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Lake Ontario Shoreline Management Plan Update

Niagara Peninsula Conservation Authority

November 2009
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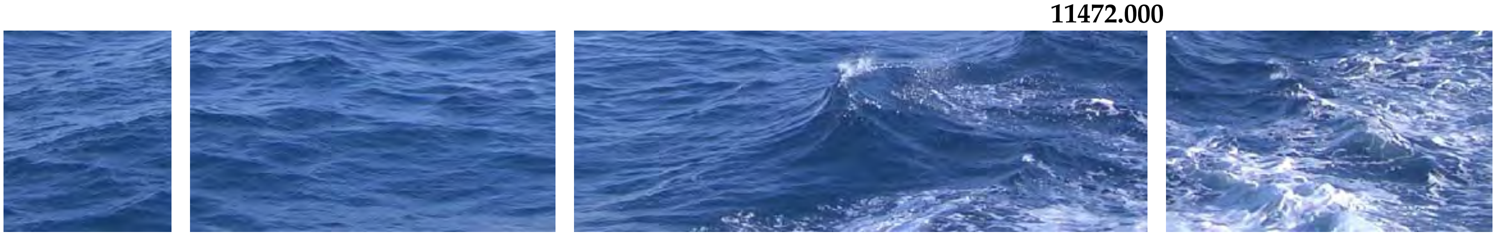

Navigating New Horizons

Lake Ontario Shoreline Management Plan Update

Prepared for

Niagara Peninsula Conservation Authority

Prepared by

Baird

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background and Purpose of Study

The 1994 Niagara Peninsula Conservation Authority (NPCA) *Lake Ontario Shoreline Management Plan* (2 volumes, Main Report and Technical Appendices; prepared by M.M. Dillon Limited Consulting and Atria Engineering Hydraulics Inc.) included mapping of the shoreline hazard limits for flooding, erosion and dynamic beaches. The 1994 hazard mapping was based on the then draft standards and guidelines prepared by the Ministry of Natural Resources (MNR 1993).

Since the 1994 *Lake Ontario Shoreline Management Plan* (LOSMP) was released, a number of changes have taken place in the legislation, policies and guidelines regarding shoreline hazards. Key changes include the following:

- In 1998, the *Conservation Authorities Act* was amended as part of the *Red Tape Reduction Act* (Bill 25), to ensure that Regulations under the Act were consistent across the province and complementary to provincial policies. Significant changes were made to Section 28, which led to the replacement of the "*Fill, Construction and Alteration to Waterways*" Regulations with the current "*Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*" Regulation (MNR/CO, 2008).

- *Ontario Regulation 97/04* "*Content of Conservation Authority Regulations under Subsection 28(1) of the Act: Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*" (i.e., Generic Regulation) was approved in May 2004. This Regulation established the content requirements to be met in Regulation made by a Conservation Authority under Subsection 28(1) of the *Conservation Authorities Act.*

- *Ontario Regulation 155/06 Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*, approved in May 2004, specifically enables NPCA to regulate the Great Lakes shoreline up to the furthest landward extent of the aggregate of the flooding, erosion and dynamic beach hazards.

- To assist CA's during the preparation of new/revised Regulation Schedules the Ministry of Natural Resources and Conservation Ontario (MNR/CO, 2005) released "*Guidelines for Developing Schedules of Regulated Areas*". The guidelines were generally derived from the MNR publications "*Understanding Natural Hazards* (2001b) and "*Technical Guide for Great Lakes – St. Lawrence River System* (2001a).

- To support administration of CA regulatory programs, the Ministry of Natural Resources and Conservation Ontario (MNR/CO, 2008) released the "*Draft Guidelines to Support Conservation Authority Administration of the "Development, Interference with Wetlands and*

Alterations to Shorelines and Watercourses Regulation". This document is based on numerous existing provincial Technical and Implementation Guidelines developed and approved by the Ministry of Natural Resources.

- The *Provincial Policy Statement* (*PPS*) (March 1, 2005) was issued under the *Planning Act*. The *PPS* states that Section 3 of the *Planning Act* "requires that decisions affecting planning matters 'shall be consistent' with policy statements issued under the Act". Responsibility for providing input with respect to provincial interests under the *PPS* Section 3.1 – Natural Hazards is delegated to individual Conservation Authorities.

- In 1996, MNR released the *Technical Guide for the Great Lakes – St. Lawrence River System and Large Inland Lakes* (MNR 2001a). These guidelines provide the technical basis and procedures for establishing the hazard limits for flooding, erosion and dynamic beaches as well as acceptable scientific and engineering practices for addressing the hazards.

- MNR prepared "*Understanding Natural Hazards*" (2001b) to assist the public and planning authorities with explanation of the Natural Hazard Policies (3.1) of the *Provincial Policy Statement* of the *Planning Act*. This publication updates and replaces the 1997 *Natural Hazards Training Manual* (MNR).

The purpose of this study was to update the hazard limits for flooding, erosion and dynamic beaches in the existing *Lake Ontario Shoreline Management Plan* (1994) to the current mapping and technical standards identified in the above noted documents, particularly the MNR *Technical Guide for the Great Lakes – St. Lawrence River System and Large Inland Lakes* (MNR 2001a).

1.2 Study Limits and Scope

The study area for the 1994 LOSMP was the entire Lake Ontario shoreline within NPCA's jurisdiction; approximately 50 km from Fifty Point to Mississauga Point. For the present study, the majority of the work focused on the area between Fifty Point and Port Weller; the Niagara-on-the-Lake portion of the NPCA shoreline was updated through the 2008 Niagara-on-the-Lake Watershed Plan (Aquafor Beech, 2008). However, the mapping component of the present study includes the work from the NOTL Watershed Plan (HCCL 2006) such that one complete set of consistent maps for the entire NPCA Lake Ontario shoreline was produced. Figure 1.1 shows the study limits. A larger map with street names is provided in Appendix C.

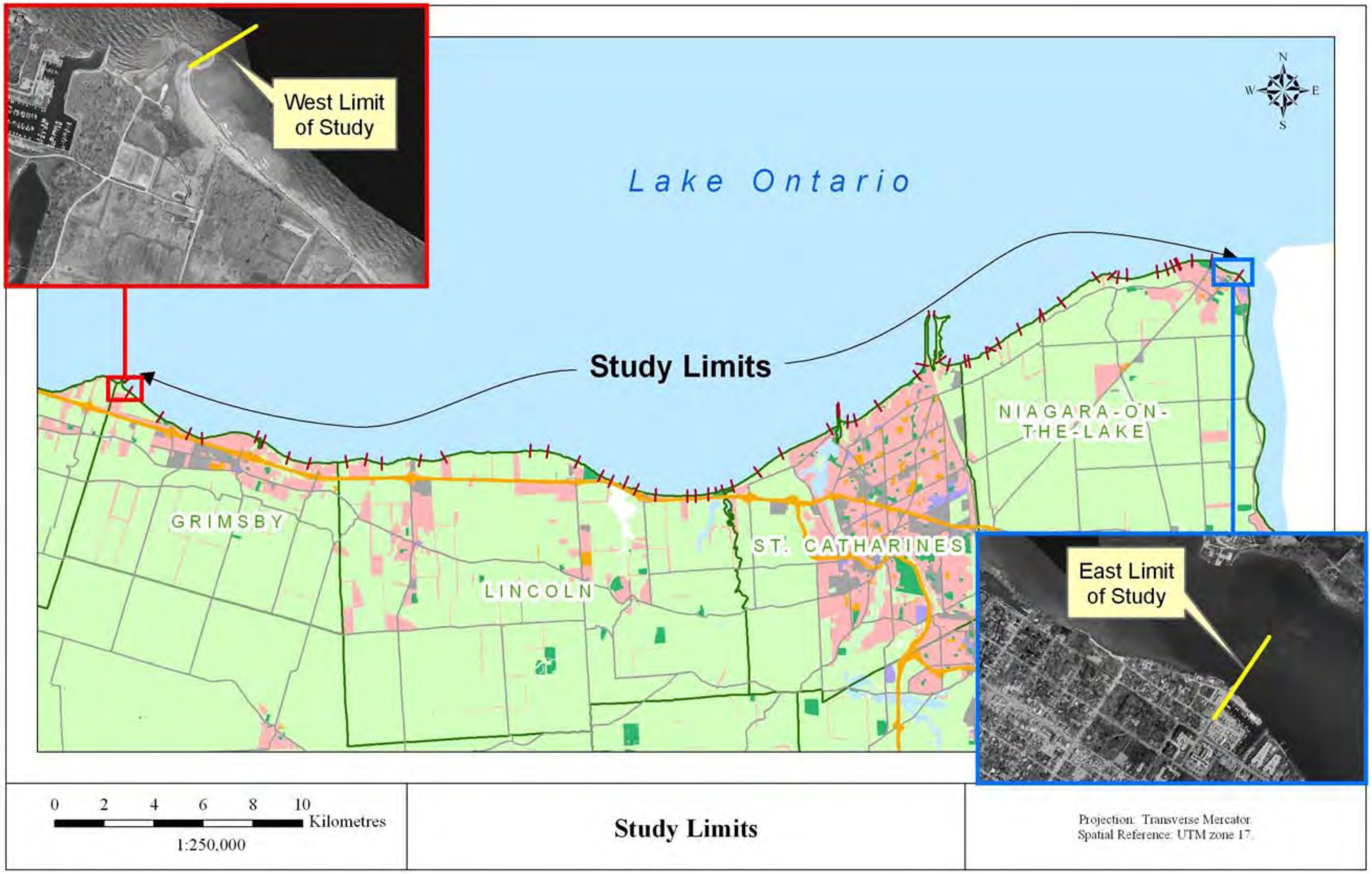


Figure 1.1 Study Limits

2.0 SHORELINE RECONNAISSANCE

2.1 Site Visits

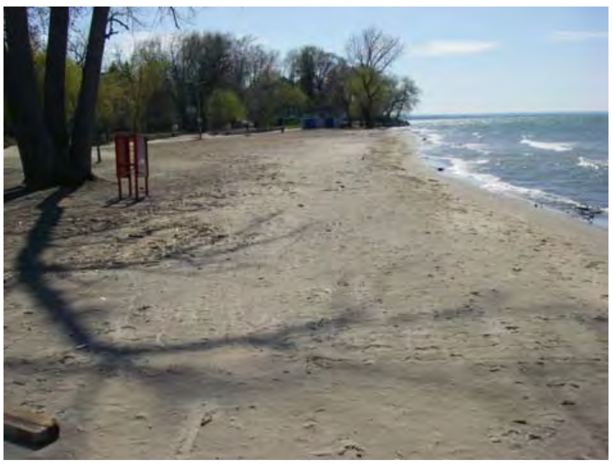
A shoreline reconnaissance was undertaken and 32 sites were visited. Sites 1 through 26 were visited on April 29, 2009 and sites 27 through 32 on May 6, 2009. The site visit locations are shown in Figure 2.1. The sites were chosen as representative of the various shoreline conditions encountered within the study area, including eroding bluffs, low shores, beaches and various erosion protection structures (see Figure 2.2). The sites included most of the sites that were reported in the 1994 LOSMP.

A standardized form was used for note taking at each site, including water level and wind information at the time of the visit. The forms and photographic records for each site visit are provided in Appendix A.

Figure 2.1 Location of Site Visits

Eroding Bluff - Site 29 Reach 40

Low Shore - Site14 Reach 13



Beach - Site 25 Reach 28

Armour Stone Revetment - Site 26 Reach 32

Stacked Concrete Block Wall – Site 29 Reach 40

Ad Hoc Protection - Site 15 Reach 15

Figure 2.2 Examples of Site Visit Photographs April-May 2009

2.2 Oblique Aerial Photographic Inventory of Shoreline

An existing Baird photographic database was used to provide the photographic inventory of the shoreline. The database consists of approximately 170 shoreline oblique digital photographs taken in August 2003 from a helicopter flying parallel to the shoreline about 200 m to 600 m offshore at an elevation of about 100 m. Each photo is a high-resolution 5-Megapixel image, with a GPS location marking the spot where the photo was taken (see Figure 2.3). The complete set of photos is provided in Appendix B. The photos are also included in the GIS database submitted with this study.

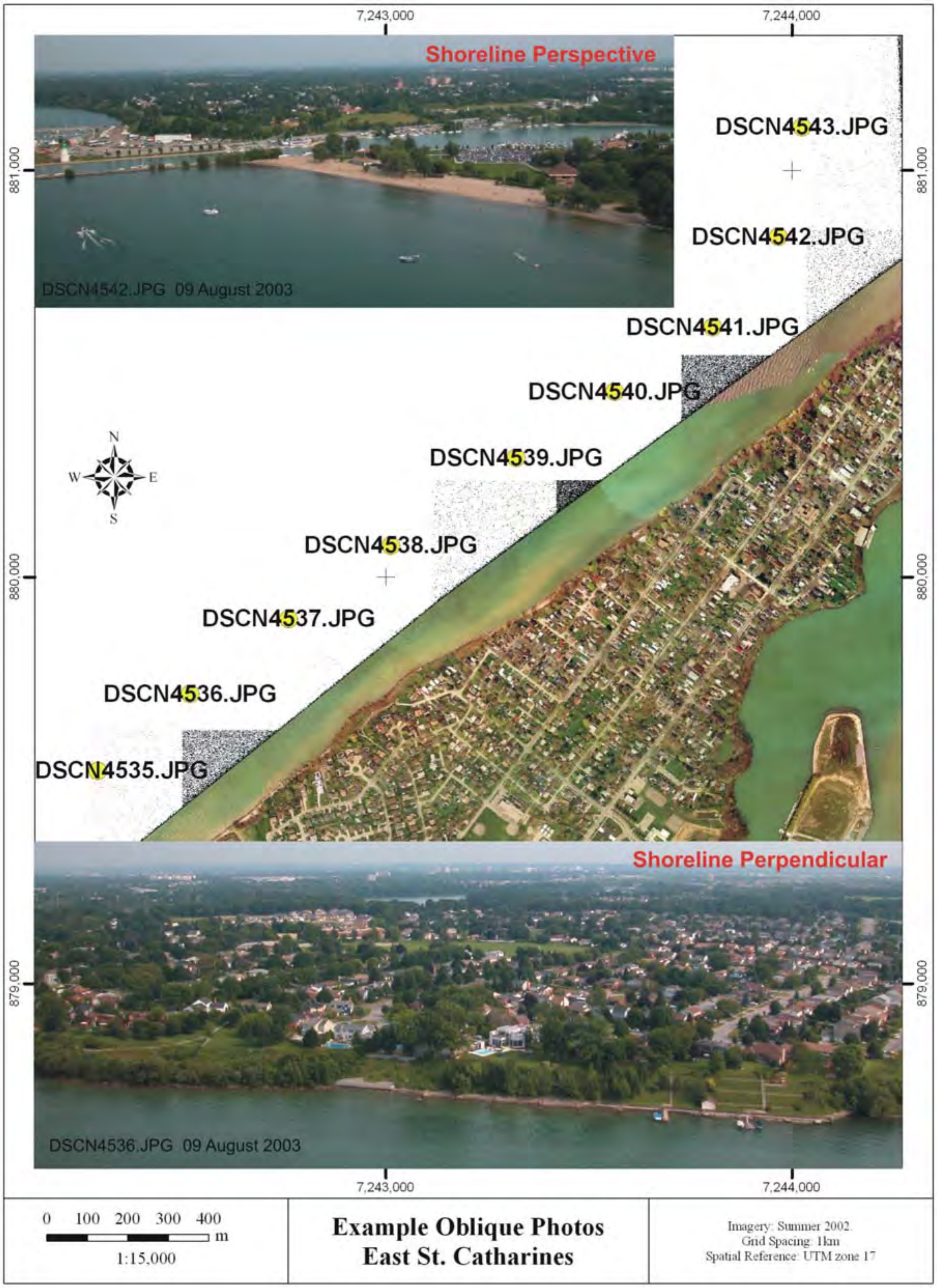


Figure 2.3 Example of Oblique Aerial Photographs, August 2003

3.0 SHORELINE REACHES

The 1994 LOSMP delineated the study shoreline into 59 reaches (Reaches 0, 1, 2, 3…58). A reach is a length of shoreline having common physiographic characteristics, shore dymnamics, environmental elements and land use. In delineating the reaches the following factors were considered:

- Shoreline stratigraphy (i.e., shale, sand til, silt till, silt);
- Nearshore composition (bedrock, boulders, cobbles, glacial till, sand);
- Wave exposure;
- Shoreline orientation;
- Nearshore bathymetry;
- Littoral transport characteristics (including littoral subcell);
- Bluff height;
- Recession rate;
- Flood susceptibility;
- Environmental sensitivity; and land use.

The reach numbering extended from Reach 0, at the western limit of the study area to Reach 58 at the eastern limit. The full extent of Reaches 0 and 58 were not shown in the 1994 LOSMP because the mapping at that time did not provide coverage for the entire study area.

The 1994 LOSMP reaches were reviewed for this study and it was concluded that the reach delineation was appropriate and suitable for the SMP update. The 1994 LOSMP reach numbering system with some modifications was retained for this study for consistency. Figure 3.1 shows the modified shoreline reaches. A larger map is presented in Appendix C. The geographic boundaries of the reaches are presented in Table 3.1.

Figure 3.1 Shoreline Reach Boundaries

Table 3.1 Geographic Boundaries of Reaches

Reach	Description	
0	Fifty Mile Point headland to west of Rifle Range	Grimsby
1	West of Rifle Range to Hunter Rd.	
2	Hunter Rd. to 350 metres west of Roberts Rd.	
3	West of Roberts Rd. to 240 metres east of Roberts Rd.	
4	East of Roberts Rd. to Elizabeth St. (Forty Mile Creek/Grimsby Harbour, Murray Street Park)	
5	Forty Mile Creek/Grimsby Harbour	
6	Nelles Beach (Maple Ave. to west of Jacob's Landing)	
7	West of Baker Rd. to Betts Ave.	
8	Betts Ave. to Durham Rd. North(350 metres east of Grimsby/Lincoln boundary)	
9	Durham Rd. North to 140 metres west of Mountainview Rd.	Lincoln
10	West of Mountainview Rd. to Thirty Rd. North	
11	Thirty Rd. North to midway between Ontario St. N. and Bartlett Rd. N.	
12	West of Bartlett Rd. to 250 metres west of Sam Rd. N.	
13	West of Sam Rd. N. to Creek 140 metres west of Cherry Ave. North	
14	West of Cherry Ave. to 280 metres west of Martin Rd. North	
15	West of Martin Ave. to 100 metres east of Victoria Ave.	
16	East of Victoria Ave. to east end of former Prudhomme water park	
17	Prudhomme water park to Jordon Harbour	
18	Jordan Harbour, armoured shoreline of Prudhomme Boulevard and QEW Hwy.	
19	Jordon Harbour marina	
20	Jordon Harbour marina to creek 500 metres east of Jordan Rd.	
21	Creek to 50 metres east of Thirteenth St.	
22	East of Thirteenth St. 325 metres to west of Sixteen Mile Creek	
23	West of Sixteen Mile Creek	
24a	Sixteen Mile Creek and parts of Charles Daley Park	
24b	Charles Daley Park	
24c	Fifteen Mile Creek	
25	West of Gregory Rd. to west of Oakview Ave.	St. Catharines
26	West of Oakview Ave. to 335 metres west of Courtleigh Rd.	
27	West of Courtleigh Rd. to Lakeside Park	
28	Lakeside Park	
29	Port Dalhousie, entrance channel	
30	Port Dalhousie outer marina (Michigan Beach)	
31	Westcliffe Park, along Westgate Park Drive	
32	Westcliffe Park to 120 metres west of Geneva St.	
33	West of Geneva St. to west of Arthur St. (Garden City Beach)	
34	Municipal Beach	
35	Welland Canal - west	
36	Welland Canal - east	
37	Jones Beach, Broadway Rd. to 50 metres west of Newport St.	
38	West of Newport St. to 180 metres east of Read Rd.	

39	Butkin Drain	Niagara-on-the-Lake
40	Butkin Drain (520 metres west of Stewart Rd.) to Eight Mile Creek	
41	Eight Mile Creek, McNab Marsh	
42	300 metres east of McNab Rd. to 120 metres west of McNab Rd. (Firelane 14c)	
43	Firelane 14c to 90 metres west of Irvine Rd.	
44	West of Irvine Rd. to Six Mile Creek	
45	Six Mile Creek (Townline (Grantham) Rd.)	
46	Six Mile Creek to Firelane 6 Rd.	
47	Firelane 6 Rd. to Firelane 4 Rd.	
48	Firelane 4 Rd. to east of Firelane 2 Rd. (Four Mile Point)	
49	Firelane 2A Rd.	
50	Four Mile Creek	
51	Four Mile Creek to Two Mile Creek	
52	Two Mile Creek	
53	Rifle Range	
54	Shakespeare Ave. to One Mile Creek	
55	One Mile Creek	
56	Niagara Blvd. to Queen St.	
57	Queen St. to Mississauga Point (midway in golf course)	
58	Mississauga Point to Melville St. (NOTL marina basin)	

Some typical examples of the modifications in Reaches 0 to 36 include the following:

- Some boundary lines shifted slightly to better match with the newer, more detailed mapping. For example, the boundary between Reaches 7 and 8 was shifted west by less than 10 m to align with the centre of Betts Avenue.

- Slight adjustments to reach boundaries shown on 1994 LOSMP mapping to match the boundaries originally delineated on more detailed 1994 working draft mapping.

- Boundary between Reaches 18 and 19 was shifted approximately 100 m to match the limits of the marina breakwater, which did not exist in the 1994 mapping (see Figure 3.2).

- Reach 24 was further subdivided into 3 sub-reaches (24a, 24b and 24c) to better delineate the beach areas. The change does not affect the numbering on the other reaches.

Complete documentation of the notable reach modifications is provided in Appendix C.

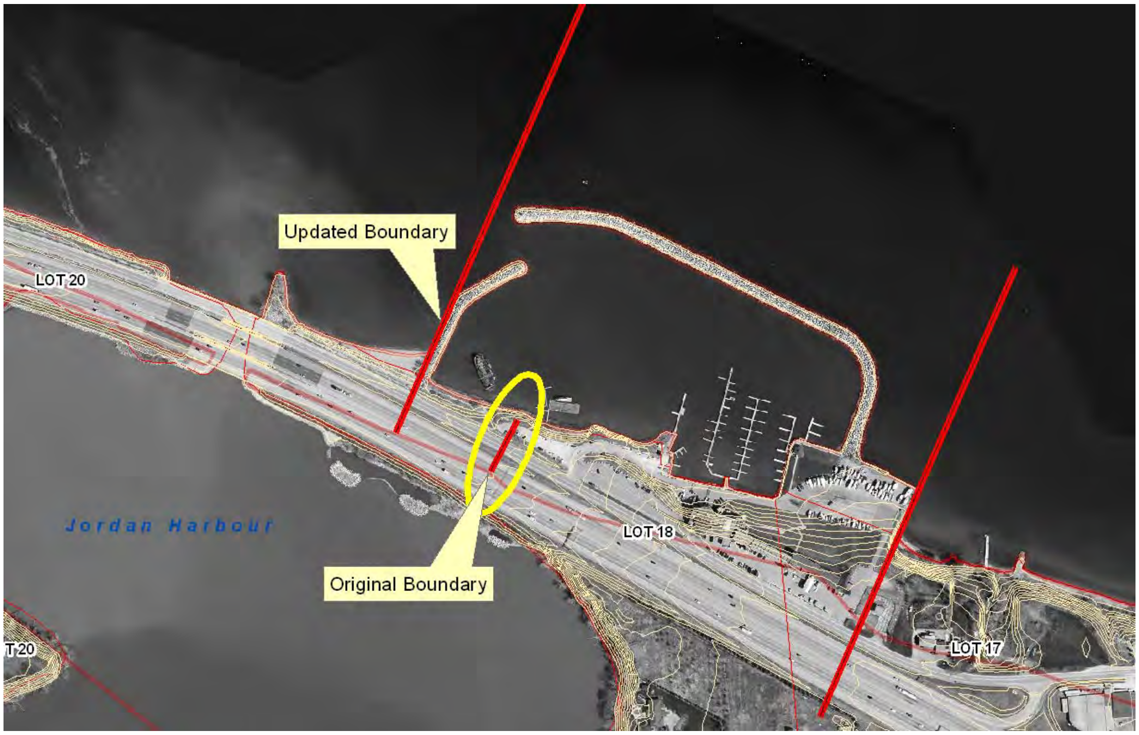
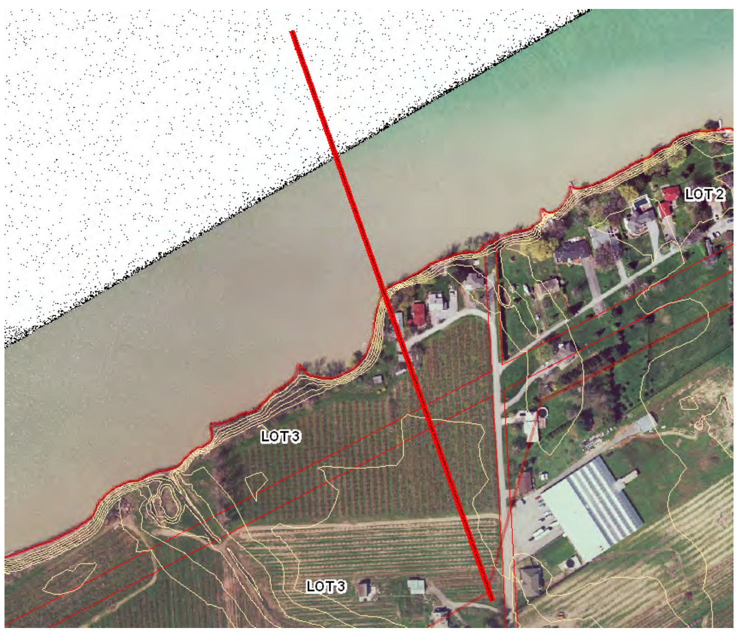


Figure 3.2 Updating Boundary Between Reaches 18 and 19

For Reaches 37 to 58 within Niagara-on-the-Lake, HCCL (2006) reported that they accepted the reach definitions used in the 1994 LOSMP and maintained them for the sake of consistency. As part of the present study, the boundaries of Reaches 37 to 58 in Niagara-on-the-Lake, as presented by HCCL (2006), were compared with the original 1994 boundaries. The HCCL boundary lines generally matched the 1994 limits with some noteworthy exceptions; these exceptions are described in Appendix C. For the present study, the HCCL boundaries were revised to match the original 1994 boundaries as intended. Figure 3.3 shows an example of a revised reach boundary. In addition, the reach boundary lines shown in the HCCL (2006) mapping were illustrative in nature and all were drawn with an arbitrary due-north orientation, not shore perpendicular, as is standard practice. The HCCL boundaries were therefore revised to a shore perpendicular orientation and were also created as larger 500 m line segments so they could be used for geoprocessing with other datasets.

Boundary delineated by HCCL (2006) shifted the line to match Irvine Road.



Boundary shown above matches the original 1994 delineation; this was retained.

Figure 2.4 Example of Reach Boundary Correction, Reaches 43-44

4.0 SHORELINE HAZARDS

4.1 Overview of Shoreline Hazards

Section 6.0 Definitions of the *PPS* defines hazardous lands as "property or lands that could be unsafe for development due to naturally occurring processes. Along shorelines of the Great Lakes – St. Lawrence River System, this means the land, including that covered by water, between the international boundary, where applicable, and the furthest landward limit of the flooding hazard, erosion hazard or dynamic beach hazard limits.

The technical basis and methodologies for defining and applying the hazard limits for flooding, erosion and dynamic beaches are provided by the *Technical Guide for Flooding, Erosion and Dynamic Beaches, Great Lakes – St. Lawrence River System and Large Inland Lakes* (MNR 2001a). The basic procedures outlined in the *Technical Guide* (MNR 2001a) with some modifications have been included in subsequent documents, such as *Ontario Regulation 97/04* ("Generic Regulation"), *Guidelines for Developing Schedules of Regulated Areas* (MNR/CO, 2005) and *Draft Guidelines to Support Conservation Authority Administration of the "Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation* (MNR/CO, 2008). These methodologies have been applied in this study and are described in the following subsection.

It is important to note, as outlined in the *Technical Guide* (MNR 2001a), that the regulated hazard limits are to be mapped based on the assumption of <u>no shoreline protection works</u> in place. The clearly stated intent is that the mapped flooding, erosion and dynamic hazard limits are not to be modified by the presence of existing or proposed shoreline protection or filling. The limit of hazards defines the regulated area of interest and shoreline protection is only then considered in determining if the hazards can be appropriately addressed under *Ontario Regulation 155/06* "*Permission to develop*

> *3. (1) The Authority may grant permission for development in or on the areas described in subsection 2*
>
> > *(1) if, in its opinion, the control of flooding, erosion, dynamic beaches, pollution or the conservation of land will not be affected by the development."*

This approach is consistent with the *Provincial Policy Statement* (Section 3.1.6), which states that development and site alteration may be permitted in those portions of the hazardous lands "*where the effects and risk to public safety are minor so as to be managed or mitigated in accordance with provincial standards, as determined by the demonstration and achievement of all of the following:*

a) development and site alteration is carried out in accordance with floodproofing standards, protection works standards and access standards;

b) *vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies;*

c) *new hazards are not created and existing hazards are not aggravated; and*

d) *no adverse environmental impacts will result."*

The *PPS* (2005) states that development and site alteration shall not be permitted within the dynamic beach hazard.

4.2 Flooding Hazard

4.2.1 Definition of Flooding Hazard

The flooding hazard is defined by the combination of "flood level" and the "flood allowance for wave uprush and other water related hazards" (see Figure 4.1). The *Technical Guide* (MNR 2001a) requires a flooding allowance of 15 m, measured horizontally from location of the flood level, if a study using accepted engineering and scientific principles is not undertaken.

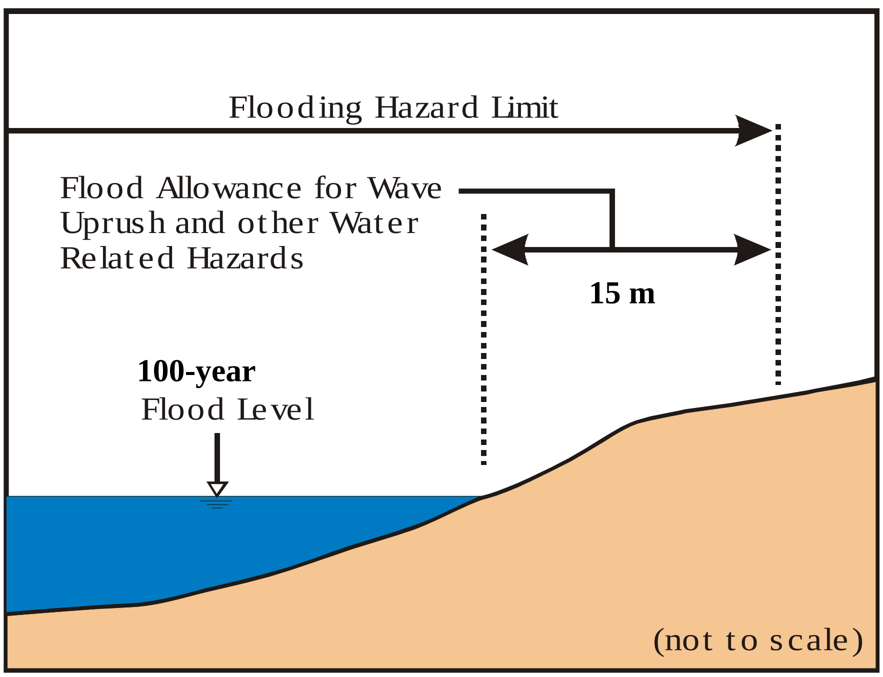


Figure 4.1 Flooding Hazard Limit With Wave Uprush

Where the shoreline is overtopped or ponding occurs, the limit of the flooding hazard is to be determined by a study using accepted engineering and scientific principles (see Figure 4.2). Wave heights are to be determined on a site-specific basis, but are typically depth limited. The depth of water physically limits the wave height.

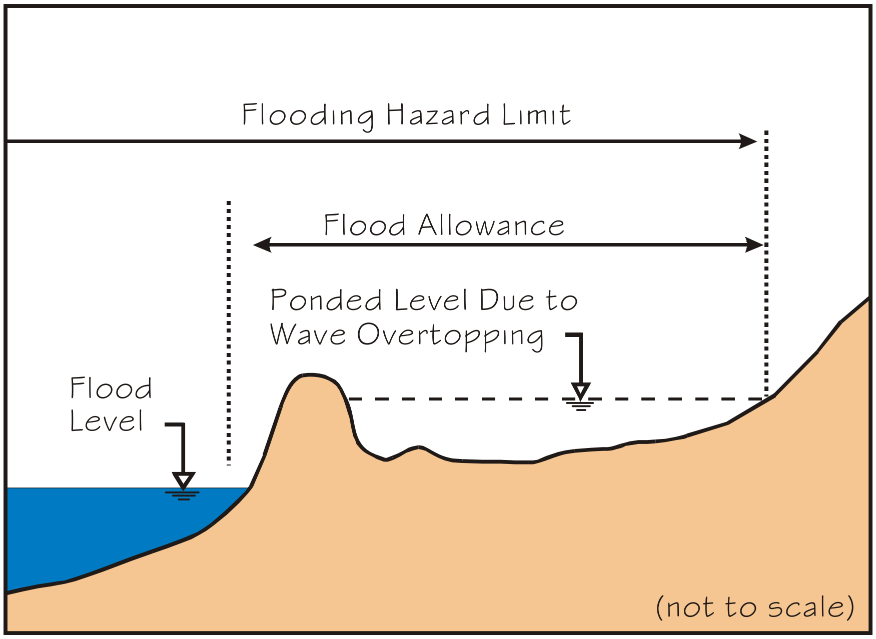


Figure 4.2 Flooding Hazard Limit With Wave Overtopping

The *Technical Guide* (MNR 2001a) states that mechanisms should be incorporated into the planning process to provide the flexibility to undertake a study, using accepted scientific and engineering principles to determine the landward limit of the flood allowance for wave uprush and other water related hazards. Empirical methodologies for estimating shoreline flooding and wave uprush outlined in the *Technical Guide* (MNR 2001a) are based on accepted engineering and scientific principles. Wave uprush is further discussed in Section 4.2.3.

4.2.2 Flood Level

The flood level is the sum of the mean lake level and storm surge with a combined probability of a 100-year return period (i.e., on average, has a 1 percent probability of occurring in any given year or on average once in 100 years). The 100-year flood level used in this study is based on the *Great Lakes System Flood Levels and Water Related Hazards* report (MNR 1989); the 100-year flood level is 76.0 m and 76.15 m GSC for Reaches 0 to 14 and 15 to 58 respectively. Based on benchmark HS 3 at Port Weller (Canadian Hydrographic Services, September 1992), International Great Lakes Datum 1985 (IGLD1985) minus GSC datum equals 0.03 m. IGLD1985 minus IGLD1955 equals 0.13 m. It should be noted that the flood level reported by HCCL (2006) in the NOTL Watershed Plan was represented by a contour line, by rounding the defined water level up to next 1 m increment contour elevation (i.e., 77 m). In this study, the value of 76.15 m GSC was used in Niagara-on-the-Lake.

The 100-year flood level determined by MNR (1989) was calculated using water levels for the period 1900 to 1987 adjusted to “Basis of Comparison” (BOC) conditions. BOC conditions include the effects of past regulation of Lake Ontario water levels. The following subsections discuss the potential impacts of changes in the regulation plan and climate change on Lake Ontario levels. The implication of water levels on recession rates is discussed in Section 4.3.3.2.

4.2.2.1 Regulation of Lake Ontario Water Levels

Monthly mean water levels for Lake Ontario are presented in Figure 4.3, from 1918 to 2004. Since 1960 the water levels have been influenced by the operation of the Moses-Saunders Power Dam in Cornwall, Ontario. Decisions on releases at the dam are based on Regulation Plan 1958D with deviations; generally the goal is to keep the water levels within the lower and upper operational range (74.15 to 75.37 m, IGLD’85). During periods of extreme high and low supplies, the water levels have exceeded these operational limits (e.g., 1964 and 1973). However, in general, the regulation plan has been successful in eliminating the historical high and low water levels and keeping the lake within the operational range.

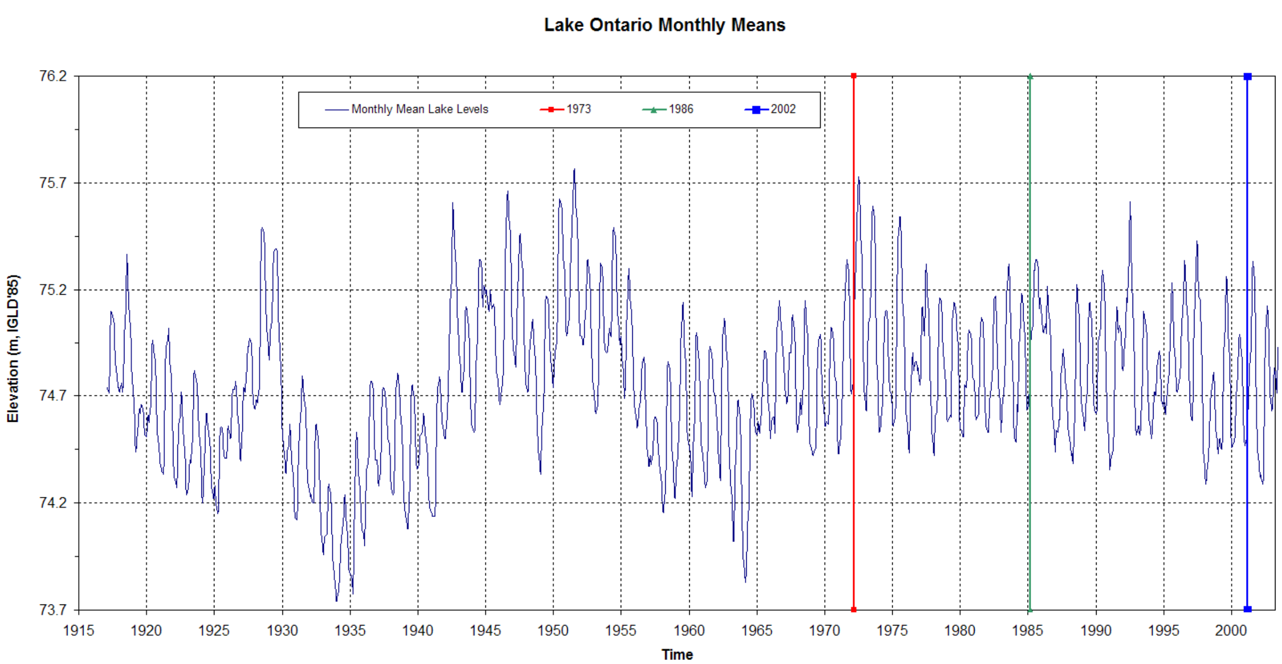


Figure 4.3 Historical Monthly Mean Water Levels on Lake Ontario

In 2000, the International Joint Commission (IJC) commenced work on a comprehensive five-year investigation on Lake Ontario and the St. Lawrence River to develop a new regulation plan for the Moses-Saunders Power Dam. The LOSLRSB (2005) summarized the findings of the regulation on shoreline erosion and flooding as follows:

- The probability of flood damage along Lake Ontario can be estimated based on a combination of water level and time of year; damage is least likely when storms are least likely (in the summer).

- Erosion on Lake Ontario will occur regardless of the regulation plan. The difference between plans is how quickly it will happen. The current regulation of Lake Ontario under Plan 1958D with deviations has slowed erosion down by as much as 40 cm/year in some highly erosive locations along the lake compared to what it would have been without regulation.

- In general, higher water level regimes result in accelerated shoreline erosion. However, it has been found that low water levels can also exacerbate erosion and shore protection damage through erosion of the "toe" of the bank, leading to the collapse of unprotected banks and the undermining of existing shore protection.

- The current regulation plan comes close to minimizing damages for Lake Ontario shoreline property owners.

- As with erosion, flooding on Lake Ontario has been significantly reduced by the current regulation plan over the unregulated condition.

- Shore protection maintenance on Lake Ontario is the aspect most affected by changes to a regulation plan. Even small differences in levels and the timing of levels can impact the overtopping and undercutting of shore protection.

The IJC is presently seeking feedback from the governments of Canada and the United States on new Orders of Approvals and Regulation Plan 2007. One of the primary goals of this draft regulation plan is the re-introduction of more natural conditions for Lake Ontario and St. Lawrence River water levels for the benefit of the natural environment. The likelihood that this plan will be adopted is unknown. However, it is possible that more extreme conditions than those observed in the past 30 years will occur in the future, due both to supply variability and new regulation plan objectives. Due to the uncertainty with respect to the implementation of any new regulation plan, no modification to the 100-year flood level, as determined by MNR (1989) was made for this study.

4.2.2.2 Climate Change

Climate change is expected to have an impact on water levels in the Great Lakes; there could be more net basin supply in winter and less net basin supply in summer and warmer air temperatures will mean less ice cover and more evaporation (Mortsch 2009). Based on these scenarios, there could be a projected water level decline that ranges from 8 cm to 47 cm (Mortsch 2009). Figure 4.4 shows the projected effect on Lake Ontario water levels of the various climate change scenarios. However, it should be noted that these are estimated long-term averages; water levels will continue to be variable with periods of both high and low levels.

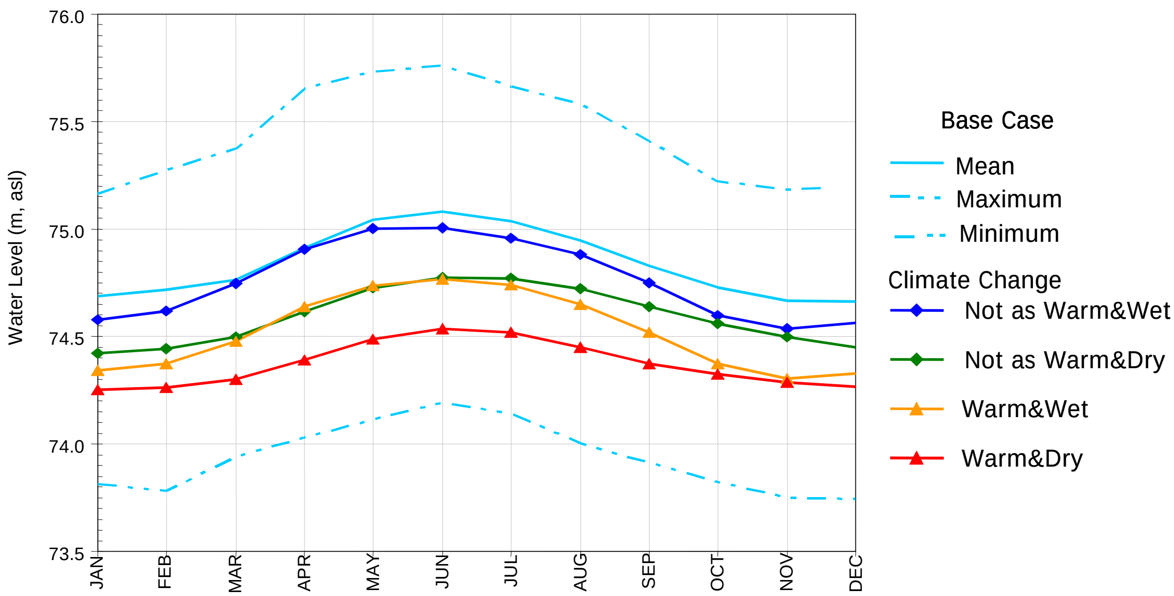


Figure 4.4 Projected Effect of Climate Change on Lake Ontario Average Water Levels (ref. Mortsch 2009)

It is postulated that less ice cover in the winter would result in more wave action at the shoreline. There is also the potential for more frequent and intense storms. The impacts of these potential changes in the wave climate on shore erosion and flooding hazards have not been evaluated within the scientific community and are not known with a sufficient degree of certainty. Therefore, there is insufficient basis at this time to change the MNR (1989) 100-year flood level due to climate change.

4.2.3 Wave Uprush

The 1994 LOSMP mapping applied the standard 15 m allowance for wave uprush (also referred to as wave runup) as described in Section 4.2.1.

Wave heights during a storm are irregular in height (i.e., they are not of uniform height). The resulting wave uprush during a storm is therefore also irregular. Similar to wave heights, wave uprush elevations are typically reported as either mean, significant or the 2% uprush. The significant wave uprush is the average of the highest one-third of all the uprush values, while the 2% wave uprush value is the uprush level only exceeded by 2% of all the values. The 2% uprush height can be approximated as 1.4 times the significant uprush height.

Many engineers have typically only reported the significant value of wave uprsh. The *Technical Guide* (MNR, 2001a) suggests the 2% uprush height should be used as the estimate for the upper limit of wave uprush. The recent EurOtop report (2007), the FEMA *Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update* (FEMA, 2007), and the FEMA Great Lakes Region Update (Collier pers. comm., 2008) also now specify the use of the 2% uprush height for hazard mapping. In addition, the EurOtop report (2007) also recommends the addition of one standard deviation to the predicted uprush for deterministic design and safety assessments. This approach ensures the wave uprush prediction incorporates a factor of safety to account for the scatter in the test results on which the equations are based.

The 1994 LOSMP reported on values of wave uprush at four representative sites along the shoreline to assess the applicability of the generic 15 m allowance for wave uprush. Using the 'upper bound" method, the 1994 LOSMP estimated the horizontal offset required for wave uprush. For this study, wave uprush was recalculated at the four representative sites using procedures outlined in EurOtop (2007) including the 2% uprush height. Table 4.1 presents the representative uprush values calculated using the upper bound method and the EurOtop method.

Table 4.1 Representative Wave Uprush Values

Station	Location	EurOtop Eqn. 5.4 (this study)		Upper Bound Method (1994 LOSMP)	
		$R_{u2\%}$ (m)	Horiz. Dist. (m)	R (m)	Horiz. Dist. (m)
0-01-30	Niagara-on-the-Lake	2.3	3.6	3.3	5.2
0-01-70	St. Catharines	0.4	9.9	0.3	7.3
0-01-90	St. Catharines	1.6	1.7	1.8	1.9
0-01-100	Lincoln	2.0	15	2.3	18
0-01-170	Grimsby	1.9	12	-	-

Table 4.1 shows that the uprush values calculated using the upper bound method and the EurOtop method are comparable. The only station that approached or slightly exceed the 15 m standard was O-1-100 in Lincoln (Reach 15); here the top elevation of the bank is only approximately 78 m IGLD85, or about 2 m above the 100-year flood level. The photo in Figure 4.5 shows the shoreline east of Martin Road, which is similar to the profile of Station O-1-100. Based on this analysis, it was determined that using the standard 15 m allowance for wave uprush, as per the *Technical Guide* (2001a), was appropriate for this study.

It is recommended that if site specific studies are undertaken to reduce the 15 m wave uprush allowance, then the 2% uprush height with one standard deviation should be used as the estimate for the upper limit of wave uprush.

Figure 4.5 Low Shoreline East of Martin Road (Reach 15)

Note that wave conditions used in estimating the wave uprush height are not necessarily the 100-year return period waves as this would result in a conservative return period for the combined probability of the 100-year flood level and waves. As outlined in the *Technical Guide* (2001a), a return period of 10 to 20 years for the waves is generally sufficient. However, in most instances close to the shore, where water depths are relatively shallow, wave conditions will be depth limited. The depths used in determining the depth-limited wave height should include an allowance for future downcutting of the nearshore profile.

Localized damage can occur as a result of ice effects on shore by wind and wave action (e.g., pile up, ride up, bulldozing). Wave spray can be driven inshore by winds; in freezing temperatures this can result in icing of roads, buildings and utilities close to the shore. No specific data is available for applying a separate allowance for other water related hazards (including wind driven wave spray and ice) and these hazards are included in the generic 15 m flood hazard allowance.

4.3 Erosion Hazard

4.3.1 Definition of Erosion Hazard

The erosion hazard is the sum of the stable slope allowance plus the erosion allowance of 100 times the average annual recession rate or a minimum erosion allowance of 30 m if sufficient recession data is not available. Figure 4.6 shows the erosion hazard limit as defined in the *Technical Guide* (MNR 2001a) and *Understanding Natural Hazards* (MNR, 2001b). The approach used in the Generic Regulation is similar but the recession allowance is applied first, then the stable slope allowance is applied; for example:

> *"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."*

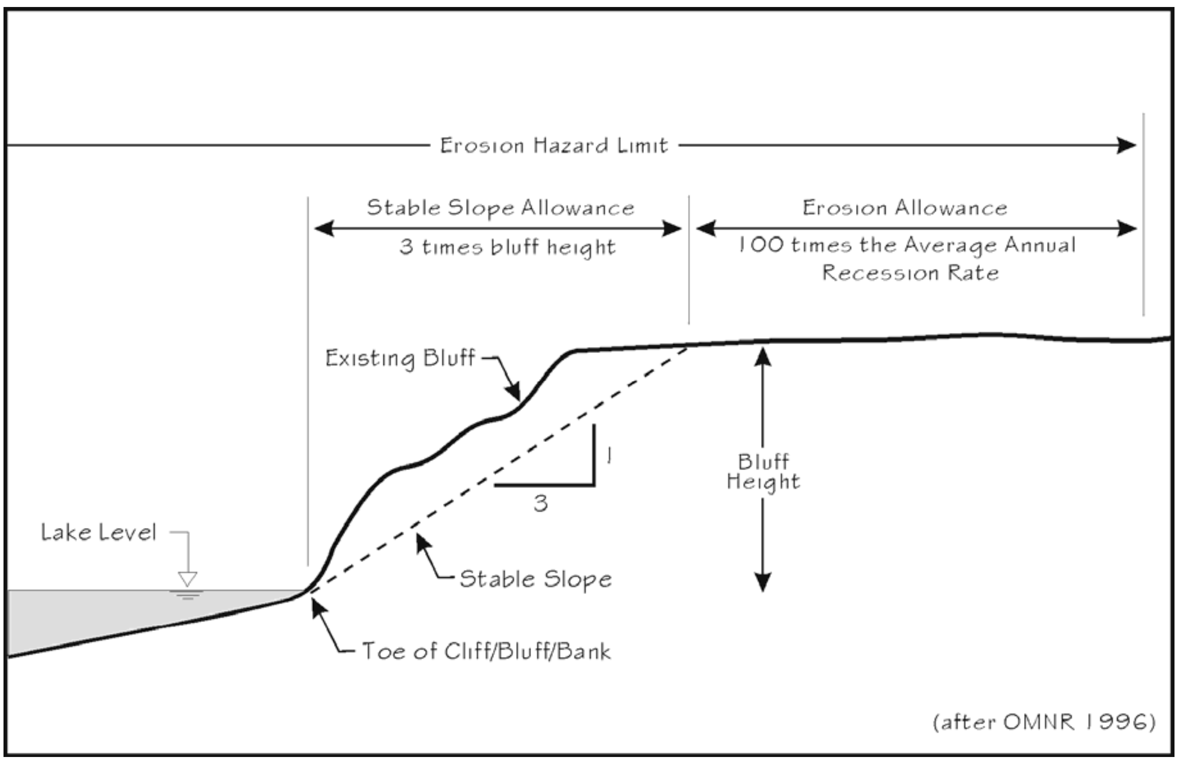


Figure 4.6 Erosion Hazard Limit Defined by *Technical Guide* (MNR 2001a)

The application of the stable slope allowance first, then the erosion allowance is a slight variation in the application of the erosion hazard as described in the generic Conservation Authority procedure; the generic procedure applies the erosion allowance first, then the stable slope allowance. The generic procedure is more in keeping with the actual physical process; an oversteepened eroding bluff would continue to erode over 100 years at which time the stable slope allowance would be applied to provide a safe shoreline position at that point in time. Applying the 100-year recession first, then the stable slope allowance, would result in a greater overall erosion hazard limit if there were a significant upwards gradient of the tableland at the top of shore bluff, thus resulting in a greater bluff height as the shoreline retreated. Along NPCA's Lake Ontario shoreline, this difference is nominal, considering the standard 3:1 slope and the recession rates used.

The approach of delineating the stable slope allowance first was selected for this study because slope stability is an immediate risk while erosion is an ongoing future risk. Development should not be permitted within the stable slope allowance, while measures can be proposed to address the erosion risk. Further details on mapping the hazard are provided in Section 5.

The average annual recession rate is used to determine the recession allowance over 100 years where there is at least 35 years of reliable recession information. Where there is no reliable recession information, the province suggests a minimum 30 m setback distance to allow for erosion along the Great Lakes-St. Lawrence River system (MNR 2001a, 2001b). For this study, the recession rates used in determining the 100-year recession limit are discussed in Section 4.3.3.

In situations where the existing slope is a flatter inclination than the stable slope allowance, MNR (2001a, 2001b) recommends application of the greater of the erosion hazard limit described above or a 30 m erosion allowance measured landward from the top of cliff/bluff/bank (i.e., first lakeward break in slope), as shown in Figure 4.7.

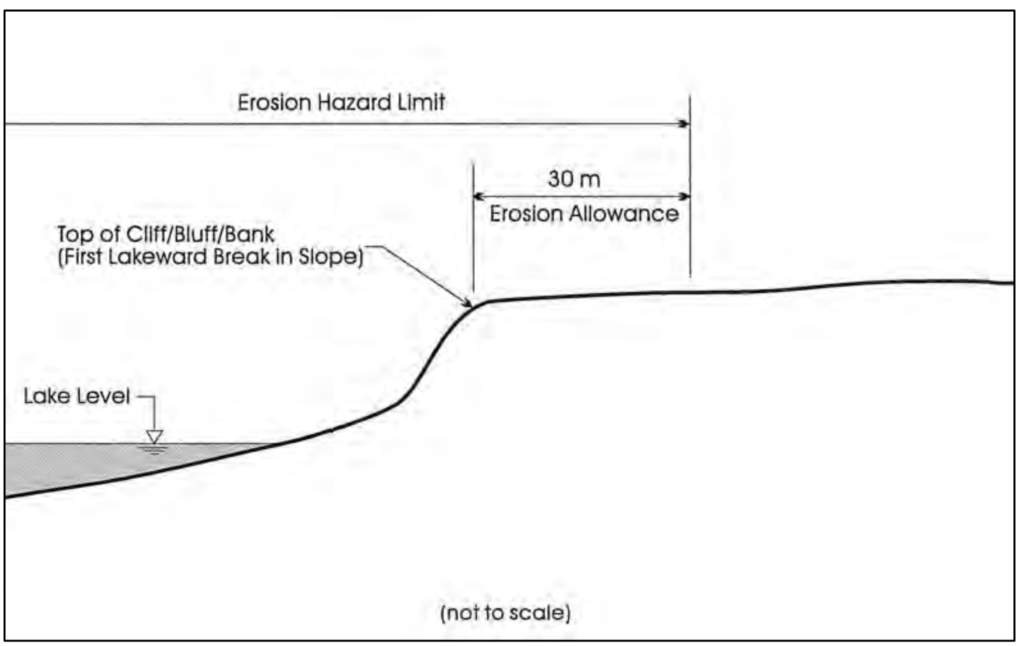


Figure 4.7 Erosion Allowance Measured From First Lakeward Break in Slope

4.3.2 Slope Stability

A slope stability allowance of 3:1 (horizontal:vertical) was used in this study. The *Technical Guide* (MNR 2001a) recommends using a stable slope allowance of 3:1 (i.e., three times the bluff height, measured from the toe of slope) unless a geotechnical engineer provides a detailed site study.

The 1994 LOSMP used 3:1 stable slope allowance based on earlier studies (Matyas, 1976 and Hegler, 1974, as reported in the 1994 LOSMP) that identified the general stable slope as 2.5:1 to 3:1 using a factor of safety of 1.5. Table 4.2 presents the minimum factor of safety for slope stability recommended by the *Technical Guide* (MNR 2001a). A factor of safety of 1.5 is suitable for most development scenarios.

Using a factor of safety of 1.3 to 1.5, it could be expected that a geotechnical study would result in a more steeply inclined slope, perhaps in the order of 2:1 for native material; shale could even be steeper and fill material would likely to remain at 2.5:1 to 3:1. A geotechnical engineer must confirm these on a site-specific basis.

The 'Factor of Safety' (FS) is the ratio of the forces that tend to resist slope movement (e.g., soil strength, or available soil shear resistance) to the gravitational forces that cause slope movement (based on soil weight, slope inclination, groundwater levels) along an assumed failure surface or plane. The Factor of Safety can be expressed as follows:

FS = Soil Resistance Preventing Movement / Gravity Forces Tending to Cause Movement

The Factor of Safety represents a measure of risk of failure or movement.

4.3.3 Recession Rates

4.3.3.1 1994 LOSMP

The average annual shoreline recession rate data utilized in the 1994 LOSMP is the only available regional dataset that provides complete coverage for the study area. The scope of this study was limited to using existing available recession rate data and did not include georegistering older aerial photographs and undertaking a detailed comparison with the earlier mapping and the 2002 and 2006 shoreline data. Therefore the 1994 LOSMP data was used as the basis for the hazard mapping update except as noted herein. The average annual recession rate data applied in this study is summarized in Table 4.3.

Table 4.2 Slope Stability Factor of Safety

Type	Land-Uses	Design Minimum Factor of Safety
A	**PASSIVE**; no buildings near slope; farm field, bush, forest, timberland, woods, wasteland, badlands, tundra	1.1
B	**LIGHT**; no habitable structures near slope; recreational parks, golf courses, buried small utilities, tile beds, barns, garages, swimming pools, sheds, satellite dishes, dog houses	1.2 to 1.3
C	**ACTIVE**; habitable or occupied structures near slope; residential, commercial, and industrial buildings, retaining walls, storage/warehousing of non-hazardous substances	1.3 to 1.5
D	**INFRASTRUCTURE and PUBLIC USE**; public use structures or buildings (i.e. hospitals, schools, stadiums), cemeteries, bridges, high voltage power transmission lines, towers, storage/warehousing of hazardous materials, waste management areas	1.4 to 1.5

The data in the 1994 LOSMP was based on a number of previous studies; these studies are described in the 1994 LOSMP. It is important to note the uncertainty in the accuracy of the historical data used in the 1994 SMP, as outlined in Section 4.3.3.2. The other sources of recession data included an updated recession rate for Reach 22 from an earlier study, updated rates for ten sites assessed during this study and the HCCL (2006) review of shoreline recession for Niagara-on-the-Lake); these other sources are described in the following subsections.

It is noted that Appendix 4 of the 1994 LOSMP provided the background information from which the representative recession rates in Table 2 of the 1994 LOSMP were derived. The rates for Reaches 13 and 14 were 0.15 m/yr and 0.25 m/yr respectively in Appendix 4 but were presented as 0.3 m/yr in Table 2; 0.3 m/yr is used in this study. The recession rate for Reach 30 (the fully armoured marina at Port Dalhousie) was revised to 0.3 m/yr for this study. Further discussion of recession rates for dynamic beach areas is provided in Section 4.4.2.

Table 4.3 Average Annual Recession Rates Used to Determine Erosion Allowance

Reach	Representative Annual Recession Rate (m/yr)	Notes
0	0.3	Dynamic beach; Fillet beach at Fifty Point headland; 0.3 m/yr recession rate applied
1	1.2	1.3 m/yr in 1994 LOSMP; adjusted based on this study at Reach 2
2	0.8	1.3 m/yr in 1994 LOSMP; adjusted based on this study 1954-2006 comparison
3	0.3	
4	0.4	0.5 m/yr in 1994 LOSMP; adjusted based on this study 1954-2006 comparison
5	0.3	Marina, Grimsby Harbour
6	0.2	0.3 m/yr in 1994 LOSMP; adjusted based on this study 1954-2006 comparison
7	0.3	
8	0.3	
9	0.3	
10	0.8	
11	0.8	
12	0.45	
13	0.15	0.15 m/yr in Appendix 4 1994 LOSMP; adjusted based on this study 1954-2006 comparison
14	0.3	0.25 m/yr in Appendix 4 1994 LOSMP, but 0.3 m/yr in report Table 2
15	0.3	
16	0.5	0.6 m/yr in 1994 LOSMP; adjusted based on this study 1954-1999 comparison
17	1.2	
18	0.3	Dynamic beach; Jordan Harbour mouth; heavily altered by highway
19	0.6	
20	0.4	0.6 m/yr in 1994 LOSMP; adjusted based on this study 1954-2006 comparison
21	0.6	
22	0.7	0.6 m/yr in 1994 LOSMP; adjusted based on this study 1954-2006 comparison and IJC study
23	0.6	
24a	0.6	Dynamic beach
24b	0.6	
24c	0.6	Dynamic beach
25	0.6	
26	0.5	
27	0.4	0.5 m/yr in 1994 LOSMP; adjusted based on this study 1954-2006 comparison
28	0.3	Dynamic beach; Lakeside Park; 0.3 m/yr recession rate applied
29	Jetties	Port Dalhousie
30	0.3	Fully armoured marina. Apply 0.3 m/yr
31	0.4	
32	1.0	
33	2.0	
34	0.3	Dynamic beach; Municipal Beach - anchored by jetty; 0.3 m/yr recession rate applied
35	W. Jetty	West Jetty of Port Weller shipping channel
36	E. Jetty	East Jetty of Port Weller shipping channel
37	0.3	Dynamic beach; Jones Beach - anchored by jetty; 0.3 m/yr recession rate applied
38	0.7	
39	1.8	
40	2.5	up to 2.5 m/yr based on this study 1954-2006 comparison; 2.8 m/yr in HCCL (2006)
41	2.0	Dynamic beach; Eight Mile Creek; 1.7 m/yr (HCCL 2006)
42	1.5	
43	1.5	2.0 m/yr in 1994 LOSMP; adjusted based on this study
44	1.2	
45	1.5	1.1 m/yr in 1994 LOSMP; adjusted based on this study
46	1.5	1.0 m/yr in 1994 LOSMP; adjusted based on this study
47	0.6	
48	0.6	
49	0.8	Dynamic beach
50	0.8	Dynamic beach; Four Mile Creek; 1.2 m/yr in 1994 LOSMP; adjusted based on this study
51	0.8	1.5 m/yr in 1994 LOSMP; adjusted based on this study 1954-2006 comparison
52	0.8	Dynamic beach; Two Mile Creek
53	0.8	
54	0.8	
55	0.3	
56	0.3	
57	0.3	
58	0.3	

4.3.3.2 *Reach 22 - East of Thirteenth St. to West of Sixteen Mile Creek, Lincoln*

As part of the IJC Lake Ontario study, Baird (2006) completed a detailed analysis of shoreline recession for "Site #6", a 200 m section of shoreline corresponding to Reach 22 (East of Thirteenth St. to west of Sixteen Mile Creek, Linclon). A suite of ArcMap GIS tools known as *Baird ShoreTools* were used to draw a baseline and calculate top of bank recession rates for three temporal periods: 1973 to 1986, 1986 to 2002, and 1973 to 2002. The automated transect measurements were completed every 5 m along the shoreline. Between 1973 and 1986, the average recession rate for the 22 transects was 19.33 m or 1.49 m/yr. Table 4.4 provides a summary of the historical recession measurements.

Table 4.4 Summary of Historical Recession Measurements at IJC Site #6 (Reach 22)

Start Year	End Year	# of Measurements	Average Recession (m)	Annualized Recession (m/yr)
1973	1986	22	19.33	1.49
1986	2002	39	9.53	0.60
1973	2002	21	28.02	0.97

It is worth noting this temporal period corresponds to the very high lake levels of the 1970s (refer to Figure 4.3). From 1986 to 2002, the annualized recession rate decreased significantly to 0.6 m/yr. Given the relatively short temporal duration for these two estimates, using the average annualized recession rate of 0.97 m/yr from 1973 to 2002 is recommended for Reach 22 and was included in Table 4.3.

The shoreline change investigation at IJC Site #6 utilized current tools and knowledge of shoreline erosion to document the long-term recession rate for this reach of shoreline. The annualized recession rate for the site was 0.97 m/yr, which is approximately 50% higher than the rate used in the 1994 LOSMP (0.6 m/yr; based on Hegler 1974). There are numerous potential reasons for this discrepancy:

- Limitations with Hegler (1974) rate: Errors in photographs (not registered); measurement techniques were not as accurate, single station measurement was not representative of the local trend;

- Lake level trends: The Hegler recession rates were measured from 1931 to 1969. The Lake Ontario hydrograph for this temporal period was presented in Figure 5.1. The Hegler measurements started and finished with a period of very low lake levels, with high conditions in the middle (the 1950s). When the 1973 to 2002 period is compared, water levels were all average or high, and never dropped below Chart Datum. Based on studies (e.g., Baird, 2006) of water level impacts on bluff recession, it is not surprising that the Hegler recession rate is lower than the value calculated for IJC Site #6, since a significant amount of the incoming wave energy between 1931 and 1969 would have been dissipated on the lake bottom and would have never reached the bluff; and

- Wave energy variations: Storm conditions and total wave energy may have been lower in the 1931 to 1969 period. Similarly, there may have been more shoreline ice during this temporal period, which protects the bluff from direct wave attack during the winter.

4.3.3.3 Niagara-on-the-Lake

HCCL (2006) completed a review of the Niagara-on-the-Lake portion (Reaches 37 to 58) of the study area and found that the majority of the shoreline showed relatively little change since the 1994 mapping was completed. HCCL observed that there were some areas of minor to moderate recession consistent with dynamic shoreline areas.

For Reach 40, HCCL (2006) suggest a recession rate of 2.8 m/yr, based on a comparison of 1994 shoreline mapping and 2002 aerial photographs. For the present study, it is noted that this rate is based on a relatively short period of comparison (8 years); nevertheless, it is consistent with the rate of 2.5 m/yr presented in the 1994 LOSMP. Mapping prepared by HCCL appears to use 2.5 m/yr. Sites such as Reach 40, which remain unprotected, should be evaluated in greater detail over a longer period using georegistered aerial photographs and updated mapping techniques. An additional assessment of recession rates is discussed in Section 4.3.4. Further discussion of recession rates for dynamic beach areas in Niagara-on-the-Lake is provided in Section 4.4.2.

HCCL (2006) report that filling and protection works have altered the shoreline immediately east of Firelane 8 in Reach 46 and suggest that this would result in a change in the orientation of the hazard limit in this area. For this study, it is noted that the hazard limit should be mapped without consideration of the effects of protection works and filling (see Section 4.1).

4.3.4 Additional Assessment of Recession Rates

The recession rates at ten additional sites were assessed as part of this study. The following sites were chosen based on the availability of suitable aerial photographs from 1954 and the lack of visible protection in the 2006 aerial photographs:

- Reach 2 - at the end of Casablanca Blvd. (Site Visit #2);
- Reach 4 - at the eastern end of the Reach, east of the parkette between Whittaker and Old Orchard (Site Visit #5);

- Reach 6 – at 61 – 71 Lake Street, Grimsby;
- Reach 13 - at Merritt Rd., 50 m unprotected section of shoreline (Site Visit #14);
- Reach 16 - newer subdivision along South Shore Blvd. (unprotected bluff in 1994; now protected by 220 m armour stone revetment; 1999 topographic survey provided by NPCA was used to determine top of bank). (Site Visit #17);
- Reach 20 - east of Jordan Rd. (Site Visit #19);
- Reach 22 - at 13th St. road allowance, (Site Visit #20);
- Reach 27 - at the western end of the Reach, at the end of Courtleigh Rd. (Site Visit #23);
- Reach 40 - at the end of Stewart Rd. (Site Visit #29); and
- Reach 51 - green space across from Niagara Lake Shore Cemetery, (Site Visit #32).

The 1954 airphotos, provided by NPCA, were scanned at a high resolution and then examined to ensure that they were suitable for use (e.g., visibility of edge of bluff, distortion, notable landmarks). Using visible landmarks, the scanned photos were georegistered with the ArcMap Georegister Toolbar based on the 2002 and 2006 imaging. The top of bluff was digitized for nine of the sites; for Reach 16 the 2000 topographic survey was used to extract the top of bluff. The Baird Transect Tool was then used to create transects at 5 metre intervals. The recession rate was determined based on the mean of the transect recessions at each site plus one standard deviation. The results are summarized in Table 4.5; further details are provided in Appendix D. This additional recession rate data was considered and the final representative recession rates used for the reaches in this study are presented in Table 4.3.

4.3.5 Recommendations for Future Determination of Recession Rates

As outlined in the *Technical Guide* (MNR 2001a) and Zuzek et al (2003), and as described in Section 4.1, recession rates should be based on the natural, ambient recession of the shoreline (i.e., unaffected by shoreline protection). This is often difficult to do in the study area because there are a limited number of sites that have been left unprotected. For this reason, it is important to consider historical records of recession rates. Further studies of areas that are unprotected are recommended.

Table 4.5 Additional Recession Rates, 1954 to 2006

Location	From Year	To Year	Temporal Period (Years)	Mean Recession for Profiles (metres)	1.0 Standard Deviation (metres)	Total (metres)	**Annualized Average Recession Rate (metres/year)**
Reach 2	1954	2006	52	36.3	3.0	39.3	**0.76**
Reach 4	1954	2006	52	11.7	1.6	13.3	**0.26**
Reach 6	1954	2006	52	3.2	1.6	4.9	**0.09**
Reach 13	1954	2006	52	7.2	0.8	7.9	**0.15**
Reach 16	1954	1999	45	19.7	4.5	24.2	**0.54**
Reach 20	1954	2006	52	16.0	4.7	20.6	**0.40**
Reach 22	1954	2006	52	32.4	3.4	35.8	**0.69**
Reach 27	1954	2006	52	11.8	2.2	14.0	**0.27**
Reach 40A	1954	2006	52	81.9	16.0	97.9	**1.88**
Reach 40B	1954	2006	52	123.1	8.5	131.6	**2.53**
Reach 40 Total, Mean							**2.21**
Reach 51	1954	2006	52	27.4	6.4	33.9	**0.65**

The evaluation would involve comparison of georegistered aerial photographs and should follow the standards applied to IJC Study Site #6, as described in Section 4.3.3.2 and Zuzek et al (2003). Future challenges to the hazard zone mapping generated by this update, specifically the long-term recession rates used for the erosion hazard setback, should also follow the standards described in Zuzek et al (2003).

4.4 Dynamic Beach Hazard

4.4.1 Definition of Dynamic Beach Hazard

The dynamic beach hazard involves the calculation of the cumulative impact of the flooding hazard, the average annual recession rate and a dynamic beach allowance. In addressing these factors, the dynamic beach hazard is defined as:

- The landward limit of the flooding hazard (100 year flood level plus a flood allowance for wave uprush and other water related hazards) plus a 30 metre dynamic beach allowance (see Figure 4.8);

  OR

- The landward limit of the flooding hazard (100 year flood level plus a flood allowance for wave upursh and other water related hazards) plus a dynamic beach allowance based on a study using accepted scientific and engineering principles.

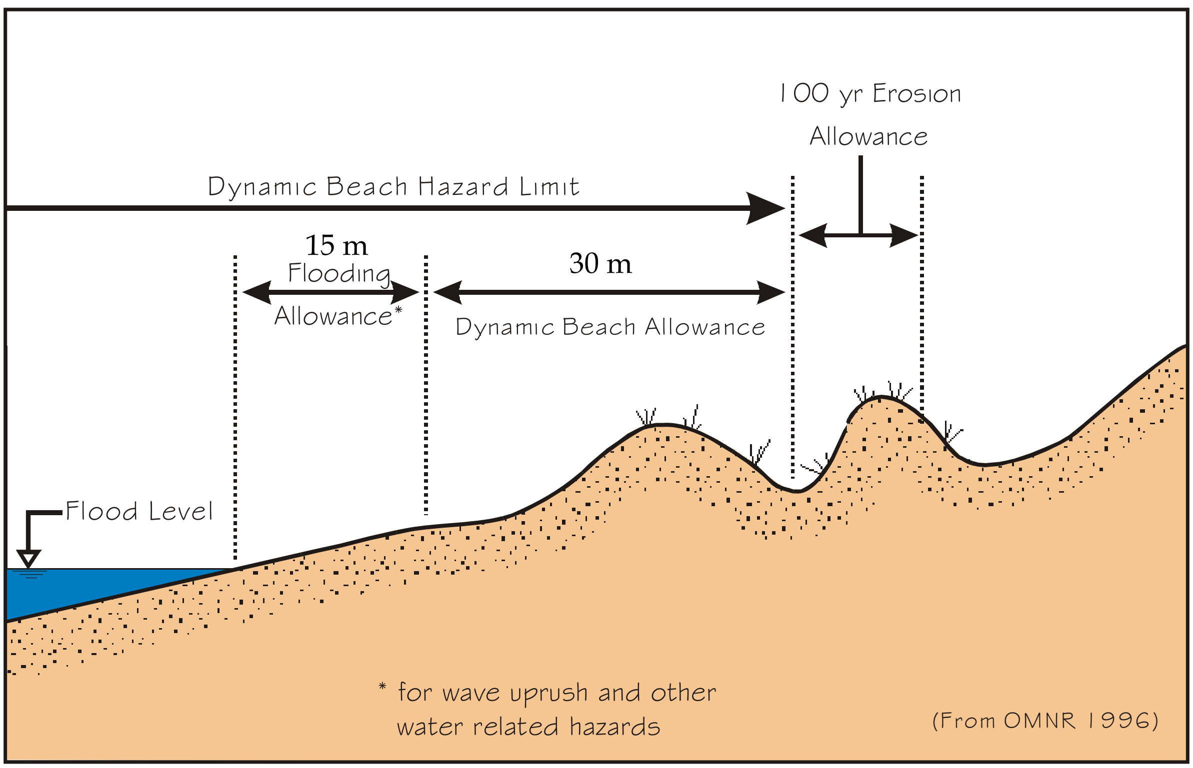


Figure 4.8 Dynamic Beach Hazard Limit

A detailed discussion of the nature of dynamic beaches is provided in the *Technical Guide* (MNR 2001a).

The "flood level" and the "flooding allowance" represent the flooding hazard, as described in Section 4.2. The flooding allowance accommodates waves, which rush up the shoreline beyond the water level. The *Technical Guide* (MNR 2001a) requires a flooding allowance of 15 m, measured horizontally from location of the flood level, if a study using accepted engineering and scientific principles is not undertaken.

The dynamic beach allowance is intended to permit the natural erosion and accretion of the beach/dune system in response to variable lake levels and storm events. The *Technical Guide* (MNR 2001a) requires a dynamic beach allowance of 30 m if no study using accepted engineering and scientific principles is undertaken. The sum of the combined flooding and dynamic beach hazard allowances is 45 m measured horizontally from the position of the 100-year flood level.

The standard "default" values for the flooding and dynamic beach hazards reasonably encompass most sites on the Great Lakes. In the development of the dynamic beach hazard limit, the landward side of the first main foredune was deemed to be a reasonable limit in most situations. The Technical Guide (MNR 2001a) states:

> *"…where developments and site alterations have been directed to locations inland of the beach or dune features (i.e., landward of the first main foredune), these features often naturally prevent flood waters from reaching inland areas and absorb the erosive impacts and forces of wave action."*

As sand accumulates on a beach, an embryo dune will begin to form. Eventually the embryo dune grows high enough to be termed the foredune. The first main foredune is the first fully formed sand dune nearest the lake. A detailed description of beach and dunes processes is provided in the *Technical Guide* (MNR 2001a).

In addition to the flooding and dynamic beach hazard allowances, an erosion allowance must also be considered where appropriate. The erosion allowance is intended to accommodate long-term recession of the shoreline. Application of the recession allowance is applicable at dynamic beach sites within NPCA's Lake Ontario jurisdiction where barrier beaches at creek mouths are retreating in tandem with the overall recession of the shoreline.

The Technical Guide (MNR 2001a) outlines several circumstances under which natural factors may require redefining the landward limit of the dynamic beach hazard based on field investigations that may result in the dynamic beach hazard limit being adjusted lakeward. These include:

- Where a cliff or bluff, consisting of cohesive sediments or bedrock, exists landward of the beach, the toe of the bluff/cliff acts to limit the landward extent of dynamic beach profile adjustment. In these areas the dynamic beach hazard limit should be defined as the toe of the cliff or bluff (Figure 4.9). The stable slope allowance and the erosion allowance should be applied to the cliff/bluff.

- Where the dynamic beach exists on a narrow barrier system, the landward limit of the dynamic beach hazard may fall within the marsh or bay that exists landward of the barrier. In these areas the dynamic beach hazard limit should be defined by the toe of barrier slope on the landward side (i.e., intersection of the unconsolidated material and the marsh or bay bottom) (Figure 4.10). In addition, it should be noted that most barrier beach configurations retreat in tandem with the adjacent shores and are thus subject to consideration of the erosion hazard limit. Barrier beaches are essentially depositional features resulting from alongshore transport of sediment and are formed when the beach and any associated dune system is separated from the mainland by a bay, lagoon or marsh area. The profile of the barrier generally consists of the barrier platform, which is deposited on the underlying lakebed by sediments being transported along the shoreline, and of the sub-aerial beach, dune and back-barrier system built on the barrier platform by wave and wind action (*Technical Guide*, MNR 2001a).

- On some low shoreline plains the beach and associated dune deposits, or cobble deposits in the case of cobble beaches, may be of such low height and width that the flooding hazard is at a higher elevation or extends landward of the beach deposits. In this case the landward limit of the dynamic beach hazard is mapped as the lesser of the landward boundary between the beach and associated dune deposits and the material forming the low plain or 30 metres measured landward from the first break in slope on the lee side of the first dune (Figure 4.11).

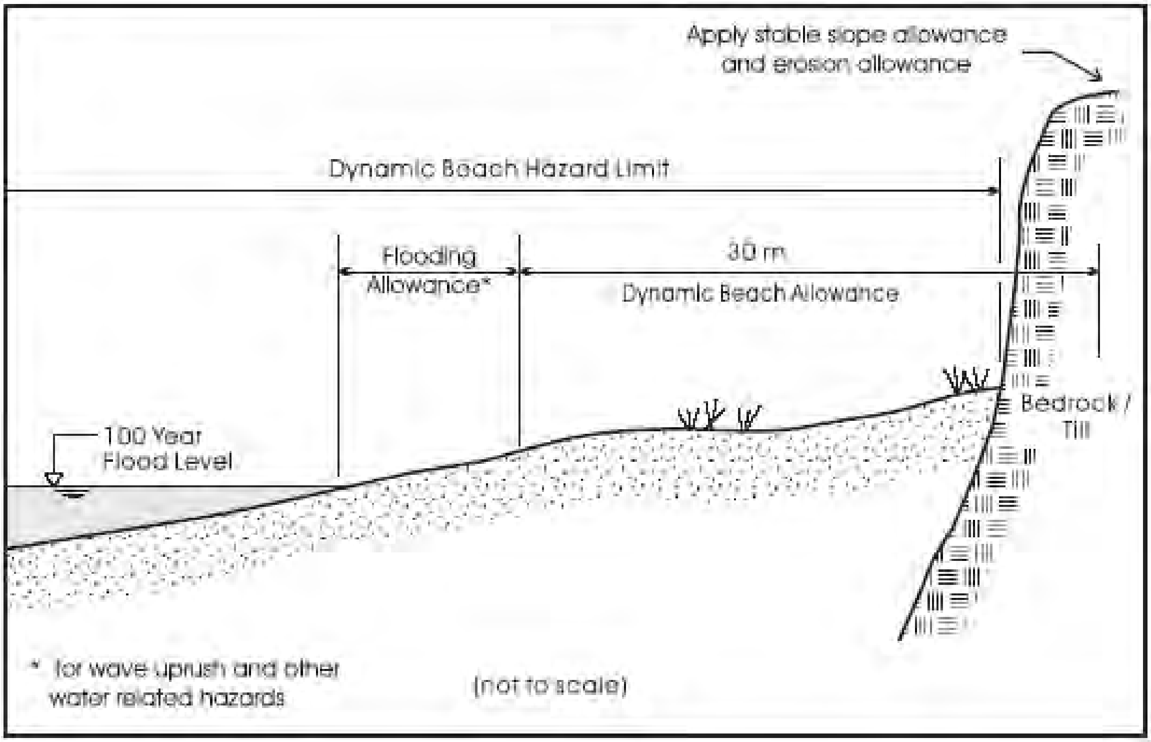


Figure 4.9 Dynamic Beach Hazard Limit Backed for Bluff

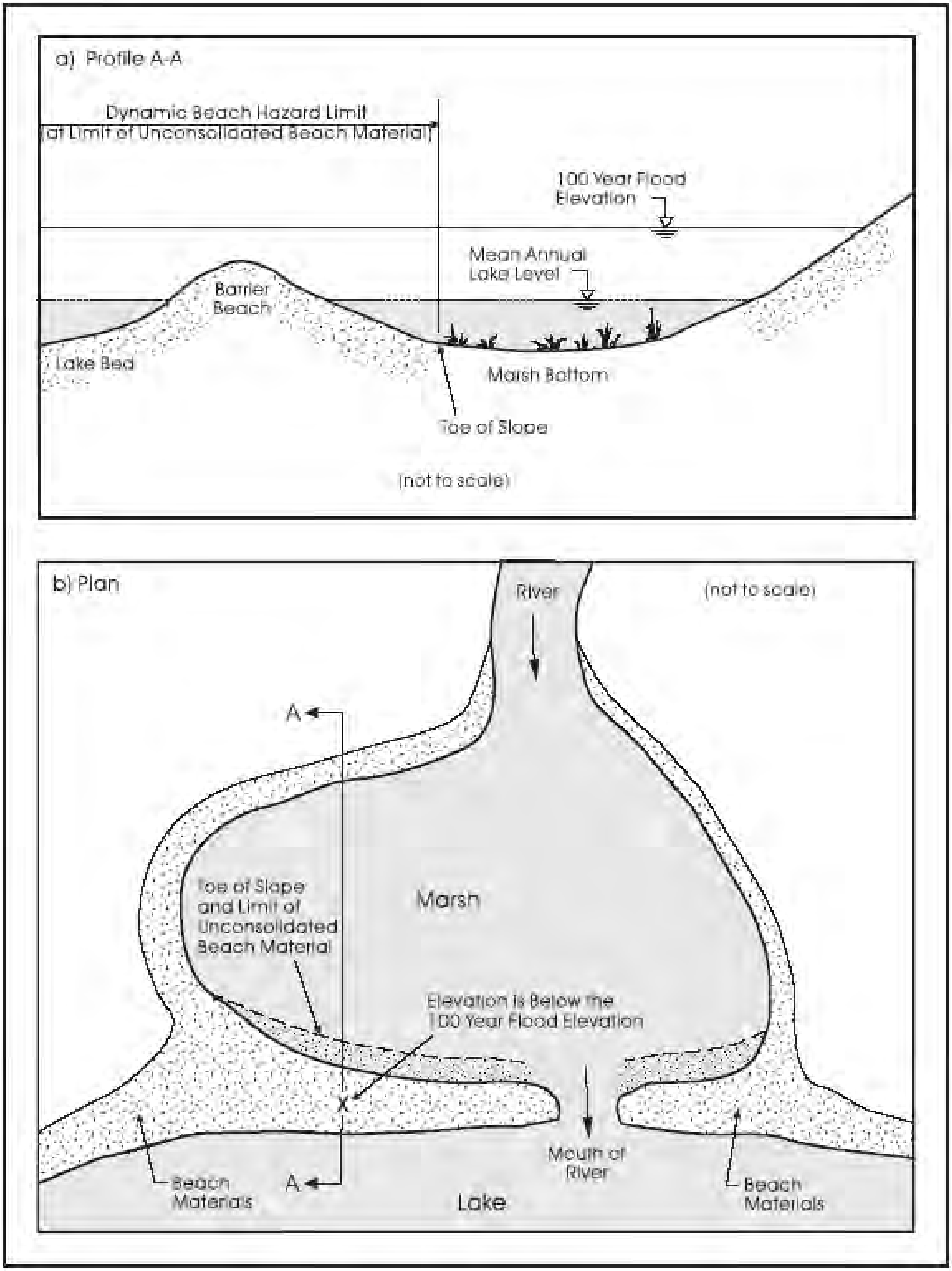


Figure 4.10 Dynamic Beach Hazard Limit for Narrow Barrier System

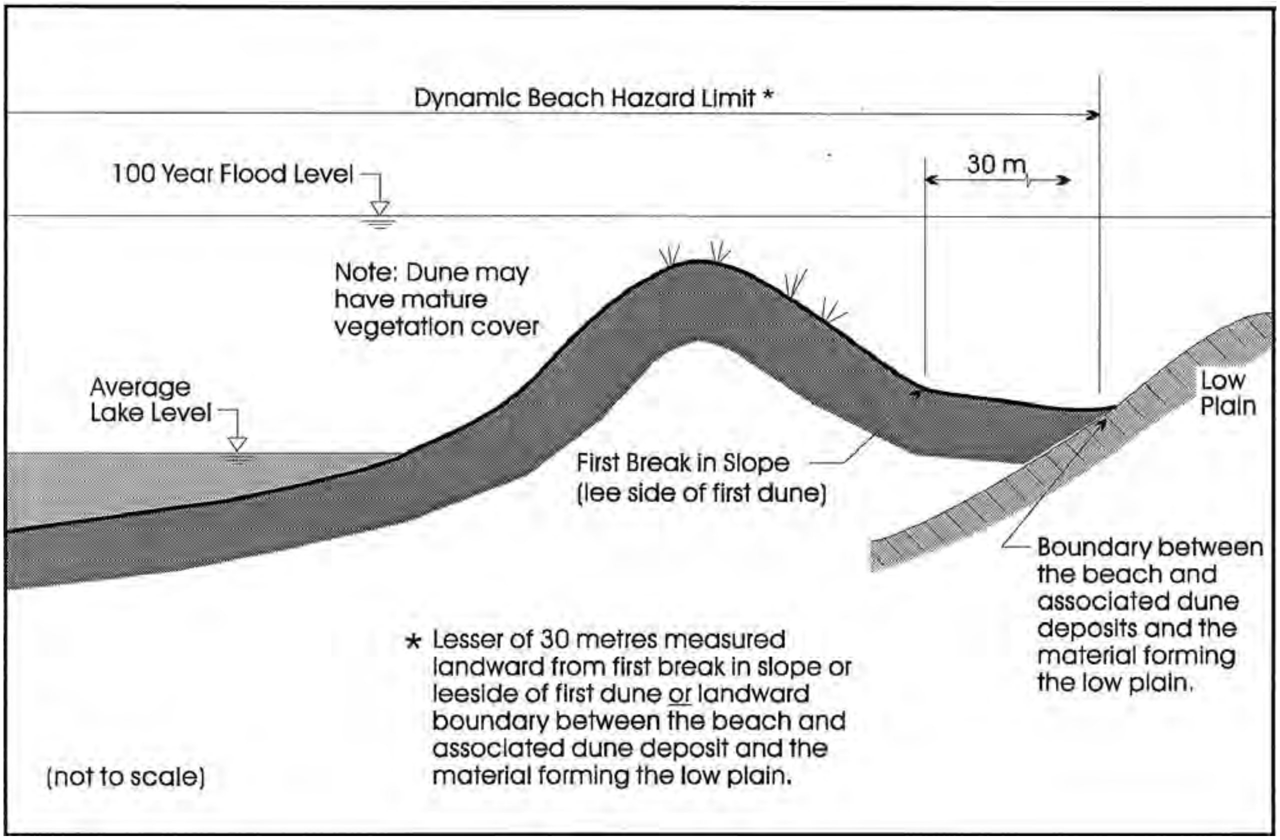


Figure 4.11 Dynamic Beach Hazard for a Beach Profile Lower than the 100 Year Flood Level

On dynamic beaches backed by a cliff or bluff, the calculation and definition of the erosion hazard is applied to the cliff or bluff feature and as such, recession of the beach is accounted for in the determination of the landward limit of the erosion hazard for the cliff or bluff feature. For shorelines involving low plain beach and barrier beach classifications, however, there is no explicit inclusion of an erosion allowance to address shoreline recession. The primary reason for this is the difficulty associated with obtaining precise and accurate measurements of the average annual recession rate on these shoreline types. However, where shoreline managers have found evidence that shoreline recession is occurring on these shoreline types, efforts should be taken to obtain the best estimate of the recession rate and to incorporate this measurement into the determination of the landward limit of the dynamic beach hazard. As noted previously, most barrier beach configurations retreat in tandem with the adjacent shores and are thus subject to consideration of the erosion hazard limit.

The *Technical Guide* (MNR 2001a) provides for the flexibility to undertake a study, using accepted scientific and engineering principles to determine the landward limit of the dynamic beach hazard to replace the default 45 m value, as measured from the 100-year flood level. A proper study to further evaluate the dynamic beach limit typically involves a two-step process. The first step is an initial site reconnaissance to determine if further, more detailed analysis would be warranted. The initial reconnaissance would be accompanied by a review of existing data on the coastal processes and geomorphology of the area. The second step involves site specific field surveys of the nearshore and beach/dune profiles, compiling offshore bathymetric data, collecting sand samples and testing for grain size, determining design flood levels and wave conditions and numerical modeling of the likely limit of the dynamic beach hazard under storm and high water conditions using appropriate cross-shore beach profile models.

4.4.2 Identifying Dynamic Beaches

The 1994 LOSMP identified dynamic beaches in Reaches 0 (fillet beach east of Fifty Mile Point), 18 (Jordan Harbour), 24 (Sixteen Mile Creek to Fifteen Mile Creek), 28 (Lakeside Park, Port Dalhousie), 34 (Municipal Beach, St. Catharines), 37 (Jones Beach, St. Catharines), 41 (Eight Mile Creek, Niagara-on-the-Lake), 50 (Four Mile Creek) and 52 (Two Mile Creek). Note that Table 2 in the 1994 LOSMP contains typographical errors; the description of the "Onshore Shoreline Type" for Reaches 41 and 42 should be interchanged and Reach 0 should be shaded to indicate it contains a dynamic beach. The dynamic beach hazards at these sites were identified and mapped in accordance with the *Technical Guide* (MNR 2001a). The locations of the dynamic beaches are shown in Figure 4.12 and are described as follows:

- Reach 0, Fifty Point: The dynamic beach east of the headland at Fifty Point is a fillet beach; it was formed by accretion of longshore sediment that was trapped following the construction of the large headland. A fillet beach is typically adjacent to a headland or shore-perpendicular jetty and is roughly triangular in planform. Longshore transport is described in the 1994 LOSMP. The beach is virtually inundated by the 100-year flood level and the dynamic beach limit extends only to the backshore bank (consolidated material). No recession rate has been determined due to formation of the fillet beach. However, a minimum 30 m erosion allowance has been applied.

- Reach 18, Jordan Harbour: The shoreline at Jordan Harbour (see Figure 4.13) was most likely a barrier beach that has been altered extensively with the presence of the highway infrastructure. For the purpose of this study, the dynamic beach hazard was mapped as the approximate limit of the toe of the barrier slope on the landward side (i.e., intersection of the unconsolidated material and the marsh or bay bottom, see Figure 4.10). The erosion hazard includes a 30 m erosion allowance.

- Reaches 24a and 24c, Sixteen Mile Creek and Fifteen Mile Creek: Both dynamic beaches are barrier beaches. At Reach 24a, the dynamic beach hazard is limited by the backshore bluff and by the toe of the barrier slope on the landward side (i.e., intersection of the unconsolidated material and the marsh or bay bottom, see Figure 4.10). The toe of the barrier slope on the landward side defines the dynamic beach hazard at Reach 24c. A 60 m erosion allowance has been included.

- Reach 28, Lakeside Park: The beach at Lakeside Park may possibly be the remnants of a barrier beach that now appears more as a fillet beach that is anchored by the west jetty at Port Dalhousie (see Figure 4.14). The dynamic beach hazard was mapped at the transition from the unconsolidated beach materials to the low plain. The beach does not appear to be recessional but due to the overall recessional nature of the shoreline, a 30 m erosion allowance has been applied. The flood hazard is located further landward.

- Reach 34, Municipal Beach: The beach at Municipal Beach is a fillet beach on the west side of the jetty at Port Weller. The dynamic beach hazard was mapped at the standard 30 m from the flood hazard, except towards the westerly end where it is limited by the estimated backshore bank and/or transition from the unconsolidated beach materials to the low plain. The shoreline does not appear to be recessional but due to the overall recessional nature of the shoreline, a 30 m erosion allowance has been applied.

HCCL (2006) completed an evaluation of the dynamic beach sites within Niagara-on-the-Lake and provided the following summary:

- Reach 37, Jones Beach (Port Weller East): HCCL (2006) defines the dynamic beach limit at the transition from the unconsolidated beach materials to the low plain (typically the landscaped edge of the condominium development). No recessional data is defined, but for this update study a 30 m erosion allowance has been used in the erosion hazard due to the overall recessional nature of the shoreline.

- Reach 41, Eight Mile Creek Barrier Beach: HCCL (2006) correctly notes there was a typographic error in Table 2 of the 1994 LOSMP; the description of the "Onshore Shoreline Type" for Reaches 41 and 42 should be interchanged. HCCL (2006) estimated a recession rate of 1.7 m/yr, based on a comparison of aerial photographs, which is consistent with the 2.0 m/yr estimate in the 1994 LOSMP; 2.0 m/yr was applied in this study. The erosion hazard is the most landward hazard defined for this reach. Due to inundation of the barrier beach at the 100-year flood level, the dynamic beach extents have been defined at the toe of the barrier slope on the landward side of the barrier (see Figure 4.7).

Figure 4.12 Dynamic Beach Locations

Figure 4.13 Jordan Harbour, Reach 18

Figure 4.14 Lakeside Park Dynamic Beach, Reach 28

- Reaches 49 and 50, Four Mile Creek Beach: Reach 50 was identified as a dynamic beach in the 1994 LOSMP. HCCL (2006) reports that Reach 49 should also be defined as a barrier beach. This has been accepted for this study. Based on the inundation of the beach profile by the 100-year flood level, the dynamic beach limit was defined at the expected transition between the unconsolidated beach material and the low plain. This line was established by HCCL (2006) on the basis of the location of the historic river mouth, and established mature trees. For this study a recession rate of 0.8 m/yr is applied to Reach 49. Reach 50 is described as a barrier beach. HCCL (2006) reports that a review of historic aerial photographs is inconclusive with respect to recession and the recession rate used in the 1994 LOSMP (1.2 m/yr) was reduced to 0.8 m/yr for this study. HCCL (2006) note that the barrier beach is inundated by 100-year flood level and recommend that the dynamic beach limit be defined at the toe of the barrier slope on the landward side of the barrier and that the erosion allowance be included. The erosion hazard is the most landward hazard defined for this reach.

- Reach 52, Two Mile Creek Barrier Beach: A review of historic aerial photographs by HCCL (2006) is inconclusive at this location; therefore they recommend no change to the estimated shoreline recession rate proposed in the 1994 LOSMP. The 100-year flood level inundates the barrier beach, and therefore HCCL (2006) defines the dynamic beach limit at the toe of the barrier slope on the landward side of the barrier. Given the recessional nature of the adjacent reaches and the riverine setting landward of the barrier beach, HCCL (2006) includes the erosion hazard limit based on 1994 LOSMP recession rate. The erosion hazard is the most landward hazard defined for this reach.

It should be noted that in describing the attributes of the specific dynamic beaches in Niagara-on-the-Lake, HCCL (2006) reports that the erosion hazard limit is not defined for areas of dynamic beach. However, this is inconsistent with earlier text in Section 3.4 of their report which states *"Where the dynamic beach has been found to be erosional or receding, the landward limit of the dynamic beach would also include a horizontal distance representing 100 times the average annual recession rate."* In fact, HCCL actually does apply an erosion allowance. Providing an erosion allowance for recessional dynamic beaches is consistent with the intent of the *Technical Guide* (MNR 2001a), as can be seen in Figures 4.8 and 4.9, and has been applied in this study.

5.0 MAPPING THE HAZARDS

In accordance with the project scope, this study focused on updating the flooding, erosion and dynamic beach hazards in the area from Fifty Point to Port Weller (Reaches 0 to 36); the remainder of the study area, from Port Weller to Mississauga Point in Niagara-on-the-Lake (Reaches 37 to 58) was previously updated through the mapping prepared by HCCL (2006) for the 2008 Niagara-on-the-Lake Watershed Plan.

The flooding, erosion and dynamic beach hazard lines have been derived from the 1:2000 scale digital terrain model (DTM) and orthoimagery and do not consider the effect of local irregularities and physical shoreline conditions that may affect site specific hazards. Where development is proposed, the location of the hazard limits should be reviewed with regard to the most recent and detailed site information available, with due consideration to the effect of adjacent shoreline conditions and associated hazards.

5.1 Fifty Point to Port Weller (Reaches 0 to 36)

The steps undertaken to map the hazard limits From Fifty Point to Port Weller (Reaches 0 to 36) are consistent with the *Technical Guide* (MNR 2001a), as described in Section 4.0, and are summarized as follows:

- 100-Year Flood Level: The 100-year flood level was derived using automated contour extraction from the NPCA's 2002 Digital Elevation Model (DEM).

- Flood Hazard Limit: The flood hazard limit was delineated using the 100-year flood level as a baseline and then mathematically generating, for each reach segment, a spatial buffer tool to add a wave uprush allowance of 15 metres, measured horizontally.

- Toe of Bluff: According to the *Technical Guide* (2001a) "toe and top of the cliff, bluff, or bank positions usually correspond with contour lines on topographic maps, with visible changes, often in slope, on aerial photographs…" For this study, the toe of bluff feature was traced by visually interpreting from the 2006 airphoto, using "heads-up digitizing" onscreen within a GIS environment at a map resolution of about 1:1,000-scale; where clarification was needed other supplemental datasets were used, including the topographic contours and the colour 2002 airphotos. The toe of bluff line is segmented to match each Reach segment.

- Stable Slope Allowance: The stable slope allowance (SSA) was calculated uniquely for each Reach. The SSA was mathematically generated using a spatial buffer tool with the toe of bluff lines as the base and 3 times the bluff height. The average bluff height was determined on a per reach basis by reviewing the 2002 topographic contours at 1 metre intervals and by averaging a number of bluff height measurements within the reach. The number of height measurements taken was determined by the reach length; for reaches under 2 km in length, bluff height measurements were taken every 200 metres and for reaches over 2 km in length, a total of 10 bluff height measurements, representative of the entire reach length, were taken.

- Erosion Hazard Limit: The landward limit of the erosion hazard is the sum of the stable slope allowance plus 100 times the average annual recession rate (i.e., 100 year recession; recession rates in Table 4.3) measured landward from the toe of the shoreline cliff, bluff, or bank. It was mathematically generated for each reach segment, using a spatial buffer based on the toe of bluff line. Where the shore was intersected by a relatively narrow creek or watercourse, the erosion and flood hazards were simply extended across the creek mouth. At larger rivers, the erosion and flood hazards were extended up the river, following the banks, until they intersected with the river flood hazard lines.

- Dynamic Beach Hazard: The dynamic beach hazard limit was mapped as the flood hazard limit plus 30 m or as described in Section 4.4.

5.2 Port Weller to Mississauga Point (Reaches 37 to 58)

The hazard mapping for Niagara-on-the-Lake from Port Weller to Mississauga Point (Reaches 37 to 58) was taken from HCCL (2006) and is summarized as follows:

"A general update of the Regulatory Hazard Limits was also completed. This update was based on a review of the updated topographic model and aerial images. The hazard lines were re-established on the basis of the most recent information available to the Study Team. The majority of the shoreline shows relatively little change since the 1994 mapping was completed; there are some areas of minor to moderate recession, which are consistent with dynamic shoreline areas. In general, the shoreline recession over the last 10 years is somewhat less than that which would be predicted by the recession estimates presented in the 1994 report. This is in part due to the effect of shoreline protection works."

NPCA provided a digital vector dataset of the regulation mapping with the shoreline hazard mapping that included mapping features from both the 1994 LOSMP and the hazard mapping developed by HCCL (2006). The hazard mapping developed by HCCL (2006) was used for this study with the exception of the flood level, which was revised to 76.15 m GSC (see Section 4.2.2) and the erosion hazard limit at selected reaches where the recession rate was adjusted as a result of this study (see Section 4.3.4). In addition, to maintain consistency in appearance, the hazard mapping was augmented by the addition of the toe of slope and the stable slope allowance (see Section 5.1). The hazard mapping provided for Niagara-on-the-Lake was not adjusted in this study to reflect the minor modifications of the reach boundaries (see Section 3) on the overall mapping.

HCCL (2006) "suggested that Hazard Lines should be interpreted with the following considerations in mind.

- The location of the various hazard lines has been derived on the basis of aerial photography interpretation and digital topographic modelling, and does not consider the effect of local irregularities in the physical shoreline conditions that may affect the site specific hazards. Where development is proposed, the location of the Regulatory Hazard Limits should be reviewed with regard to the most recent and detailed site information available, with due consideration to the effect of adjacent shoreline conditions and associated hazards.

- The Regulatory Flood Hazard Limit has been developed on the basis of a 100 year Regulatory Flood Limit [76.15 m as discussed in Section 4.2.2] with a 15 m offset to account for water related hazards.

- The Regulatory Erosion Hazard Limit has been developed on the basis of a stable slope consideration (3:1) and an offset equivalent to 100 times the estimated average annual recession rate. The effect of protection works is not necessarily well accounted for in the estimate of recession rates.

- The Regulatory Dynamic Beach Hazard Limit has been developed as per the discussion presented…".

6.0 DEVELOPMENT WITHIN HAZARD LANDS AND SHORELINE PROTECTION

6.1 Shoreline Development and the *PPS* and Ontario Regulation 155/06

Prevention is the preferred approach for management of the Great Lakes shoreline hazards as it reduces or minimizes losses by modifying the loss potential by controlling, restricting and/or prohibiting development activities within the hazardous lands. The *Provincial Policy Statement* (2005) states that development shall generally be directed to areas outside of hazardous lands adjacent to the shorelines of the Great Lakes which are impacted by flooding hazards, erosion hazards and/or dynamic beach hazards.

As discussed in Section 4.1 of this report, the *PPS* (2005) prohibits development within the dynamic beach hazard.

The *PPS* (Section 3.1.6) does allow that development and site alteration may be permitted in those portions of the flood and erosion hazard lands "where the effects and risk to public safety are minor so as to be managed or mitigated in accordance with provincial standards, as determined by the demonstration and achievement of all of the following:

a) development and site alteration is carried out in accordance with floodproofing standards, protection works standards and access standards;

b) vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies;

c) new hazards are not created and existing hazards are not aggravated; and

d) no adverse environmental impacts will result."

The inclusion of these requirements under Section 3.1.6 is intended to provide flexibility to recognize local conditions (*Technical Guide*, MNR 2001). Areas of existing development are one specific local condition that is explicitly recognized in the *Technical Guide* as appropriate for consideration of flexibility in applying the requirements of the protection works standards (i.e., see Appendix A7.2, Existing Development Within the Hazardous Lands).

Ontario Regulation 155/06 states the Authority may grant permission for development in regulated areas if in their opinion the control of flooding, erosion, dynamic beaches, pollution or the conservation of land will not be affected by the development.

6.2 Addressing Flood and Erosion Hazards

As outlined in Section 6.1, development and site alteration may be permitted in those portions of the flood and erosion hazard lands where the effects and risk to public safety are minor so as to be managed or mitigated in accordance with floodproofing standards, protection works standards and access standards.

6.2.1 Floodproofing Standard

Floodproofing is generally defined as a combination of structural changes and/or adjustments incorporated into the basic design and/or construction or alteration of individual buildings, structures or properties subject to flooding hazards so as to reduce the risk of flood damages, including wave uprush and other water related hazards. Floodproofing and flood protection works can only reduce the risk and/or lessen the damage to properties. No measure will prevent all damages due to flooding. Where it has been determined that development and site alteration could possibly be located within the less hazardous portion of the flooding hazard, the floodproofing standard should be applied. The minimum floodproofing standard is as follows: development and site alteration is to be protected from flooding, as a minimum, to an elevation equal to the sum of the 100 year monthly mean lake level (elevation 75.56 m GSC) plus the 100 year wind setup (0.94 m Reaches 0 to 14; 1.06 m Reaches 15 to 58) plus a vertical flood allowance for wave uprush and other water related hazards determined on a site specific basis.

6.2.2 Protection Works Standards

By definition (*PPS*, Section 6.0 Definitions), protection works standards "means the combination of non-structural or structural works and allowances for slope stability and flooding/erosion to reduce the damages caused by flooding hazards, erosion hazards and other water-related hazards, and to allow access for their maintenance and repair" (PPS 2005). The *Technical Guide* (MNR 2001a), developed in support of the *PPS*, outlines specific guidelines for the protection works standard including protection works, the stable slope allowance and the erosion hazard allowance.

The three key elements of the protection works standard are described in the *Technical Guide* (MNR 2001a) as follows:

- Protection works should be of sound, durable construction and be designed by a qualified coastal engineer according to accepted practice;

- Protection works should be used in conjunction with appropriate stable slope and hazard allowances; and

- There must be access to the protection works for suitable equipment for future rehabilitation, replacement or repairs.

6.2.2.1 Planning Horizon for Development

The erosion hazard allowance is dependent on the recession rate and the planning horizon for the development. For new development, the *PPS* supports a planning horizon of 100 years. In areas of existing development, the *Technical Guide* (MNR 2001a) suggests that "in an infilling situation where there is good and ready access for future repairs or replacement, it may be appropriate to permit a lesser hazard allowance provided the protection works are substantial and well designed." Infilling is described as development on undeveloped lots generally bounded by existing development of adjacent sides.

6.2.2.2 Shoreline Protection Structure Design Life

Structure design life differs from the planning horizon of the project. Structure design life is the length of time that a structure, with routine maintenance, is able to safely and adequately perform its function. Structures requiring replacement or significant rehabilitation have reached the end of their useful design life. The design life of a structure can be extended beyond its original design life by rehabilitation or restoration provided sufficient funds and suitable construction access are available. Guidelines for the typical expected design life of shoreline structures are outlined in the *Technical Guide*:

- "In areas with low recession rates (i.e., 0.3 m/yr), it may be appropriate to consider that a sound, well designed, properly constructed and well maintained structure will have a life span in the order of 25 to 40 years. This assumes that proper measures have been taken to address flanking of the protection. Evidence supporting a design life longer than 40 years should be clear and convincing and should include continuous and unobstructed access to the shoreline for future maintenance and repairs." " A design life greater than 50 years generally should not be considered without compelling evidence of the long-term stability of underlying material and the likelihood that the proponent, or subsequent owners, will undertake any necessary future repairs and/or rehabilitation."

- "In areas of moderate recession rates (i.e., 0.3 m/yr to 0.7 m/yr), it may be appropriate to consider a structure design life in the order of 15 to 25 years for sound, well designed, properly constructed and well maintained structures. Due to the ongoing nearshore erosion and the potential for undermining, shoreline managers should be cautious about accepting a claim for a design life greater than 25 years. For example, along cohesive shores there are practical construction limitations to the amount of excavation that can be done to sufficiently embed the toe of the structure to provide downcutting protection."

- "In areas of high (i.e., 0.7 m/yr to 1.2 m/yr) to severe recession rates (i.e., >1.2 m/yr), undermining may become a significant concern within as little as 10 to 15 years.

In all instances a qualified coastal engineer should evaluate the life span of the structure including specific discussion of the approach to address nearshore downcutting.

6.2.2.3 Stable Slope Allowance

The stable slope allowance is defined by consideration of the geotechnical conditions at the site and the appropriate factors of safety (see Section 5.2.1). It should be noted that the stable slope allowance is determined from the toe of the natural bank behind the protection work, not from the top of the protection works.

The stable slope allowance should be applied in all situations. Development should not be permitted within the stable slope allowance, with the exception of minor structures such as staircases and walkways.

6.2.2.4 Erosion Hazard Allowance

As outlined in the *Technical Guide*, the erosion hazard allowance is determined by subtracting the design life of the protection structure from the planning horizon with the remaining number of years then multiplied by the average annual recession rate. The resultant erosion hazard allowance is then measured horizontally from the limit of the stable slope allowance. For example, considering an average annual recession rate of 0.3 m/yr, a planning horizon of 100 years and installation of protection works with a structure design life of 20 years, the erosion allowance required should be 24 m measured from the stable slope allowance ([100 years – 20 years] x 0.3 m/yr = 24 m).

For inland lots, with no direct ownership at the shoreline, and which fall within the erosion hazard limit, imposing the full erosion hazard allowance would be impractical; consideration should be given to relaxing the standard requirements. In all instances, the property owner should be advised of the long-term shoreline hazards. Flood hazards should be addressed.

6.2.2.5 Access

The design and installation of protection works must allow for access to the protection works for appropriate equipment and machinery for regular maintenance and/or repair purpose. Typically the width for access should be in the order of 5 m and should extend both to the shore and along the shore. Access is particularly important in situations where the erosion hazard allowance has been relaxed due to specific site constraints.

6.2.3 Recommended Protection Structure - Armour Stone Revetment

The 1994 LOSMP provided a discussion of alternative protection measures and recommended the armour stone revetment as the preferred structure where shoreline protection is necessary at individual properties. Representative shoreline protection structures were reviewed during this study and armour stone revetments are shown in Figures 6.1 and 6.2.

Figure 6.1 Armour Stone Revetment (Belmont Park at Beachview Drive; Site 26, Reach 22)

Figure 6.2 Armour Stone Revetment (Queens Royal Park, NOTL, Reach 5, constructed 2004)

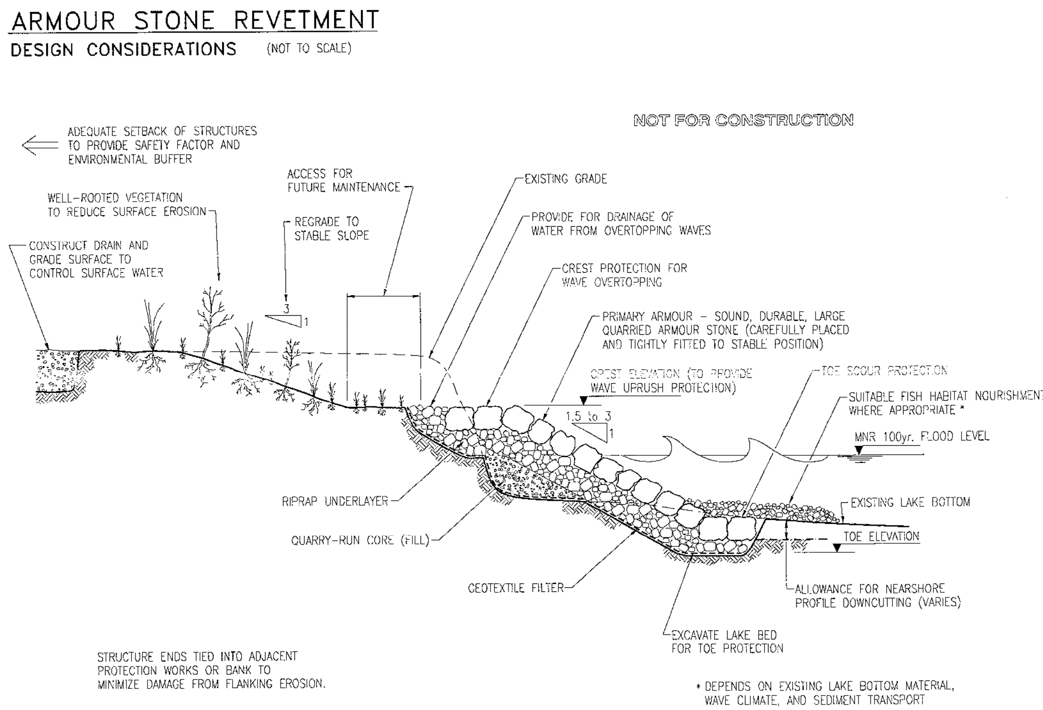


Figure 6.3 Armour Stone Revetment

It was found that well-designed and constructed armour stone revetments, using good quality, durable stone continue to be effective and the armour stone revetment remains the recommended structure if protection works are necessary. Figure 6.3 presents the recommended armour stone revetment. The primary advantages and disadvantages of the revetment were outlined in the 1994 LOSMP along with general design and construction guidelines.

Providing a proper allowance for nearshore profile downcutting (see Section 6.2.7) and coordination with adjacent properties to minimize outflanking (see Section 6.2.8) remain two key factors that will affect the expected design life and hence the erosion setback that must be provided; a stable slope allowance must also be included in the setback consideration.

Other key design features for the armour stone revetment include: sound, good quality, durable armour stone with sufficient size to resist wave action and ice; sufficient crest elevation to protect against wave overtopping; riprap underlayer; and geotextile filter to prevent loss of backfill. The armour stone size is dependent on the wave height, the inclination of the revetment slope and placement (i.e., degree of "interlocking"). Typically, the individual armour stones in an armour stone have a mass of 3 to 5 tonnes for a single layer of armour; slightly smaller stones could be used with flatter slopes or double layers. A qualifed coastal engineer should design the revetment. A double layer of armour provides more "reserve capacity" (i.e., damage to a double layer armour revetment is more progressive than damage to a single layer).

The implementation of the structure must consider the impacts to the environment. Section 6.2.9 provides further discussion of environmental considerations.

6.2.4 Stacked Seawalls

Stacked stone and block seawalls are frequently used as shore protection. Figures 6.10 and 6.11 show examples of stacked armour stone walls. Depending on the foundation conditions and the design and construction details, stacked walls have had mixed success. Figure 6.12 shows a 50 m to 60 m long concrete block wall in a 2006 aerial photograph that appears to have toppled over; in the 1994 LOSMP study, this wall had been identified as "leaning lakeward". Figure 6.13 shows an example of the ineffectual use of stacked blocks at the shoreline immediately east of Hunter Road, just east of boundary between Reaches 1 and 2, in 2009. In Figure 6.13, the concrete blocks in 2009 appear to have been scattered and are ineffective. At this location the 1994 LOSMP study site visit indicates that there was no protection and the 2003 oblique photograph (Appendix B) shows continued bluff erosion.

Stacked stone and block walls must carefully consider the foundation conditions, as they are less flexible than revetments and more prone to collapse due to settlement and undermining. Vertical, impermeable walls (e.g., concrete and steel sheet pile) are generally not recommended due to concerns with wave reflection and scour. Vertical walls are rigid and much less reserve strength (i.e., ability to withstand wave conditions exceeding the design wave) than armour revetments.

Gabion baskets often have a limited life span when used on exposed shorelines and are generally not recommended for use on the open lake. Figure 6.14 shows a collapsed gabion basket wall. Gabion baskets are not recommended for use along the open, exposed shorelines.

6.2.5 Groynes and Headlands

As described in the 1994 LOSMP, groynes and headlands (see Figure 6.15) can provide effective protection in certain circumstances. Figures 6.16, 6.17 and 6.18 show examples of anchored beaches that appear to be effective although no evaluation of potential adverse effects, if any, was carried out for this study. Groyne/headland anchored beaches are generally more complex approaches that require analysis and design by qualified coastal engineers. Potential impacts are discussed in the 1994 LOSMP and Section 6.2.9.

Figure 6.10 Stacked Armour Stone Wall (Ryerson Park, NOTL, Reach 54; constructed 1997)

Figure 6.11 Stacked Armour Stone Wall (Site 11 east of Bartlett Ave; Reach 12; constructed since 2006)

Figure 6.12 Concrete Blocks Appear to Be Toppled (Reach 26, 2006 aerial)

Figure 6.13 Ineffective Concrete Blocks (east of Hunter Road at boundary Reaches 1 and 2)

Figure 6.14 Collapsed Gabion Basket Wall

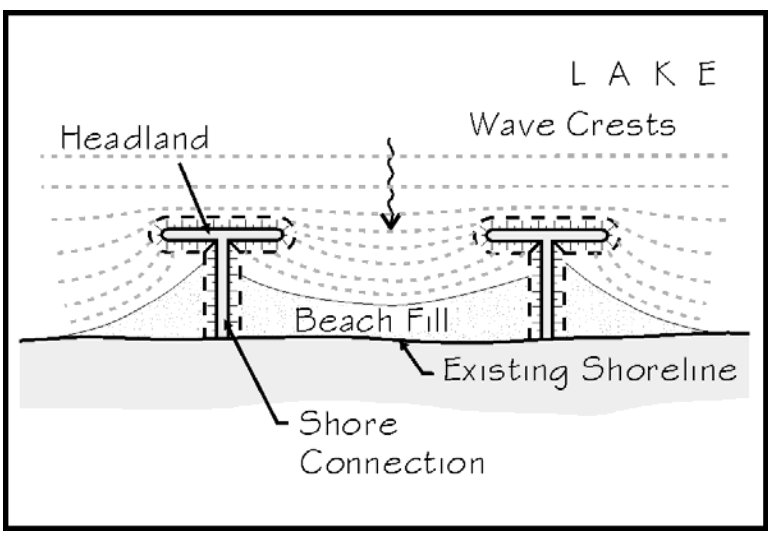


Figure 6.15 Headland Anchored Beach

Figure 6.16 Anchored Beach, Grimsby (Reach 4)

Figure 6.17 Groynes at Westerly End of Tupper Road (Reach 8)

Figure 6.18 Headland Anchored Beach and Revetment (Bal Harbour, Reach 8)

6.2.6 Ad Hoc Protection

There are extensive amounts of ad hoc protection consisting dumped stone and concrete rubble, inverted concrete pipes and miscellaneous other materials. Figure 6.19 provides an example of an ad hoc structure consisting of poured concrete over stone.   Ad hoc structures are often ineffective in the longer term due to limited or no toe embedment (i.e., lack of consideration of nearshore downcutting), lack of geotextile filters, insufficient crest height to protect against wave overtopping, and poor quality materials.

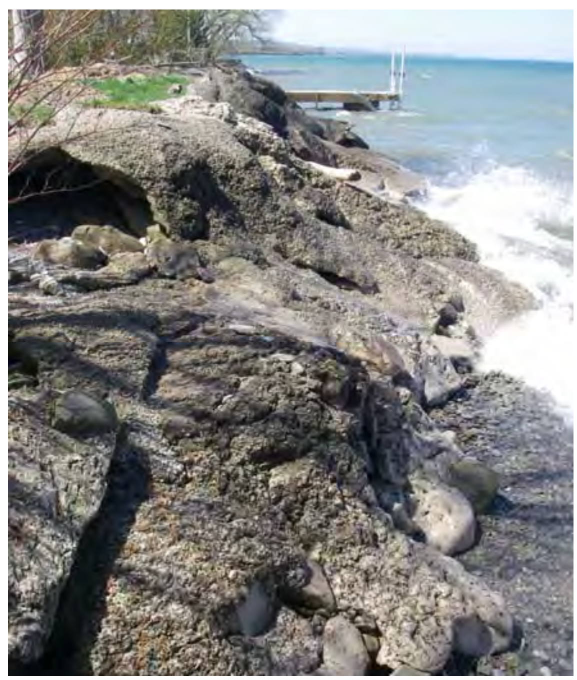


Figure 6.19 Ad Hoc Protection
(Poured concrete over stones; Site 12 , end of Sann Rd., Reach 13)

6.2.7 Allowance for Nearshore Profile Downcutting

As described in the *Technical Guide* (MNR 2001a) and the 1994 LOSMP, much of the study shoreline is cohesive. As such, the controlling process for erosion of the shore is the downcutting of the lakebed, which has significant implications for the design and lifespan of the shoreline protection. Specifically, downcutting of the nearshore lake bottom in front of the shoreline protection structure will eventually result in undermining of the structure leading to damage and perhaps failure of the structure as shown in Figure 6.20. In addition, this process will result in deeper water in front of the structure, thus allowing larger waves to attack the structure. For shore protection to be effective over the medium to long term, the design must consider the future downcutting of the lake bottom, and the larger waves, which will ultimately attack the structure. It is important to note the distinction between localized scour (see Figure 6.21) and downcutting. Localized scour, generated by wave reflection at the toe of the structure, can be addressed by proper design of scour protection.

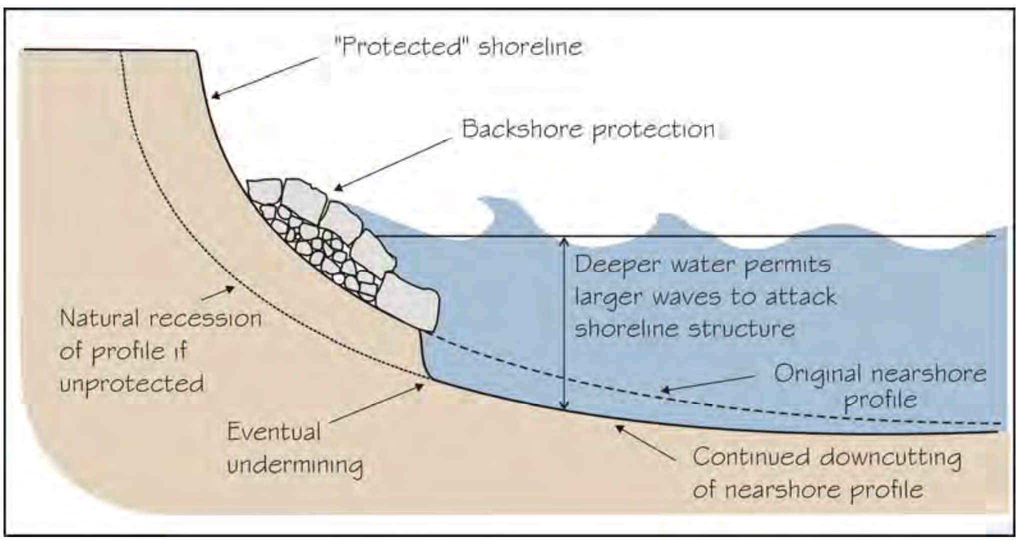


Figure 6.20 Future Undermining of Structure Due to Downcutting

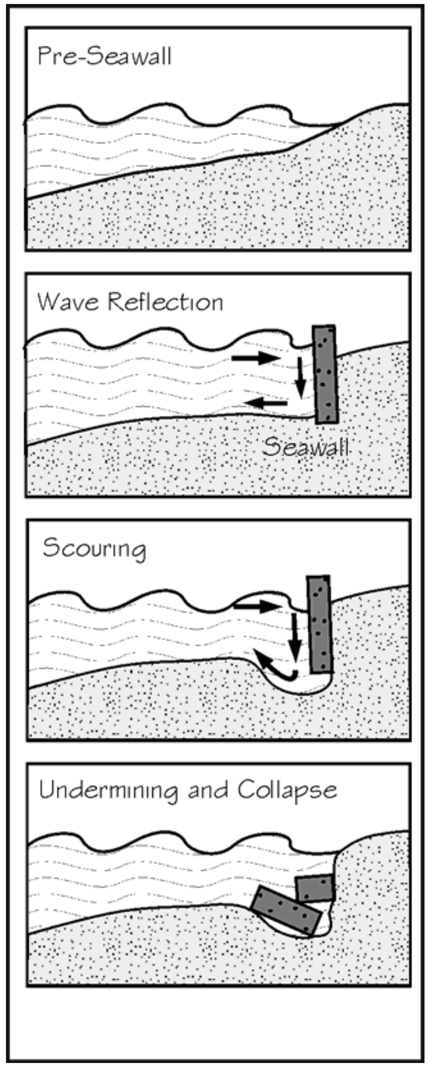


Figure 6.21 Localized Scour

6.2.8 Coordinated Protection

The importance of coordinated, cooperative protection (see Figure 6. 22) was described in the 1994 LOSMP; individual efforts are often outflanked, reducing the effectiveness and design life of the protection. Figures 6.23 and 6.24 provide examples of shoreline protection being outflanked, with recession continuing at the adjacent shoreline.

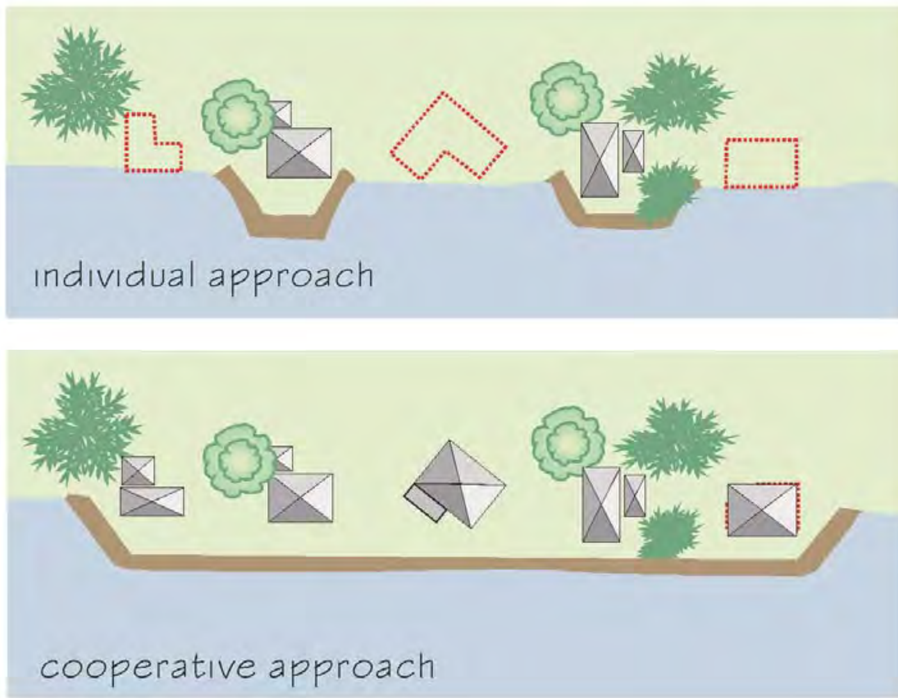


Figure 6.22 Cooperative Protection

Figure 6.23 Outflanking of Shoreline Protection (left hand side; Reach 2 at Casablanca Blvd.)

Figure 6.24 Outflanking of Shoreline Protection (right hand side; 13th Street Road Allowance)

6.2.9 Increased Consideration of Environmental Impacts

Recognition of the potential environmental impacts of shoreline protection has increased since the 1994 LOSMP. The environmental impacts were discussed in the 1994 LOSMP but three particular aspects now require greater consideration

1. Loss of fish habitat;
2. Cumulative impact of reducing sediment supply; and
3. Diverting and/or blocking longshore transport.

Fisheries and Oceans Canada Technical Fact Sheet T-6 states that the high water mark (HWM) is the guideline elevation that is used by DFO in the review of development projects in or near water to determine the minimum elevation that will be considered as the boundary for fish habitat. The HWM corresponds to the 80th percentile elevation for the month in which the highest annual water level occurs. For Lake Ontario, the HWM elevation is 75.32 m IGLD85. The effect of the strict application of this requirement the protection structure must be located further shoreward than was typically the case at the time of the 1994 LOSMP; moving the structure further into the shoreline requires more excavation of the existing bluff.

Successful shoreline protection, by definition, will reduce erosion of the shore. As described in the 1994 LOSMP, erosion of the bluffs and nearshore generate the sediment that forms the beaches at the shoreline. Reduction of the bluff supply by placing shoreline protection will impact, cumulatively over time, the downdrift beaches by reducing the supply of new sediment to the beaches while the existing sediment at the beach is lost through natural degradation and abrasion.

Structures that extend into the nearshore have the potential to trap sediment on the updrift side as well as divert or deflect sediment offshore, resulting in possible downdrift erosion (see Figure 25).

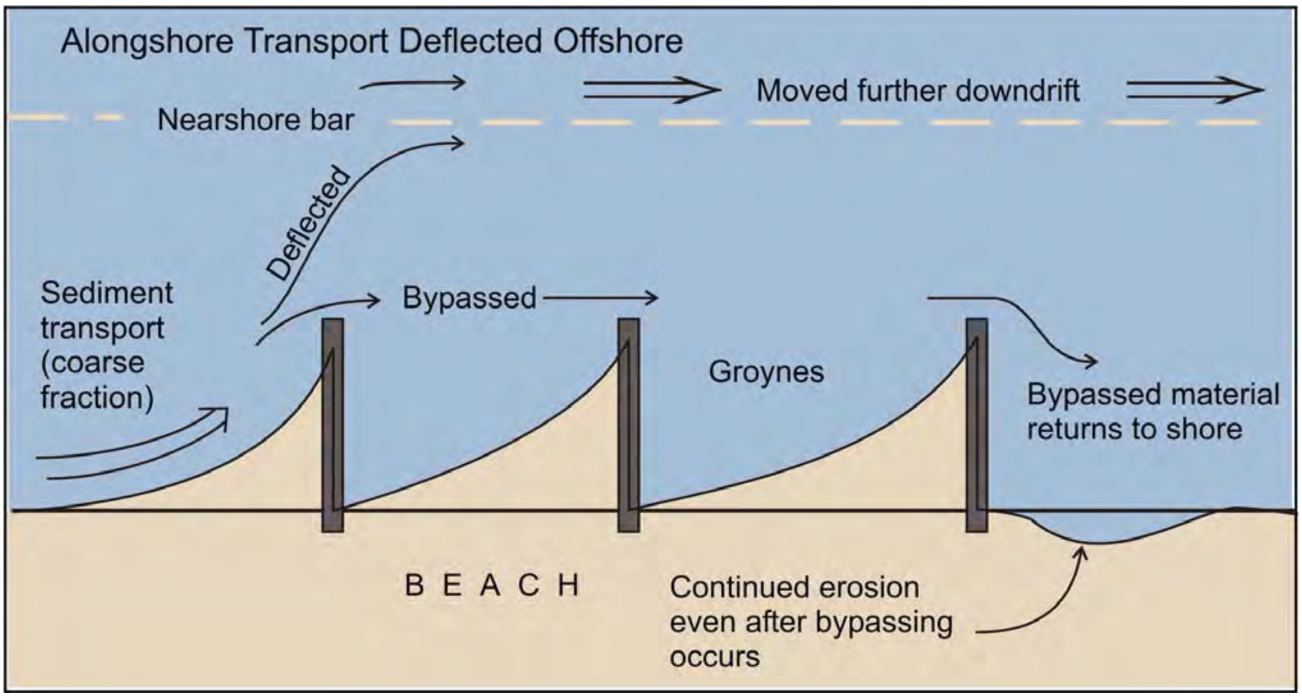


Figure 6.25 Potential Impacts of Groynes

6.3 Addressing Dynamic Beach Hazards

Along dynamic beach shorelines, the simplest, most effective and most desirable approach to addressing the hazard is to setback all permanent construction such as buildings, roads, and parking lots, landward of the dynamic beach hazard limit (i.e., landward of the area that will be affected by wave action and other natural beach processes). The *PPS* (2005) prohibits development within the dynamic beach hazard.

For areas where development has already taken place within the dynamic beach hazard, the *Technical Guide* (MNR 2001a) provides guidance on addressing the hazard on non-erosional and erosional dynamic beaches. As presented in the *Technical Guide*, a "non-erosional" dynamic beach is defined as one where there is no measurable recession rate and no evidence of longterm shoreline recession. A "non-erosional" dynamic beach shoreline will exhibit movement in the beach profile, in response to water level variations and wave action, but the overall, long-term position of the shoreline will remain constant.

The *Technical Guide* provides a preferred order to implementing the potential range of responses to addressing the hazard where development already exists within the dynamic beach hazard limit on a non-erosional beach:

1. Relocate buildings, roads, and other facilities to a position landward of the dynamic beach hazard limit. This in turn will permit removal of retaining walls and shore protection structures such as revetments, walls and groynes from the dynamic beach hazard limit.

2. Where existing buildings, roads and other facilities are located near landward margin of the dynamic beach hazard limit and are subject to wave action only infrequently (i.e. less than once every 10 years) they may be protected by changes to the structure itself to minimise the impact of wave action and to reduce interference with the natural processes. Such changes could include raising the structure on stilts or removing porches and windows at low levels.

3. Protection in the form of a wall or revetment may be used to prevent wave action from reaching a building. However, this should be placed next to the primary building itself and as far away from the beach as possible in order to minimize impact on normal beach processes. Seawalls, revetments and other protection works positioned for the protection of non-essential structures and features, including but not limited to ancillary structures (e.g., gazebos, sheds etc.), lawns and/or other landscaping features, and which extend into the dynamic beach hazard, should not be permitted.

4. Where existing buildings, road and other facilities are located so close to the beach that they are subject to wave action more than once every ten years, then a greater degree of protection than set out in 3 above will be required. This should be permitted only in exceptional cases where it is essential for the operation of the facility that it remains located in this area, otherwise the preferred solution is relocation. In this case it is likely that the hazard will be overcome by constructing some form of seawall or revetment close to the building. The protective structure should be designed to minimize impact on the beach in front of the property and on adjacent beaches. However, it should be recognized that it is impossible to build a structure within this zone without having a significant impact on the beach environment. Alternative approaches that involve either building out of the beach, through trapping of sand in groynes, or behind detached breakwaters, are likely to have an even greater impact on downdrift areas and are therefore even less desirable.

Where one of the first three approaches is taken, the protection afforded by the beach and associated dunes on a sandy beach can be enhanced by promotion of dune development through protection of the natural dune vegetation and through measures designed to minimize the impact of activities on the vegetation and the dune form. These will promote deposition of sand within this zone as well as preventing losses of sediment inland. Boardwalks, boat houses and other similar facilities should be made removable so that they are placed during summer months and removed during the period of maximum storm activity in the spring and fall, and so that their location can be adjusted to long-term lake level fluctuations.

At erosional dynamic beaches, where there is existing development, relocation landward of the dynamic beach hazard limit is also the preferred alternative, particularly if existing development is close enough to the water to interfere with normal beach processes. Where it is not possible to do this, protection against waves and other water related hazards could be accomplished using the four alternatives described for non-erosional dynamic beaches. However, it should be recognized that the frequency and magnitude of the hazard would increase through time as the shoreline position recedes, and the structure becomes located further and further into the nearshore zone. Thus the effectiveness of the approach chosen will decrease. Ultimately, as the shoreline recedes, the shoreline will reach the building or other facility. Thus, measures 2, 3, and 4 outlined for non-erosional beaches, do not provide a permanent solution on an eroding beach and their longevity will need to be assessed carefully, along with the possible environmental impact of them.

6.4 Shoreline Protection Mapping Classification

This study included mapping shoreline protection features. The shoreline protection features were identified from the 2002 and 2006 aerial photography and classified as one of the following types:

Walls	-Stacked Armourstone -Stacked Block -Concrete -Steel Sheet Pile -Gabion
Revetments	-Armourstone -Concrete Block
Groynes	
Headlands Anchored Beaches Ad Hoc	

Actual structures may vary.

7.0 REFERENCES

Aquafor Beech Ltd., 2008. Niagara-on-the-Lake Watershed Plan

Baird, 2006. Detailed Study Sites for the Coastal Performance Indicators. A report prepared for Buffalo District United States Army Corps of Engineers, Prepared by W.F. Baird & Associates Coastal Engineers Ltd., Dec. 31, 2006

Collier, K. (Michael Baker Corporation), 2008. Personal Communications Regarding the Draft Guidelines and Specifications for Flood Hazard Mapping in the Great Lakes Basin for the FEMA National Flood Insurance Program.

EurOtop, 2007. Wave Overtopping of Sea Defences and Related Structures: Assessment Manual. Prepared by the Environment Agency, UK, Expertise Netwerk Waterkeren, NL, and Kuratorium fur Forschung im Kusteningenieurwesen, DE.

FEMA, 2007. Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, Draft Final Report, Federal Emergency Management Agency, February.

Geomatics International, 1992. Great Lakes Shoreline Classification and Mapping Study: Canadian Side, Final Report.

HCCL, 2006. Niagara-on-the-Lake Dynamic Beach Evaluation and Regulatory Shoreline Hazard Update. Report prepared by HCCL for Aquafor Beech Ltd., April.

Hegler, D.P., 1974. Lake Ontario Shoreline Erosion in the Regional Municipality of Niagara. Unpublished M.A.Sc. Thesis, Civil Engineering, University of Waterloo.

Lake Ontario – St. Lawrence River Study Board (LOSLRSB), 2005. Options for Managing Lake Ontario and St. Lawrence River Water Levels and Flows, Pre-Release Final Report. A Report of the International Lake Ontario - St. Lawrence River Study Board to the International Joint Commission, November 10, 2005.

Matyas, E.L., 1976. Shoreline Erosion in Western Lake Ontario, Part II, Geotechnical Factors Affecting Shoreline Erosion and Bluff Stability, Deptment of Civil Engineering, University of Waterloo.

Ministry of Natural Resources/ Conservation Ontario (MNR/CO), 2008. Draft Guidelines to Support Conservation Authority Administration of the "Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation", prepared by Section 28 Peer Review and Implementation Committee, April 21.

Ministry of Natural Resources and Conservation Ontario (MNR/CO), 2005. Guidelines for Developing Schedules of Regulated Areas, October.

Ministry of Natural Resources (MNR), 2001a. Technical Guide for Flooding, Erosion and Dynamic Beaches, Great Lakes – St. Lawrence River System and Large Inland Lakes. CD-ROM Published by the Watershed Science Centre, Trent University, Peterborough, Ontario for the Ontario Ministry of Natural Resources.

Ministry of Natural Resources (MNR), 2001b, Understanding Natural Hazards – An Introductory Guide for Public Health and Safety Policies 3.1, Provincial Policy Statement.

Ministry of Natural Resources (MNR), 1993. (Draft) Provincial Great Lakes – St. Lawrence River Shoreline Policy Statement.

Ministry of Natural Resources (MNR), 1989. Great Lakes System Flood Levels and Water Related Hazards, February.

Mortsch, L., 2009. Climate Change State of the Science: Relevance to Impact and Adaptation Assessments in the Great Lakes Region, presentation at Great Lakes Climate Change & Policy Meeting April 8, 2009 – Burlington, Ontario, Adaptation and Impacts Research Division, Environment Canada

Zuzek, P.J., Nairn, R.B., and Thieme, S.J., 2003. Spatial and Temporal Considerations for Calculating Shoreline Change Rates in the Great Lakes Basin. Journal of Coastal Research, Special Edition 38, p.125-146.