rate (AARR) was then determined by calculating the average of the transects in the population. To account for the spatial variability of the transects (i.e., the variance), the standard deviation of the erosion transects in the population was also calculated. The long-term recession rate for an area was based on the sum of the AARR and one annualized standard deviation. This technical approach is consistent with the methodology first outlined in Zuzek et al. (2003) and recently integrated into the updated Great Lakes Technical Guide (Zuzek Inc., 2023). An example of erosion transects for a section of eroding bluff west of Oxley on Lake Erie is presented in Figure 2.4. Transects were generated for the temporal period 1947 to 2022. There are 23 transects that featured an AARR of 0.48 m/yr and an annualized standard deviation of 0.12 m/yr. Therefore, the long-term recession rate for mapping the *erosion hazard* at this reach was 0.60 m/yr.

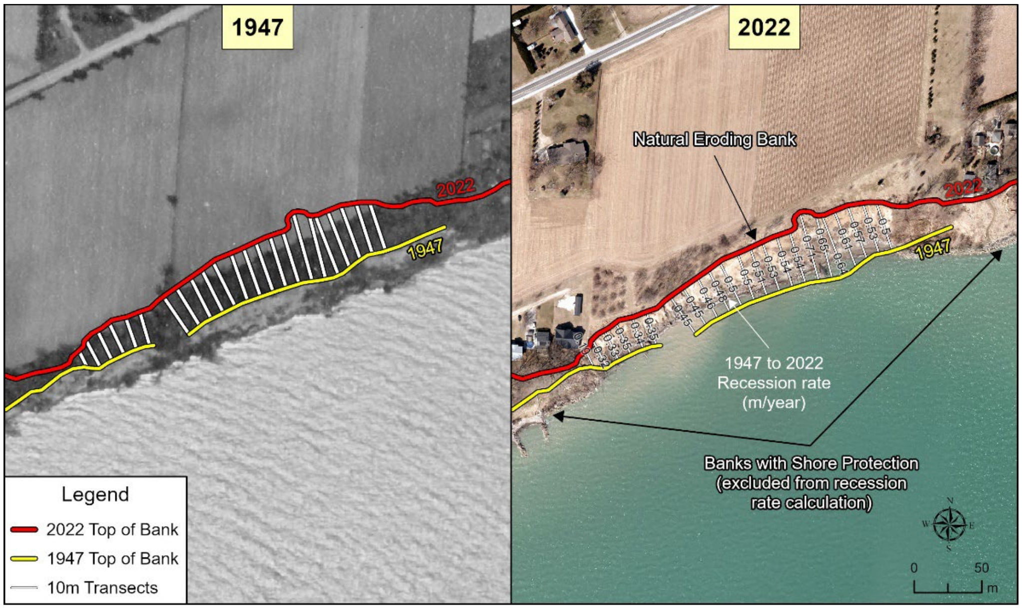
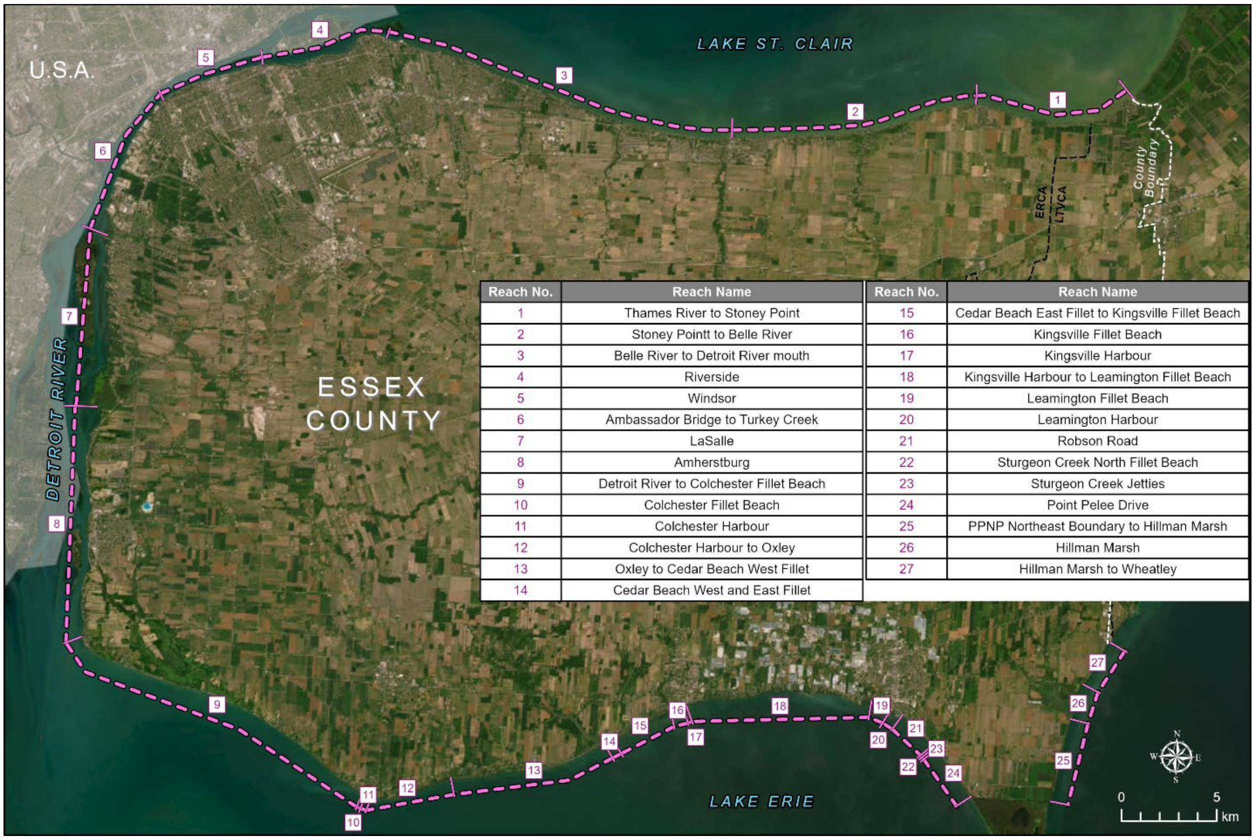


Figure 2.4 Top of bluff transects for the 1947-2022 temporal period at the Oxley site

The recession analysis is summarized by reach, which were defined as sections of shoreline with similar exposure to wave energy, shoreline and nearshore geology, shoreline morphology, physical processes such as erosion and deposition, development density, and sensitive ecological habitat. Refer to Section 3.4 of the main FHIMP report for additional details on defining the reach boundaries. For reference, the 27 hazard mapping reaches are presented in Figure 2.5.



Reach No.	Reach Name	Reach No.	Reach Name
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14	Cedar Beach West and East Fillet		

Figure 2.5 Hazard mapping reaches

The analysis described above generated historical recession rates for Reaches 9, 12, 15, and 18, as summarized in Table 2.2. The reach recession rate table has been supplemented with published data from several previous studies. For example, rates for Reaches 1 to 3 on Lake St. Clair were published in the 1976 Dillon report (Dillon, 1976). Today, the majority of the shoreline in Reaches 1 to 3 is armoured, making it impossible to establish updated long-term recession rates.

The degree of alterations and hardening along the Detroit River also make it impossible to calculate long-term recession rates based on today's shoreline. In such cases, knowledge of erosion forces, local geology, and expert judgement are needed to establish a reasonable long-term recession rate for the *erosion hazard* limit.

The Colchester to Southeast Shoal Littoral Cell Study (Baird, 2008) report contained recession rates for the western basin Reaches, including 12, 13, 15, 18, and 21. In the Colchester and Oxley area, a long-term rate of 0.52 m/yr was measured, which is similar to the analysis completed for this study. The Sustainable Management Strategy for Southeast Leamington –

Phase 2 report (Baird, 2007) contained recession rates for Reaches 25 to 27, which ranged from 0.18 to 1.28 m/yr. The recommended long-term recession rate in the study was 1.25 m/yr for the shoreline from Wheatley to PPNP. Additional sources of published historical recession rates are noted in Table 2.2 below.

Table 2.2 Summary of measured and historical recession rates

	Reach Number	Reach Name	Average Annual Recession Rates in m/yr (* standard deviation of transport population not included where available)										
			1947-2022	1975-2017	1975-2022	2017-2022	Dillion 1976	Baird 2007	Baird 2008	Twp of Malden SMP 1989	Kingsville SMP 1990	Windsor East SMP 1991	Twp of Mersea 1993
LAKE ST CLAIR REACHES	1	Thames River to Stoney Point	-	-	-	-	0.5	-	-	-	-	-	-
	2	Stoney Pointt to Belle River	-	-	-	-	0.4	-	-	-	-	-	-
	3	Belle River to Detroit River mouth	-	-	-	-	0.3	-	-	-	-	30 ft minimum	-
DETROIT RIVER REACHES	4	Riverside	-	-	-	-	-	-	-	-	-	30 ft minimum	-
	5	Windsor	-	-	-	-	-	-	-	-	-	-	-
	6	Ambassador Bridge to Turkey Creek	-	-	-	-	-	-	-	-	-	-	-
	7	LaSalle	-	-	-	-	-	-	-	-	-	-	-
	8	Amherstburg	-	-	-	-	-	-	-	-	-	-	-
LAKE ERIE REACHES	9	Detroit River to Colchester Fillet Beach	0.54 *	-	-	-	-	-	not evaluated	0.2	-	-	-
	10	Colchester Fillet Beach	-	-	-	-	-	-	-	-	-	-	-
	11	Colchester Harbour	-	-	-	-	-	-	-	-	-	-	-
	12	Colchester Harbour to Oxley	0.49 *	0.41 *	0.45 *	1.05 *	1.2 (4 ft/yr)	-	0.52	-	-	-	-
	13	Oxley to Cedar Beach West Fillet	-	-	-	-	~0.24 (0.8 ft/yr)	-	0.52 to 0.28	-	-	-	-
	14	Cedar Beach West and East Fillet	-	-	-	-	-	-	-	-	-	-	-
	15	Cedar Beach East Fillet to Kingsville Fillet Beach	0.06 *	0.09 *	0.09 *	0.32 *	~0.24 (0.8 ft/yr)	-	0.45	-	0.6	-	-
	16	Kingsville Fillet Beach	-	-	-	-	-	-	-	-	-	-	-
	17	Kingsville Harbour	-	-	-	-	-	-	-	-	-	-	-
	18	Kingsville Harbour to Leamington Fillet Beach	0.29 *	0.32 *	0.34 *	1.15 *	~0.54 (1.8 ft/yr)	-	0.28	-	-	-	-
	19	Leamington Fillet Beach	-	-	-	-	-	-	-	-	-	-	-
	20	Leamington Harbour	-	-	-	-	-	-	-	-	-	-	-
	21	Robson Road	-	-	-	-	-	-	0.11	-	-	-	-
	22	Sturgeon Creek North Fillet Beach	-	-	-	-	-	-	-	-	-	-	-
	23	Sturgeon Creek Jetties	-	-	-	-	-	-	-	-	-	-	-
	24	Point Pelee Drive	-	-	-	-	-	-	0.3 (accretion)	-	-	-	-
	25	PPNP Northeast Boundary to Hillman Marsh	-	-	-	-	-	0.18 - 0.49	-	-	-	-	0.6
	26	Hillman Marsh	-	-	-	-	-	0.26 to 1.28	-	-	-	-	-
	27	Hillman Marsh to Wheatley	-	-	-	-	-	1.25	-	-	-	-	-

2.1.4 Reach 9 Beach Changes

The waterline position from the 1947 to 2022 aerial images were compared in Reach 9 at Bar Point to Willow Beach Road, as seen in Figure 2.6. Near the northwest reach boundary at Bar Point, accretion was measured from 1947 to 2022. Further to the southeast at Willow Beach Road, the waterline eroded from 1947 to 2022.

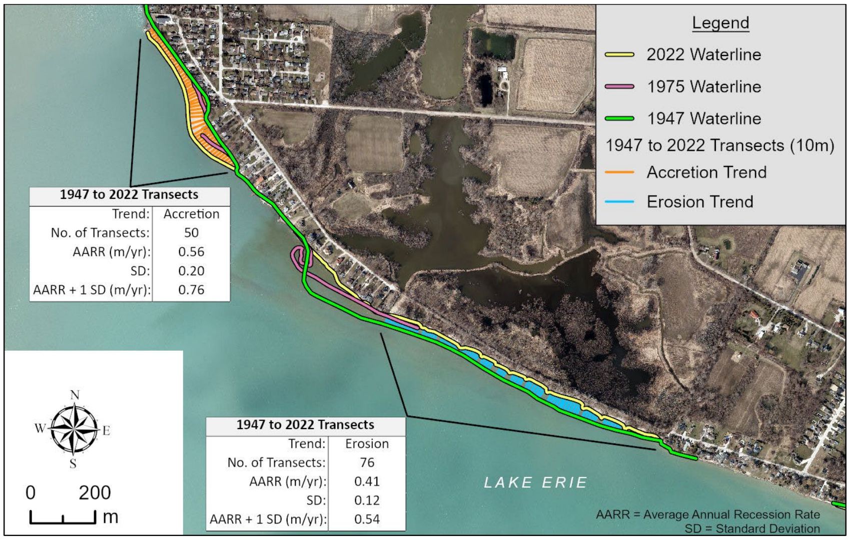


Figure 2.6 Bar Point to Willow Beach Road shoreline change from 1947 to 2022

Further east in Reach 9, similar contrasting trends were observed. At Lakewood Beach, the beach migrated lakeward from 1947 to 2022, with a long-term accretion rate of 0.87 m/yr. East of the outlet for the Big Creek embayment, the shoreline trend from 1947 to 2022 switched to recession, with a long-term rate of 0.43 m/yr.

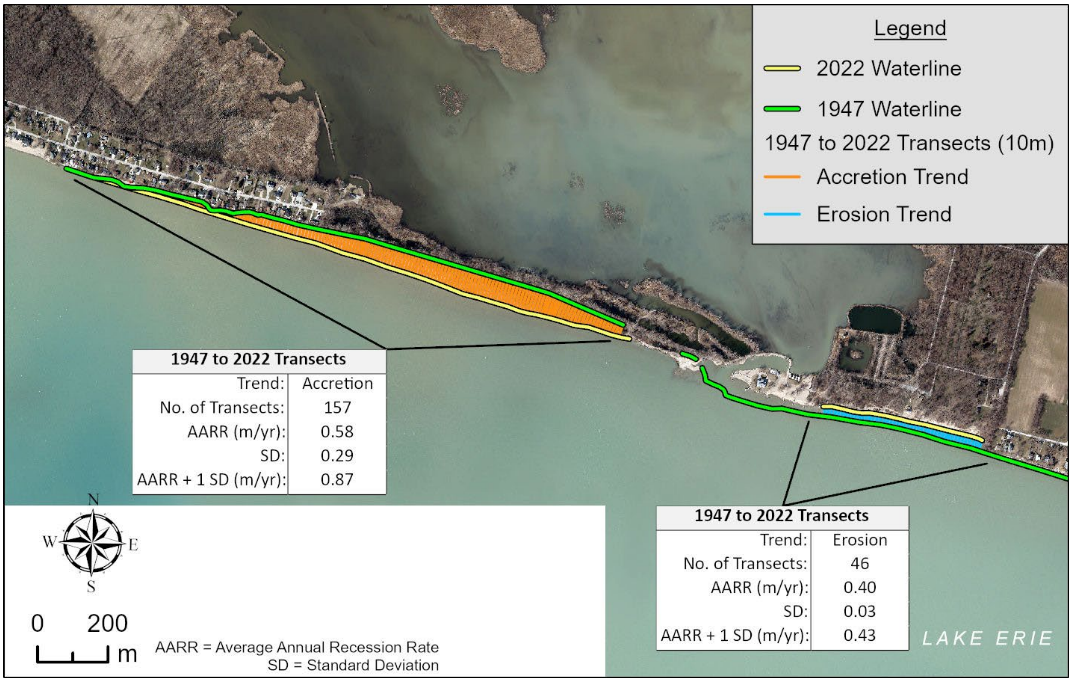


Figure 2.7 Barrier beach evolution from Lakewood Beach to Holiday Beach, 1947 to 2022

These results highlight the dynamic nature of sandy beaches, especially along highly modified and armoured shorelines. Accretion deposits, such as those noted in Figure 2.6 and Figure 2.7, can switch to stable or even eroding shorelines, especially during periods of high lake levels.

2.1.5 Shoreline Change at Fillet Beaches

The study area includes numerous jettied river mouths and harbours that provide many navigation benefits, including safe refuge during storms, berthing infrastructure for commercial activities, recreational boating marinas, and ferry services. This infrastructure has also altered the natural movement of sediment along the coast and in some cases trapped significant volumes of sand and pebbles. Refer to the growth of the fillet beaches at Belle River, Cedar Beach, Kingsville, and Leamington in Figure 2.8 to Figure 2.11.

Since these fillet beaches are all growing, it is not necessary to map an *erosion hazard*. Rather, they meet the length, width, depth and wave exposure requirements to be mapped as dynamic beaches as outlined in various technical references (CO & MNR, 2005; MNR, 2001a; MNR, 2001b). Refer to Section 3.2 for further details.

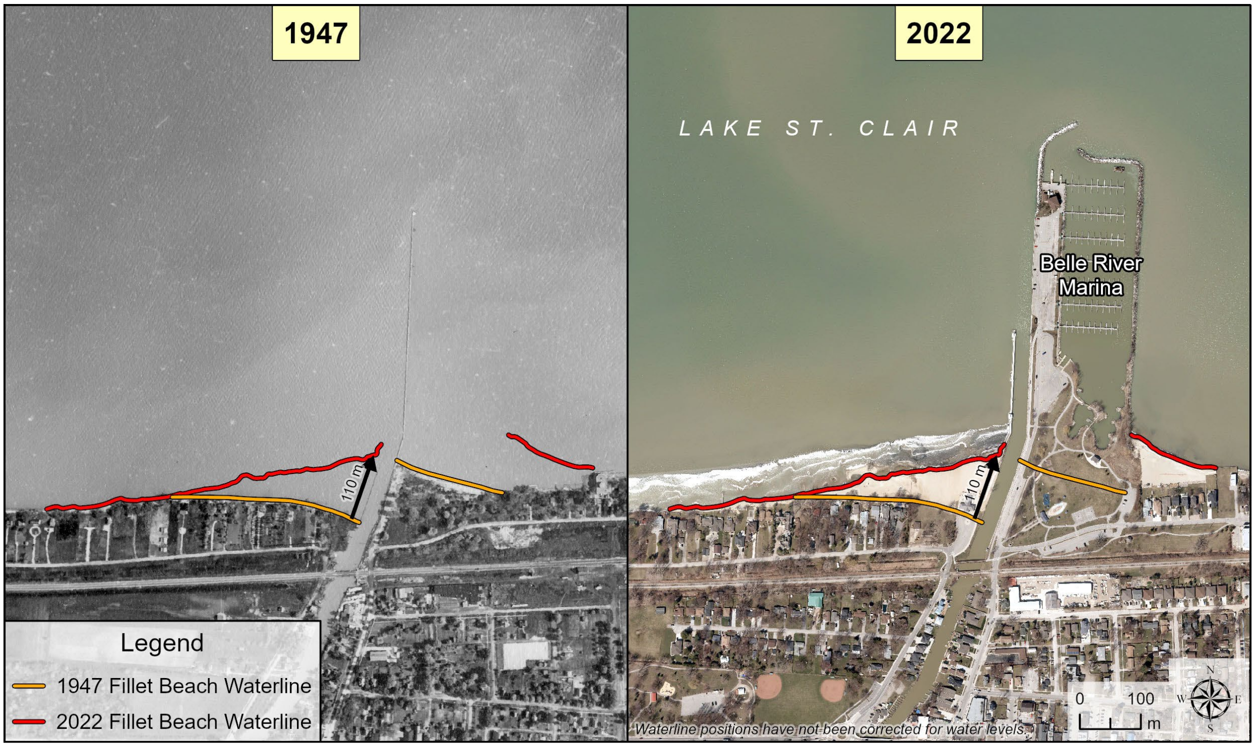


Figure 2.8 Belle River fillet beach growth from 1947 to 2022 (east and west side)

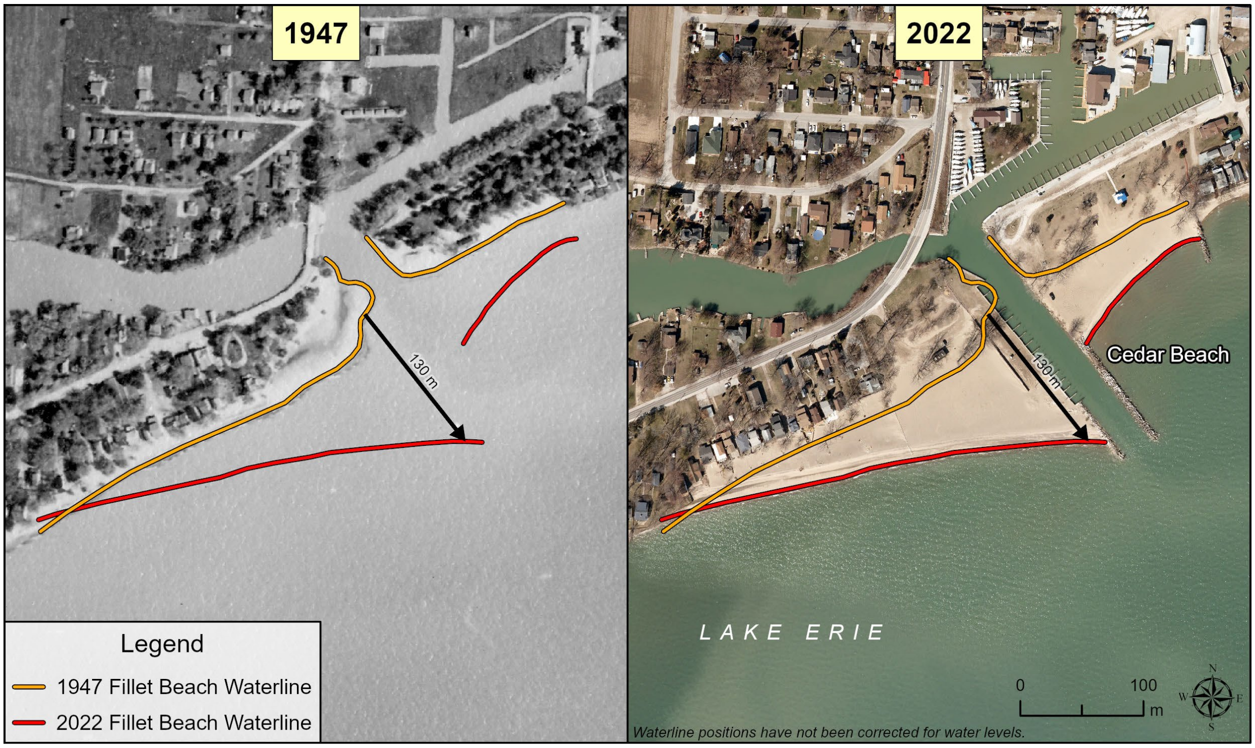


Figure 2.9 Formation and growth of the Cedar Beach fillet beaches since 1947

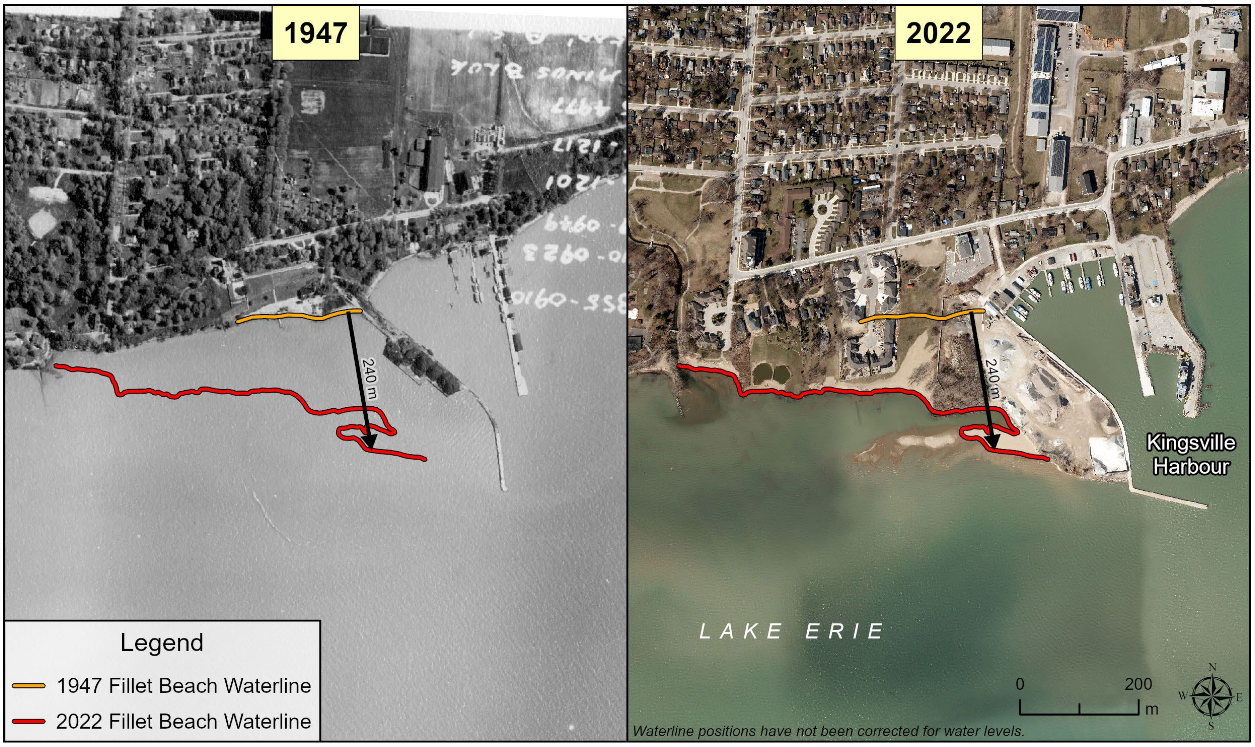


Figure 2.10 Accretion of the Kingsville fillet beach from 1947 to 2022 (240 m)

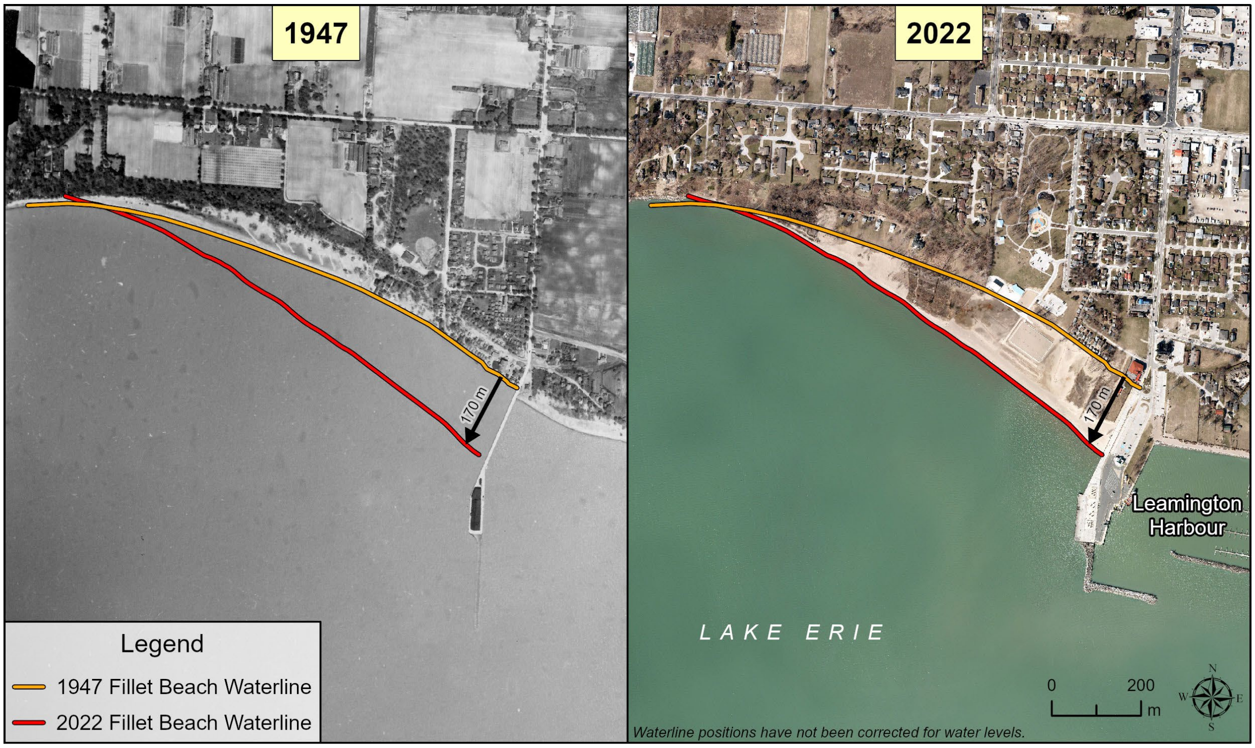


Figure 2.11 Formation and growth of Leamington fillet beach since 1947 (170 m)

2.1.6 Recommended Reach Recession Rates

The measured rates calculated for this study were compared to the historical recession rates derived from sources identified in the previous sections and those currently used by ERCA for regulating development on hazardous lands. In cases with multiple rates, a single recession rate was chosen in consultation with ERCA for each reach based on the quality and availability of the historical shoreline change data, recent trends, and expert judgement. Table 2.3 presents a summary of the recession rate selected for each reach, including the rationale for selecting the rate.

Table 2.3 Recommended recession rate by Reach

	Reach Number	Reach Name	Recommended Rate (m/yr)	Rationale
LAKE ST CLAIR REACHES	1	Thames River to Stoney Point	0.5	Dillion (1976) rates (nothing more recent)
	2	Stoney Pointt to Belle River	0.4	Dillion (1976) rates (nothing more recent)
	3	Belle River to Detroit River mouth	0.3	Dillion (1976) rates (nothing more recent)
DETROIT RIVER REACHES	4	Riverside	15m setback from top of shore protection (or top of bank if unprotected)	Existing rate/setback used by ERCA
	5	Windsor		
	6	Ambassador Bridge to Turkey Creek		
	7	LaSalle		
	8	Amherstburg		
LAKE ERIE REACHES	9	Detroit River to Colchester Fillet Beach	0.54	AARR + 1 SD from 1947 to 2022 (this study)
	10	Colchester Fillet Beach	stable	Depositional environment, not erodging
	11	Colchester Harbour	stable	Shore protection infrastructure, not eroding
	12	Colchester Harbour to Oxley	0.60	AARR + 1 SD from 1947 to 2022 (this study)
	13	Oxley to Cedar Beach West Fillet	0.24	Dillion (1976) rates (nothing more recent)
	14	Cedar Beach West and East Fillet	stable	Depositional environment, not erodging
	15	Cedar Beach East Fillet to Kingsville Fillet Beach	0.24	Dillion (1976) rates (other measurements only for small areas and not representative)
	16	Kingsville Fillet Beach	stable	Depositional environment, not erodging
	17	Kingsville Harbour	stable	Shore protection infrastructure, not eroding
	18	Kingsville Harbour to Leamington Fillet Beach	0.42	AARR + 1 SD from 1947 to 2022 (this study)
	19	Leamington Fillet Beach	stable	Depositional environment, not erodging
	20	Leamington Harbour	stable	Shore protection infrastructure, not eroding
	21	Robson Road	0.60	Dillion (1976), assumed 1931 to 1969, 25m = 0.66 m/yr
	22	Sturgeon Creek North Fillet Beach	stable	Depositional environment, not erodging
	23	Sturgeon Creek Jetties	stable	Shore protection infrastructure, not eroding
	24	Point Pelee Drive	0.60	Dillion (1976), assumed 1931 to 1969, 25m = 0.66 m/yr
	25	PPNP Northeast Boundary to Hillman Marsh	1.25	Existing rate used by ERCA (from Baird, 2007)
	26	Hillman Marsh	1.25	Existing rate used by ERCA (from Baird, 2007)
	27	Hillman Marsh to Wheatley	1.25	Existing rate used by ERCA (from Baird, 2007)

2.2 Climate Change Recession Rates

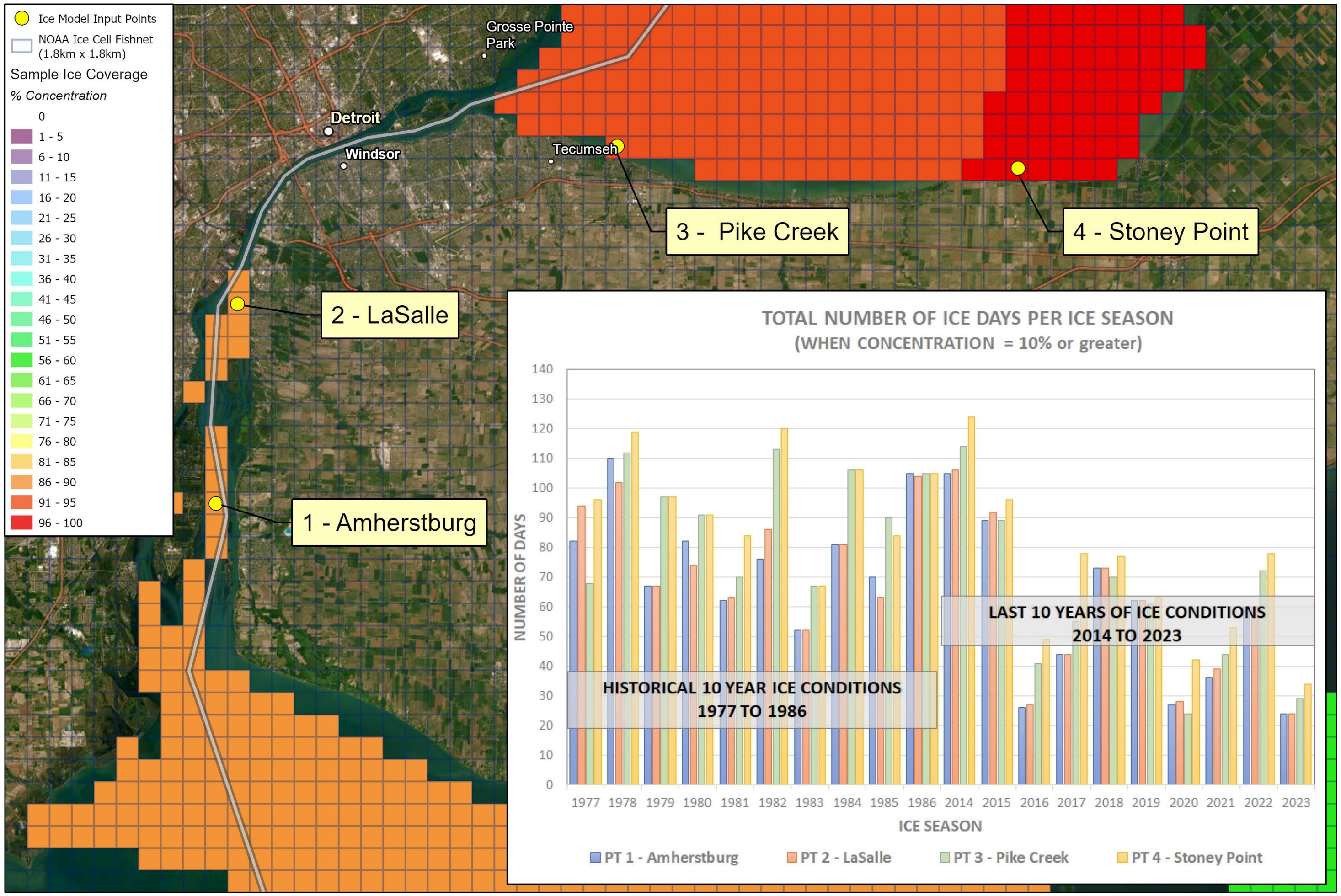
The PPS (2020) states planning authorities shall prepare for the impacts of a changing climate that may increase the risk associated with natural hazards. A technical approach to establish future recession rates based on historical trends and projected future climate change impacts was recently developed for a hazard mapping investigation on Lake Huron (Zuzek Inc., 2024b) and documented in the updated version of the Great Lakes – St. Lawrence River Technical Guide (Zuzek Inc., 2023) which is still under review. Two principal components of the recommended methodology include analyzing historical changes in nearshore ice cover and projected future conditions for nearshore wave energy. The results for the study area are described below.

2.2.1 Changes in Historical Nearshore Ice Conditions

Historical ice-cover charts for the Great Lakes are provided in a gridded format by NOAA and were analyzed to assess changes in nearshore ice cover from 1977 to 2023. The results for the historical period of 1977 to 1986 and the last ten years from 2014 to 2023 at Amherstburg, LaSalle, Pike Creek, and Stoney Point are plotted in Figure 2.12. Stony Point generally featured more ice than the two river locations but year to year trends were similar. For the historical period of 1977 to 1986, ice cover generally ranged from 70 to 110 days. By comparison, for the most recent 10-year period, nearshore ice cover at the four locations ranged from 25 to 70 days if the two polar vortex winters of 2014 and 2015 were excluded. From 2016 to 2023 there is less ice cover than the historical period of 1977 to 1986.

The same analysis was completed at four locations on the east side of the Pelee Peninsula, from the Hillman Marsh to Wheatley Provincial Park. Refer to Figure 2.13. Generally, there was less ice in the exposed and deeper portions of Lake Erie versus shallow Lake St. Clair and the sheltered Detroit River for the historical period (1977 to 1986) and the last ten years (2014 to 2023). However, the trends were the same. There has been a substantial reduction in the amount of nearshore ice cover on the east side of the Pelee Peninsula due to the documented winter warming in the last 45 years.

By late century, surface air temperatures are projected to rise anywhere from 2 to 5 degrees Celsius for global emissions scenarios RCP2.6 to RCP8.5 (Bush and Lemmen, 2019; Xue et al, 2022). These warmer air temperatures will translate to warmer lake surface temperatures in the winter (Dehghan, 2019; and Xue et al, 2022). On Lake Erie, the projected air and lake surface water warming by late century could lead to ice-free winters.



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Historical Ice Season Comparison from 1977-86 and 2014-2023

Essex County

Great Lakes Environmental Research Laboratory. (2020). Daily Great Lakes Ice Concentration, 1973 Onward, Version 1 [Data Set]. Boulder, Colorado USA. National Snow and Ice Data Center. https://doi.org/10.7265/krkb-f591. Date Accessed 05-16-2024.

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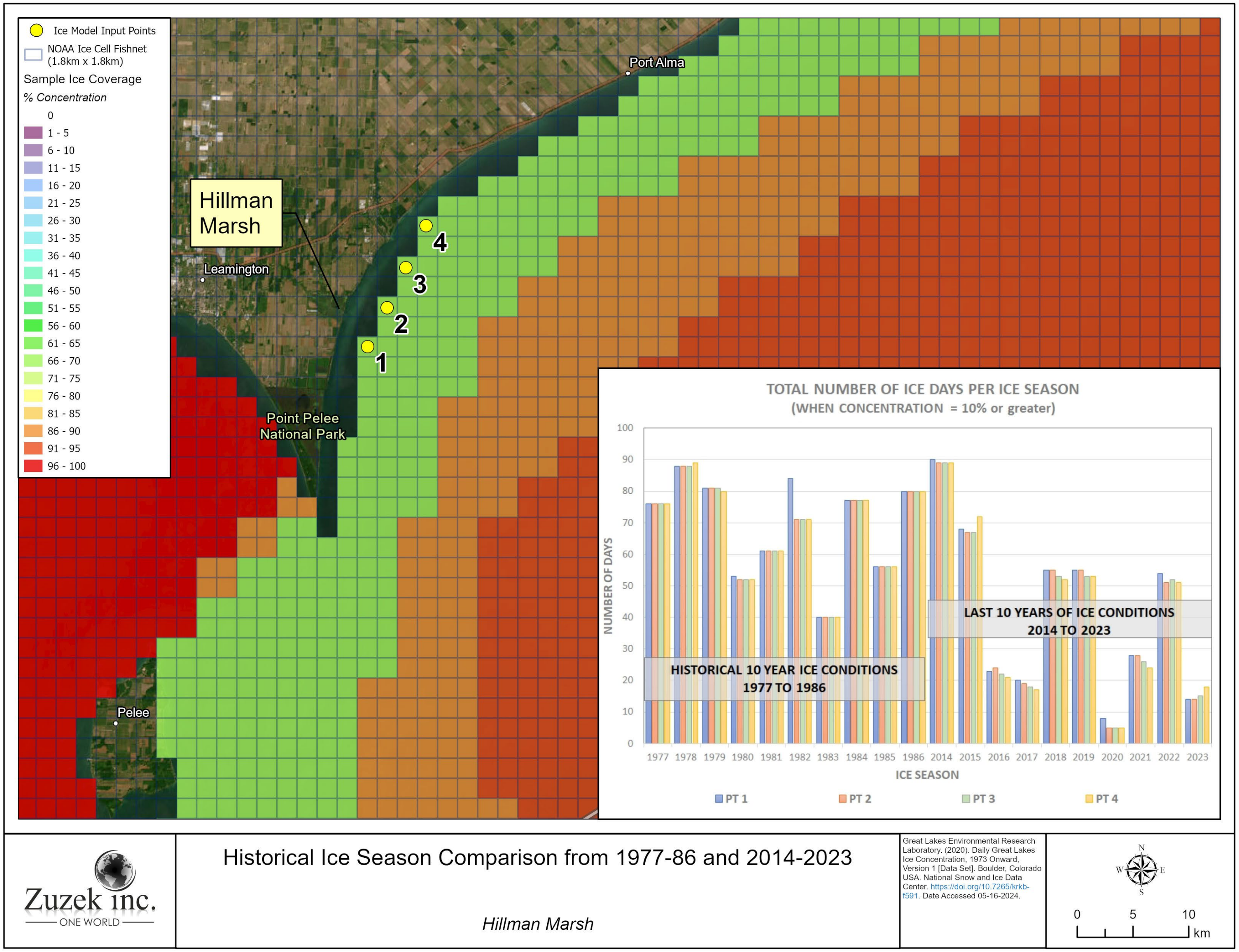
Figure 2.12 NOAA historical ice cover dataset (grid) and change analysis for Lake St. Clair and the Detroit River



Historical Ice Season Comparison from 1977-86 and 2014-2023

Hillman Marsh

Great Lakes Environmental Research Laboratory. (2020). Daily Great Lakes Ice Concentration, 1973 Onward, Version 1 [Data Set]. Boulder, Colorado USA. National Snow and Ice Data Center. https://doi.org/10.7265/krkb-f591. Date Accessed 05-16-2024.

Figure 2.13 NOAA historical ice cover dataset (grid) and change analysis for the east shore of the Pelee Peninsula

2.2.2 Lake Erie Wave Energy Analysis

To assess the impacts of both projected air and lake surface water warming on future wave generation and propagation, historical and future climate conditions were modelled using the National Center for Atmospheric Research (NCAR) Weather and Research Forecasting (WRF) model (RWDI, 2020). The WRF model was used to simulate two temporal periods. First the historical period from 2000 to 2013, followed by a late-century simulation assuming conditions for the RCP8.5 global emission scenario (Rasmussen and Liu, 2017). For both periods, an hourly-wind wave hindcast was completed using spatially varying winds across Lake Erie.

The projected increase in annual wave energy on Lake Erie for late century versus the base period is summarized in Figure 2.14. The increase for the north shore of Lake Erie ranges from 15% for the sheltered areas north of Long Point to 40% in the western basin. When only the winter season was considered, the increase in winter-specific wave energy is more dramatic for a future without ice cover, as highlighted in Figure 2.15.

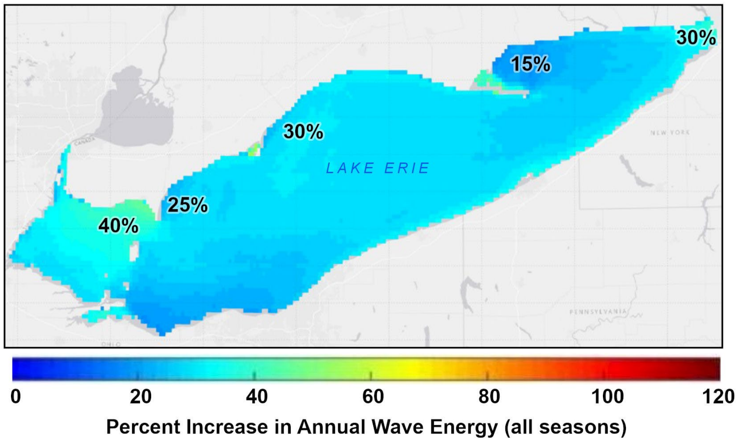


Figure 2.14 Projected increase in Lake Erie wave energy (all seasons) for RCP8.5 late-century emission scenario wind fields and zero ice assumption

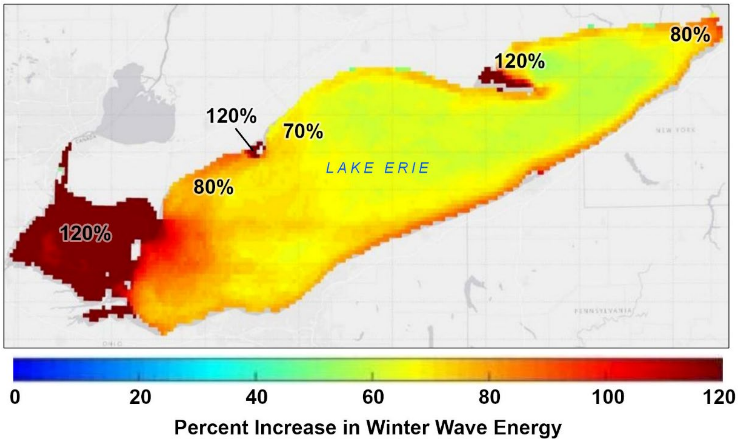


Figure 2.15 Projected increase in Lake Erie winter wave energy for RCP8.5 late-century emission scenario wind fields and zero ice assumption

Based on the wave energy analysis presented above and the fact that climate change is projected to result in higher extreme lake levels in the future as documented in Section 4.1.2 of the main FHIMP report (Zuzek Inc., 2024a), the recommended increase in the historical recession rates when mapping the climate change *erosion hazard* limit for a 100-year planning horizon is 50%. Therefore, a historical recession rate of 0.5 m/yr would be increased to 0.75 m/yr when mapping the climate change *erosion hazard* limit.

2.3 Structure Inventory

A comprehensive shoreline structure inventory was developed as a component of the study to document the state of the County of Essex and Windsor shorelines as of April 2023. The inventory was created primarily from the review of more than 3,000 oblique aerial photographs captured as a component of the FHIMP study and documented in the FHIMP report. All major built-up areas and significant private property shore protection structures were included in the database. Each shoreline segment added to the shoreline inventory was delineated with start and end coordinates and assigned a structure type. Structure types commonly encountered throughout the region include steel sheet pile seawalls, ad-hoc stone bank protection, composite revetment-seawalls, cast-in-place concrete seawalls and engineered stone revetements. Several additional shoreline infrastructure types were encountered to a lesser degree, including ad-hoc concrete rubble bank protection, and stacked armour stone and pre-cast concrete block seawalls.

The completed shoreline structure inventory was used to assess statistics pertaining to the project shoreline including the percent of shoreline armoured versus natural and the percent armoured by structure type. Statistics were tabulated for each of the 27 project reaches and for the total project shoreline. Refer to Figure 2.5 for the delineation of project reaches.

Of the approximately 154 km of document shoreline, roughly 78% or 120 km was found to feature some form of shoreline armouring. The remaining 22% of the shoreline was deemed to be in a predominantly natural state. Reaches 3, 4, 5, 11, 13, 17, 20, 21, 23, 24, 25, 27 each featured shorelines that were more than 90% armoured. Many of these reaches featured significant municipal shoreline infrastructure such as harbours, jetties or marinas in addition to private shoreline protection structures.

Of the armoured shoreline (~120 km), the most common form of infrastructure was vertical sheet pile seawall. More than 37 km of the County of Essex and Windsor shorelines feature this form of shoreline infrastructure. Although the majority of vertical sheet pile walls encountered in the region are well engineered, well constructed and in reasonable condition, they contribute to accelerated erosion of the nearshore and deepening of the lakebed at the shoreline due in large part to their influence on wave reflection. This lakebed erosion results in larger waves impacting the shoreline over time due to increased nearshore water depths. As a result, erosion and flooding due to wave overtopping of low vertical seawalls and undermining of seawalls due to lakebed scour at the toe of the wall are likely to become more severe and frequent in the future. It is recommended that all shoreline infrastructure be monitored carefully by private and public land owners and maintained as necessary, particularly where vertical walls are present and may be susceptible to the above noted processes.

Table 2.4 below presents a summary of statistics from the shoreline inventory for the entire documented shoreline. Additional statistics including breakdowns by project reach have been provided to ERCA and the County of Essex in conjunction with the fully populated and georeferenced shoreline inventory as a project deliverable.

Table 2.4 Summary statistics from shoreline inventory

Shoreline/Structure Type:	Cumulative Length (km)	% of Total Shoreline
Seawall – Steel Sheet Pile	47.1	31%
Natural Shoreline (no infrastructure)	33.3	22%
Stone Bank Protection (ad-hoc)	28.9	19%
Composite Revetment-Seawall	12.4	8%
Revetment – Stone (random placement)	9.2	6%
Seawall – Cast-in-place Concrete	8.6	6%
Concrete Rubble Bank Protection (ad-hoc)	4.9	3%
Seawall – Precast Concrete Blocks	2.3	1%
Seawall – Stacked Armour Stone	2.2	1%
Gabion Baskets	1.3	1%
Other	3.3	2%

3.0 MAPPING HAZARDOUS LANDS

The following sections summarize the approach to mapping hazardous lands based on historical conditions and accounting for relevant climate change projections. Mapping described herein was performed at a local scale, not lot by lot, based on the conditions within the 27 hazard mapping reaches. In the future, under certain circumstances, lot-specific analysis of shoreline hazards may be warranted.

3.1 Erosion Hazard Limit

The *erosion hazard* limit is defined in the Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario and MNR, 2005) as a 100-year erosion allowance plus a stable slope allowance measured horizontally from the existing stable toe of slope. When CAs identify their regulated area, an additional allowance of up to 15 metres can be added. A schematic of the setback methodology is provided in Figure 3.1.

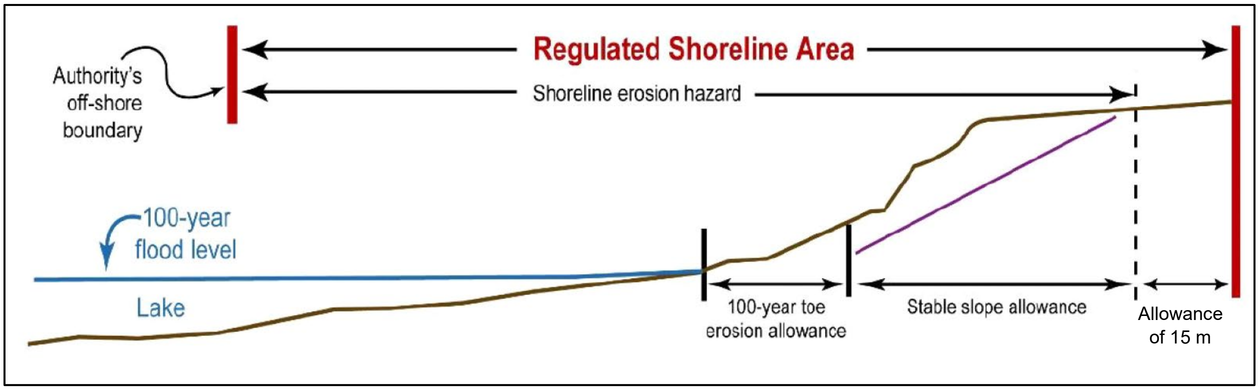


Figure 3.1 Erosion hazard definition (modified from Conservation Ontario and MNR, 2005)

3.1.1 Mapping Approach

For this study, the historical *erosion hazard* limit was mapped for all reaches using the recession rates summarized in Table 2.3. A stable slope of 3H:1V was used in the absence of detailed site-specific geotechnical analyses, as per provincial guidelines (MNR, 2001a). For the climate change *erosion hazard* limit, the historical recession rates were increased by 50% and mapped following the same procedures. Within the GIS mapping environment, the steps followed to map the *erosion hazard* limit are summarized as follows:

> **Step 1 - Determine the toe of slope location and elevation:** 20 cm elevation contours were extracted from the 2017 LiDAR DTM and used to evaluate the toe of slope position for the open coast. For natural shorelines, the toe of slope was digitized at the major break in slope from flat beach to bank or bluff face. For shorelines with vertical shore protection, the base of the protection was digitized as the toe of slope. For sloped protection (revetments), the toe was digitized at the visible toe of protection, which was often the waters edge. The digitized toe from the 2017 LiDAR contours was compared to the conditions in the 2022 ortho photos and in some cases, the toe location was modified to reflect the toe position in the more recent imagery due to shoreline erosion since 2017.

Generally, the elevation of the toe of slope coincided with +1.0 m above CD (IGLD'85), but in some local cases, the elevation was slighter higher.

- **Step 2 – Apply the 100-year erosion allowance:** Using GIS, the historical and climate change 100-year recession rates were applied as a horizontal buffer to the toe of slope line within each reach. The landward edge of the buffer represents the future toe location in 100 years. This line was converted to points spaced every 2 m and a geoprocessing tool was used to extract the 2017 LiDAR DTM elevation at each point to establish the crest height. These point elevations represent the estimated elevation for the future top of bank/bluff. The overall bank/bluff height (toe to crest) was calculated at each point by subtracting the toe of slope elevation in Step 1 from the extracted LiDAR DTM elevation for the bank/bluff elevation.

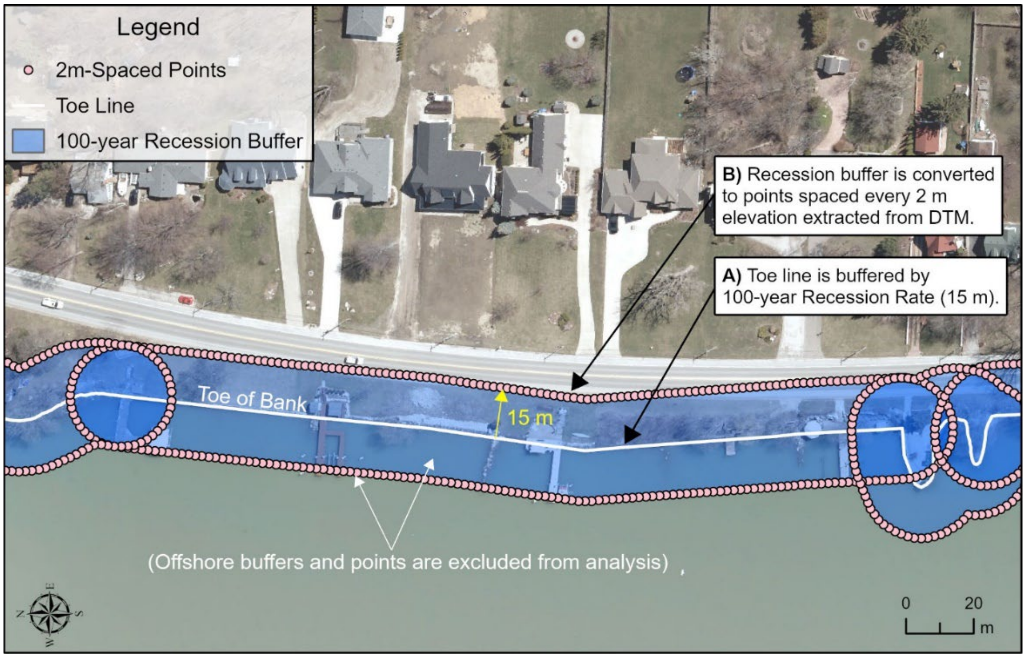


Figure 3.2 Example of existing toe of bank, future toe of bank based on a 100-year recession buffer of 15 m, and points spaced at 2 m (from converting the line to points)

- **Step 3 - Calculate the Stable Slope Setback:** A standard stable slope allowance of 3(H):1(V) was applied when the bank/bluff height was 2 m or greater. In GIS, the points (from Step 2) with a minimum height of 2 m were selected and the stable slope allowance was calculated (bank/bluff height x 3). Each selected point was buffered with the horizontal equivalent of the stable slope allowance and overlapping boundaries dissolved. These steps produce the red line in Figure 3.3.

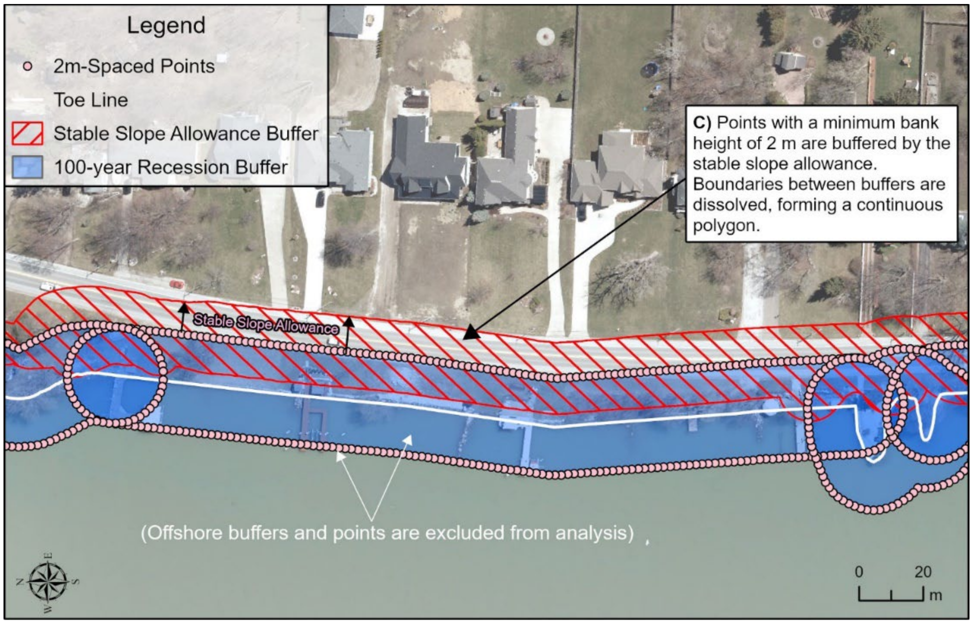


Figure 3.3 Stable slope allowance (red line) from buffering the future toe of slope points

- **Step 4 - Map the 100-year Historical and Climate Change Erosion Hazard Limit:** The *erosion hazard* was digitized along the landward edge of the stable slope buffer (where it exists for bank/bluff heights > 2 m) or the 100-year recession buffer (where the bank height < 2 m and the stable slope setback was not applied). Refer to the location of the green line in Figure 3.4.

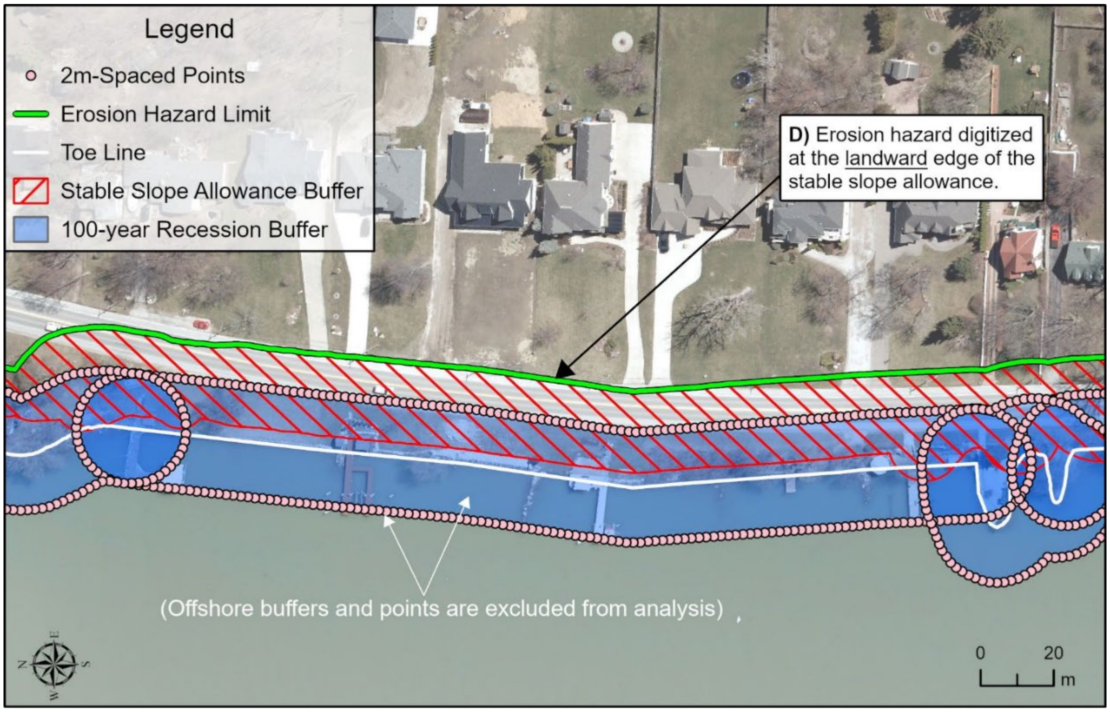


Figure 3.4 Intermediate GIS lines and final erosion hazard limit (green line)

3.2 Dynamic Beach Hazard Limit

The *dynamic beach hazard* is defined in the Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario and MNR, 2005) as the *flooding hazard* (100-year flood level plus an allowance for wave uprush and other water related hazards), plus a dynamic beach allowance to account for the dynamic nature of the beach and dune system, including periods of erosion and accretion. For local or lot-level studies or where specific geographies require it (e.g. narrow barrier beach systems) this allowance can be based on a site-specific study following the principals and beach classification scheme outlined in the Technical Guide (MNR, 2001). However, for regional shoreline hazard mapping studies the provincial guidelines stipulate a dynamic beach allowance of 30 m. When CAs map their regulated area, an additional allowance of 15 metres is added. Figure 3.5 shows a definition schematic of the *dynamic beach hazard*.

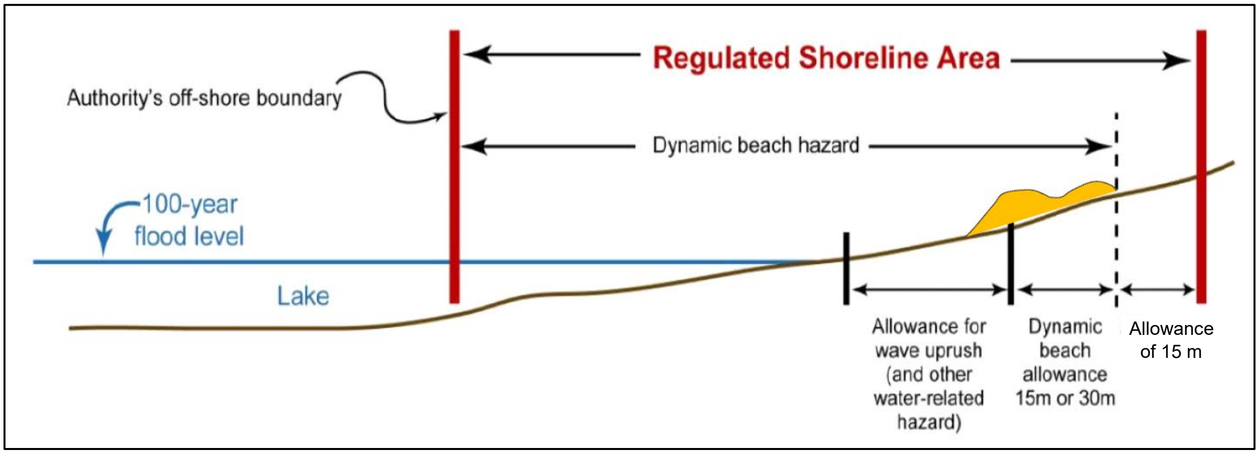


Figure 3.5 Dynamic beach hazard definition (modified from Conservation Ontario and MNR, 2005)

The purpose of the *dynamic beach hazard* is to restrict development in areas where dynamic beach materials (generally sand, gravel, pebbles, and cobbles) may evolve or erode under certain combinations of wind, wave, and water level conditions. Due to the inherent risks and the environmental and ecological importance of dynamic beach systems, the *dynamic beach hazard* is generally the most restrictive of the three shoreline hazards from a regulatory perspective. For a shoreline to be classified as a dynamic beach, the following criteria must be met (as per MNR, 2001a).

- Beach or dune deposits exist landward of the water line.
- Beach or dune deposits overlying bedrock or cohesive material are equal to or greater than 0.3 metres in thickness, 10 metres in width, and 100 metres in length.
- The maximum fetch distance measured over an arc extending 60 degrees on either side of a line perpendicular to the shoreline is greater than 5 km.

3.2.1 Mapping Approach

The *dynamic beach hazard* is typically mapped as a standard 30 metre setback inland from the *flooding hazard* (refer to the main FHIMP report, Section 5.1 for the *flooding hazard* mapping methodology), unless the beach and dune material extent was less than 30 m due to an engineered walkway or road with sub-grade, for example, or a transition to non-beach material (e.g., cohesive bluff, residential/cottage development, parking area). Due to the low land elevations in Essex County, the transition to non-beach material typically defined the landward limit of the dynamic beach, not the standard 30 m setback from the *flooding hazard* limit. Refer to Figure 3.6, which shows the *flooding hazard* extending inland further than the *dynamic beach hazard* at Cedar Beach.

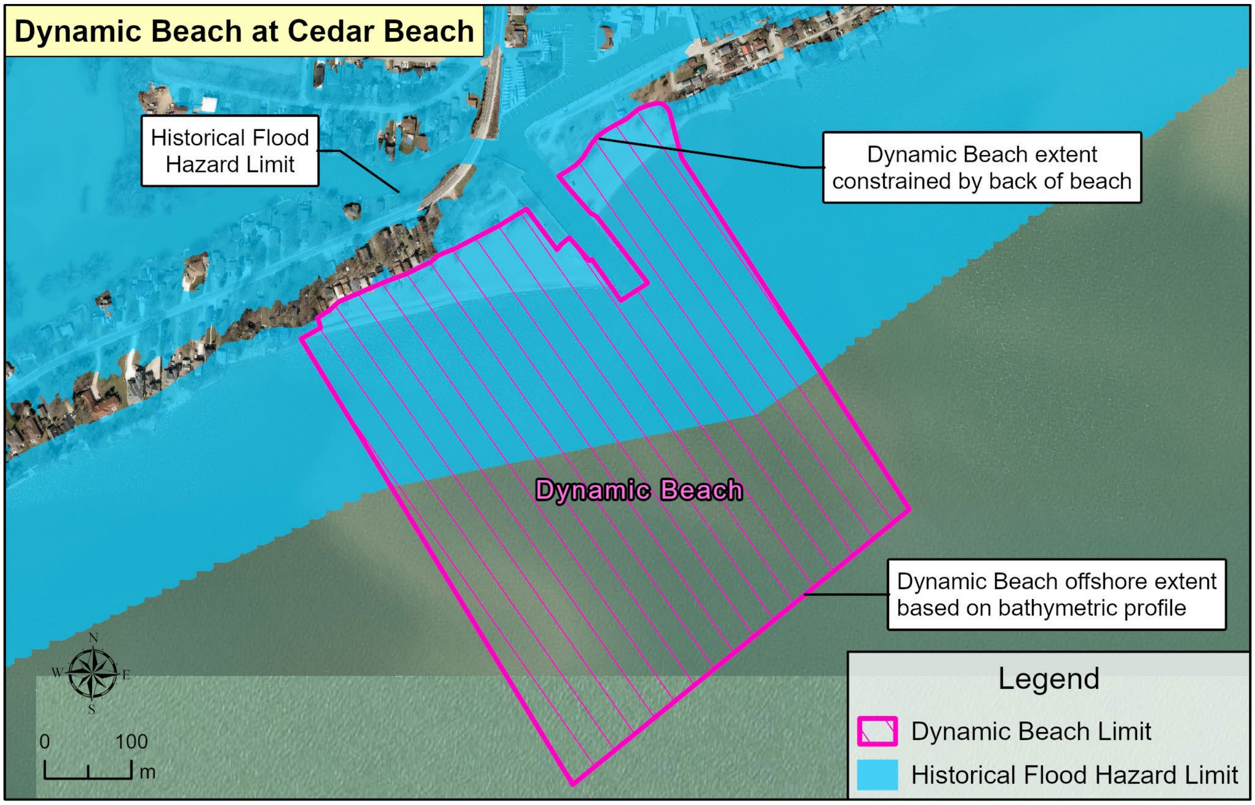


Figure 3.6 Example of dynamic beach and flood hazard at Cedar Beach

As stipulated in the MNR Technical Guide, the *dynamic beach hazard* should not only extend onshore as per the above guidelines, but should also extend offshore to the approximate limit of wave action on the lakebed (MNR, 2001a). This approach recognizes that the nearshore area, beach and dunes, are part of an inter-connected physical system and should be managed accordingly. The *dynamic beach hazard* was therefore mapped as a shaded polygon, with the offshore limit defined by the extent of mobile sediments (e.g., sand and gravel) based on a review of the profile data collected for the study.

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