PROVINCE OF ONTARIO

MINISTRY OF NATURAL RESOURCES

TECHNICAL GUIDE FOR LARGE INLAND LAKES

1996

MINISTRY OF NATURAL RESOURCES
TECHNICAL GUIDE FOR LARGE INLAND LAKES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Although Ontario's *large inland lakes* constitute one of our most precious natural resources, their effects on shoreline residents are not always benign. Like other natural phenomena, the behaviour of the lakes is often unpredictable and beyond human control.

Of fundamental importance to developing effective shoreline management and land use planning management approaches for addressing shoreline flooding, erosion and dynamic beach hazards, is the need to better understand the system, particularly its formation, evolution and potential impacts.

The document is divided into nine sections as follows:

- **Section 1** introduces this technical document;
- **Section 2** provides shoreline managers with background material on Ontario's *large inland lakes* and introducing the dynamics of flooding, erosion and dynamic beaches;
- **Section 3** outlines the recommended shoreline classification scheme intended to support the definition and implementation of the provincial policy;
- **Section 4** provides an analysis of the *flooding hazard* as defined in the Provincial Policy Statement;
- **Section 5** provides an analysis of the *erosion hazard* as defined in the Provincial Policy Statement;
- **Section 6** provides an analysis of the *dynamic beach hazard* as defined in the Provincial Policy Statement;
- **Section 7** provides an overview of the mapping and staking procedures for delineating the *flooding*, *erosion* and *dynamic beach hazards* to define the "area of provincial interest";
- **Section 8** provides direction on how to address the hazards including assessing whether or not protection works for an area of provincial interest address the *flooding*, *erosion* and/or *dynamic beach hazards*; and
- **Section 9** introduces the various methods associated with undertaking hazard management in an environmentally sound manner.

This Technical Guide is similar in format and content to the Technical Guide for Great Lakes - St. Lawrence River Shorelines. For the smaller to moderate *large inland lakes* (i.e., those with surface areas from 100 km^2 to approximately 500 km^2, or with a maximum fetch length ranging from 6 to 30 km, typically 15 km), this Technical Guide should provide a sufficient level of information for shoreline managers. For the larger *large inland lakes* (i.e., those with surface areas greater than 500 km^2 and/or with a maximum fetch length ranging from 20 to 60 km, typically 40 km), and/or for *large inland lakes* with recession rates much greater than 0.3 m/yr, the suggested requirements for managing the *flooding*, *erosion* and/or *dynamic beach hazards* and for addressing the hazards found in the Technical Guide for Great Lakes - St. Lawrence River Shorelines may be more applicable.

2.0 PHYSICAL FEATURES AND PROCESSES

Ontario's *large inland lakes* represent an extensive, significant, and physically and biologically diverse environmental resource. Each of the lakes has its own unique combination of interrelated and interdependent sets of terrestrial, wetland, and aquatic environments.

There are fifty-three *large inland lakes* in Ontario (see Table 2.1) representing thousands of kilometres of shoreline. The terrestrial or landside portion of the shoreline consists of a diversity of shore types from erosion resistant bedrock to highly erodible cohesive bluffs, to beach, dune and wetland complexes.

The lakes contain a variety of aquatic habitats. These habitats support numerous fish species and many organisms upon which fish depend.

The transportation capabilities, water supply availability, recreation opportunities, food supply and aesthetic features of the lakes attract a wide variety of shoreline interests. In some locations, competition for the use of the shoreline, by this diverse and growing range of shoreline interests has and will continue to place considerable strain on this fragile resource. In other locations, the use of the shoreline is limited by the access and the local population.

2.1 Definition of *Large Inland Lakes*

The Provincial Policy Statement (May 1996) states that development will generally be directed to areas outside of:

- *hazardous lands* adjacent to the shorelines of the *Great Lakes - St. Lawrence River System* and *large inland lakes* which are impacted by *flooding*, *erosion*, and/or *dynamic beach hazards*;

- *hazardous lands* adjacent to *river and stream systems* which are impacted by *flooding* and/or *erosion hazards*; and

- *hazardous sites*.

By definition, *large inland lakes* means those water bodies having a surface area of equal to or greater than 100 square kilometres where there is not a measurable or predictable response to a single runoff event (Provincial Policy Statement, May 1996).

2.2 Flooding, Erosion And Dynamic Beach Hazards

Having been developed and evolved from the naturally occurring processes of glaciation, ice retreat, isostatic rebound, water inundation, surface weathering (erosion, recession, accretion/deposition) and wind action, the shoreline of inland lakes continue to experience and provide evidence of these ongoing, naturally occurring processes.

In determining the appropriate shoreline management strategy for a given shoreline, an assessment of these natural processes, the current status or factors impacting on the shoreline, and the intended or proposed use of the shoreline must be examined and balanced. In general, the inundation of low-lying shorelines (i.e., flooding) and the loss of material from non-lithified shorelines (i.e., erosion) and the continuous adjustment of beach profiles (i.e., dynamic beaches) are considered by the Province to be natural processes.

Table 2.1 Ontario's Large Inland Lakes

Lakes greater than 500 km^2

LAKE	SURFACE AREA (km^2)	LATITUDE	LONGITUDE
Nipigon	4322	49 50	88 30
Lake of the Woods	3849	40 00	94 40
Lac Seul	1410	50 20	92 30
Abitibi	916	48 42	79 45
Nipissing	876	46 17	80 00
Rainy	858	48 42	93 10
Big Trout	731	53 45	90 00
Simcoe	708	44 25	79 20
St. Joseph	515	51 05	90 35

Lakes 200 km^2 to 500 km^2

LAKE	SURFACE AREA (km^2)	LATITUDE	LONGITUDE
Sandy	453	53 02	93 00
Trout	343	51 15	93 15
Timiskaming	339	46 52	79 15
North Caribou	337	52 50	90 40
Winisk	279	52 55	87 22
Eagle	277	49 42	93 13
Wunnummin	273	52 55	89 10
Attawapiskat	261	52 18	87 54
Lac Des Mille Lacs	241	48 50	90 30
Sachigo	235	53 49	92 08
Sturgeon	214	50 00	90 45
Umfreville	211	50 18	94 45
Temagami	209	47 00	80 05

Table 2.1 Continued

Lakes 100 km^2 to 200 km^2

LAKE	SURFACE AREA (km^2)	LATITUDE	LONGITUDE
Ogoki Reservoir	192	50 48	88 18
Missisa	187	52 18	85 12
Minnitaki	181	49 58	92 00
Red	176	51 03	93 49
Kesagami	167	50 23	80 15
Stull	153	54 24	92 34
Dog	148	48 46	89 32
Finger	145	53 09	93 30
Deer	143	52 38	94 25
Lac La Croix	137	48 21	92 09
Wanapitei	131	46 45	80 45
Weagomow	128	52 53	91 22
Long	128	49 30	86 50
Severn	127	53 54	90 48
Stout	127	52 08	94 35
Savant	120	50 30	90 25
Kabinakagami	120	48 54	84 25
Wapikopa	119	53 00	88 00
Basswood	119	48 05	91 35
Onaman	114	50 00	87 26
Kakagi	111	49 13	93 52
Makoop	111	53 24	90 50
Whitewater	105	50 48	89 10
Manitou	105	46 01	79 00
Muskoka	103	45 45	82 00
Shibogama	102	53 35	88 15
Seseganaga	102	50 00	90 28
MacDowell	103	52 15	92 42
Eabamet	100	51 32	87 46
Rice	100	44 12	78 10

Flooding, in general, is a phenomenon which is sensitive to and influenced by water level fluctuations. Inundation of low-lying shorelines in and of itself does not necessarily constitute a significant hazard, depending of course, on the type, design, location and density of any development which may exist in or near the flood inundated shorelines. However, where flooded lands are coupled with storm events their cumulative impact can and frequently does pose significant degrees of risk, often over extended periods of time. Of importance in managing a potential flood susceptible shoreline is the need to understand the interrelationship between pre-storm flooding, wind setup (storm surge), wave height, wave uprush and other water related hazards (i.e., ice, boat generated waves). If the area of inundation is a wetland or an undeveloped area, the resultant "damage" caused by a storm event may be minimal if measured in terms of human losses (i.e., property and life). Indeed, periodic flooding of wetland complexes has been found to be beneficial for the continued maintenance and enhanced diversity of wetland vegetation itself, by helping to eliminate the invasion of water sensitive upland vegetation into low-lying shorelines during periods of low water levels. In terms of human use and occupation of the low-lying shorelines, development decisions based on or during periods of low water levels ironically present the most serious problem. During lower water levels, the potential flood hazard to homes, cottages and other development often goes unrecognized. Consequently, when water levels return to long-term averages or high water levels, flood damages are sustained, damages which are frequently quite significant.

Erosion rates are dependent upon a number of lake and land processes as well as the composition and morphology of the shore. In general terms, identification of erosion susceptible shorelines is rather simple in that erosion of bedrock and cohesive shores involves a unidirectional process. In the absence of human intervention and/or the installation of remediation measures, once material is removed, dislodged or extracted from the shore face and nearshore profile it cannot reconstitute with the original material and is essentially lost forever. Even with the installation of remedial measures (i.e., assumed to address the erosion hazard), the natural forces of erosion, storm action/attack and other naturally occurring water and erosion related forces may prove to be such that the remedial measures may only offer a limited measure of protection and may only reduce or address the erosion hazard over a temporary period of time.

Given the naturally complex and dynamic nature of the beach environment, determining hazard susceptibility of a given beach formation requires careful assessment of a wide range of parameters. Over the short term, beach environments impacted by flood and erosion processes, may undergo alternating periods of erosion and accretion as they attempt to achieve a dynamic equilibrium with the forces acting upon them. Over the long term, beaches experiencing a positive sediment budget (i.e., more sand and gravel is incoming than outgoing) are generally accreting shore forms while those experiencing a negative sediment budget are eroding. As such, evaluation of the hazard susceptibility of dynamic beaches should be dependent on the level of information, knowledge and understanding of the beach sediment budget and the beach width over which most of the dynamic profile changes are taking place.

As has been alluded to in above discussions and will be discussed more fully throughout later sections of this Technical Guide, the degree of risk associated with flood, erosion and dynamic beach hazards are naturally intensified with the introduction of storm events. Storm impacts, generally assessed in terms of wave action and increases in water levels (i.e., resulting from wind setup; seiche effect), often pose significant increased threats of flooding, increased rates of local erosion, and in turn, increased threats to shoreline developments.

2.3 Physical Processes

One must also have a clear understanding of the physical processes and factors that are currently impacting on the shoreline and that lead to the transformation of shoreline landforms. These processes themselves and the nature of their interaction with the materials that make up the landform are extremely complex. Only a relatively simplistic overview of these processes and the associated lake/land interactions will be outlined within this section. For more detailed descriptions, the Technical Guide for Great Lakes - St. Lawrence River Shorelines should be consulted. It includes a bibliography of a number of textbooks on coastal geomorphology and coastal engineering.

To understand and ultimately predict how different types of human activities may bring about changes in the shore ecosystem, one must first understand the physical processes influencing a given shoreline and their effects under existing natural and modified conditions. By doing so, one will enhance their ability to predict the potential physical and environmental impacts associated with various human activities or actions.

Continuous change in form and configuration of a shore results from the action of natural shore processes such as those related to erosion, transport and deposition of material in the nearshore or littoral zone. The primary agents are waves and currents. The degree of impact of these primary forces is dependant on the relative strength of the nearshore materials. The impacts that waves and currents impose on shore features are further influenced by water levels and wind action.

2.3.1 Definition of the Shoreline Zone

For the purpose of implementation of the provincial policy, the shoreline zone or area of interaction between lake influences (e.g., water, waves, ice, etc.) and land influences (e.g., shore profile, shore stratigraphy, shore alignment, etc.) is divided into three distinct units (Figure 2.1):

- **onshore**, the area landward of and generally beyond the limit of wave action by a particular waterbody, and may include bluffs, dunes and wetlands subject to only occasional inundation.

- **backshore** zone which extends from the point of development of vegetation (typically at a point landward of the ordinary high water mark) or change in physiography to the landward limit of the nearshore (typically just landward of the average water level). It is typically only affected during severe storms.

- **nearshore** is an indefinite zone extending from lakeward of the breakers zone to the landward limit of the swash zone. The swash zone is the portion of the nearshore in which the beach face is alternately covered by uprush of the wave swash and exposed by the backwash. The shallow offshore extends from just lakeward of the breaking wave zone to a depth of 2 to 5 metres in large inland lakes.

2.3.2 Shoreline Characteristics and Evolution

Within the area of lake/land interaction, numerous physical and biological processes contribute to the existing characteristics and continue to shape the constant evolution of lake shoreline. The interactions between and interdependency among the various components of the lakes ecosystem are controlled by these physical and biological processes. Rather than being considered external forces, these processes, and even those which are human-related, need to be assessed and viewed as an essential part of any implementation option and/or strategy aimed toward effective and proper management shoreline ecosystem.

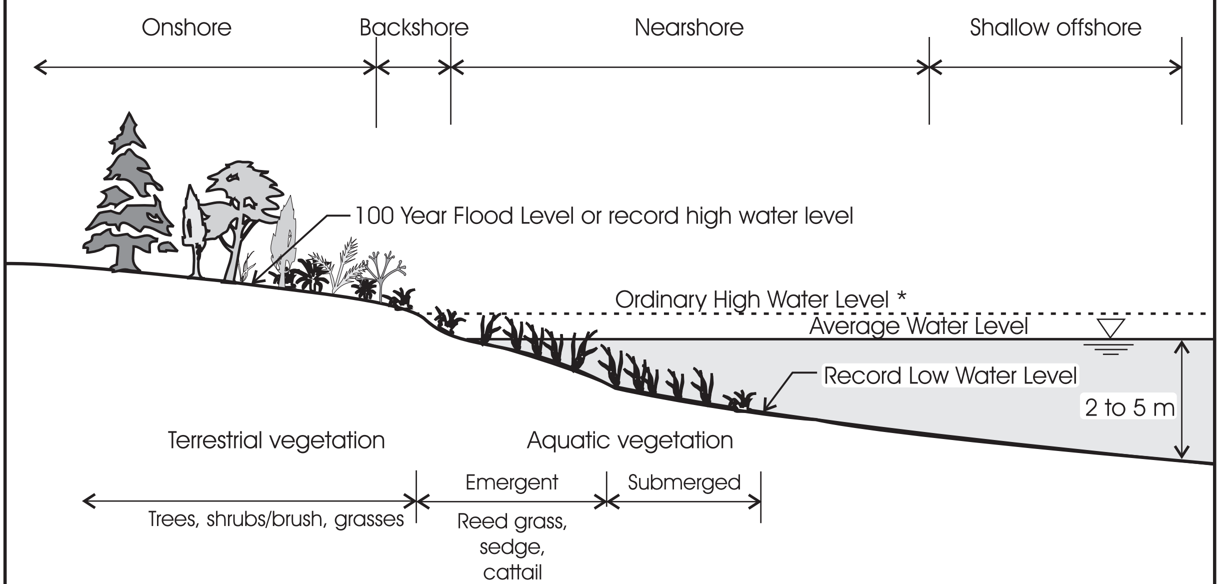
A basic characteristic which controls the long term, large scale evolution of lakes shorelines is the controlling substrate. Controlling substrate is defined as the dominant underlying material which makes up the main body of the lakebed in the nearshore and the offshore. In Section 3 there is further discussion of nearshore substrate.

2.3.3 Shoreline Processes

Continuous change in form and configuration of a shoreline results from the action of natural shoreline processes including those related to erosion, transport and deposition of material in the nearshore or littoral zone. The primary agents of change are waves and water levels. The impact that waves and water levels impose on shoreline features are further influenced by wind action.

The following provides an overview of the shoreline processes and their potential impacts on rates of shoreline erosion and recession.

Figure 2.1: Definition of the Shoreline Zone



* Highest water level which has been maintained for a sufficient period to leave evidence on the landscape. It is commonly that point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial. For lakes being used as reservoirs the ordinary high water level is the operating elevation of the normal summer pool.

a) Wind-Generated Waves

Waves are formed by a complex process of energy transfer from wind moving across a smooth water surface. This energy is carried by waves to the nearshore zone and serves as the primary energy source for shoreline changes. Wind-generated surface waves are a major factor in shoreline erosion, damage to shoreline structures, formation of depositional beach features and littoral transport. Waves generated by commercial and recreational boats (i.e., boat wakes) may be a significant part of the total wave action in the lakes, contributing streams and small harbours and may also be responsible for erosion in these areas.

Waves are generally defined in terms of their height, period, length and direction of travel (see Figure 2.2). Wave height and period generally increase with increasing wind speed, duration of wind, and with increased fetch length (i.e., the overwater length across which the wind blows). As such, at any given location along a shoreline, the largest waves that can reach the site are usually determined by the longest available fetch. Fetch and wind duration, separately or in combination, act to limit the length of time that wind energy is transmitted to the water surface. In the case of fetch length, since the wave is travelling in the direction of the generating wind, it may reach the opposite side of the lake before it attains its maximum size. In shallow waters friction on the lakebed and increased wave breaking (i.e., white capping) act to reduce the maximum wave conditions.

b) Shoaling and Refraction

The process of shoaling results in significant changes in a number of wave properties as the wave moves into shallow water. Generally, the wave length and celerity decreases and the height increases. Some reduction in wave height may also result from energy loss caused by the roughness of the lake bottom in shallow water. This reduction in wave height becomes more significant on gently sloping shorelines where the distance over which the wave shoals is long.

By comparison, the process of wave refraction occurs as waves move from deep water into a shallower shoreline region, changing their direction as the wave crests attempt to align themselves parallel to the underwater depth contours (see Figure 2.3). The degree of wave refraction depends on the wave length, water depth and nearshore bathymetry. In addition to changes in the wave direction and alignment to the shoreline, refraction may increase or decrease the wave height at shoreline locations through the concentration or spreading of wave energy.

In summary, wave refraction is a very important consideration in assessing the effects of wave action on the shoreline as opposed to assessing its impact in deep water. Refraction and shoaling, separately or in combination influence the erosion and deposition patterns of materials along the shoreline, and therefore the development of shoreline forms.

c) Wave Diffraction

The process of wave diffraction basically involves a lateral transfer of wave energy along the wave crest. Diffraction is important around islands, headlands and structures such as harbour breakwalls and groynes and can be an important controlling factor on the deposition of material transported by nearshore currents. Although islands, headlands and structures do provide shelter from wave action, waves do bend and do transport their energy onto shorelines in the lee of or sheltered area.

d) Breaking Waves

The depth at which a wave breaks, and the form of the breaking wave, are determined by the wave height and period, the water depth and the slope of the bottom. For example, in deep water, waves break (i.e., white-capping) when the wave height becomes too large relative to the wave length (i.e., the wave becomes "too steep"). In shallow water, waves break as a result of the limiting water depth.

Figure 2.2: Wave Characteristics

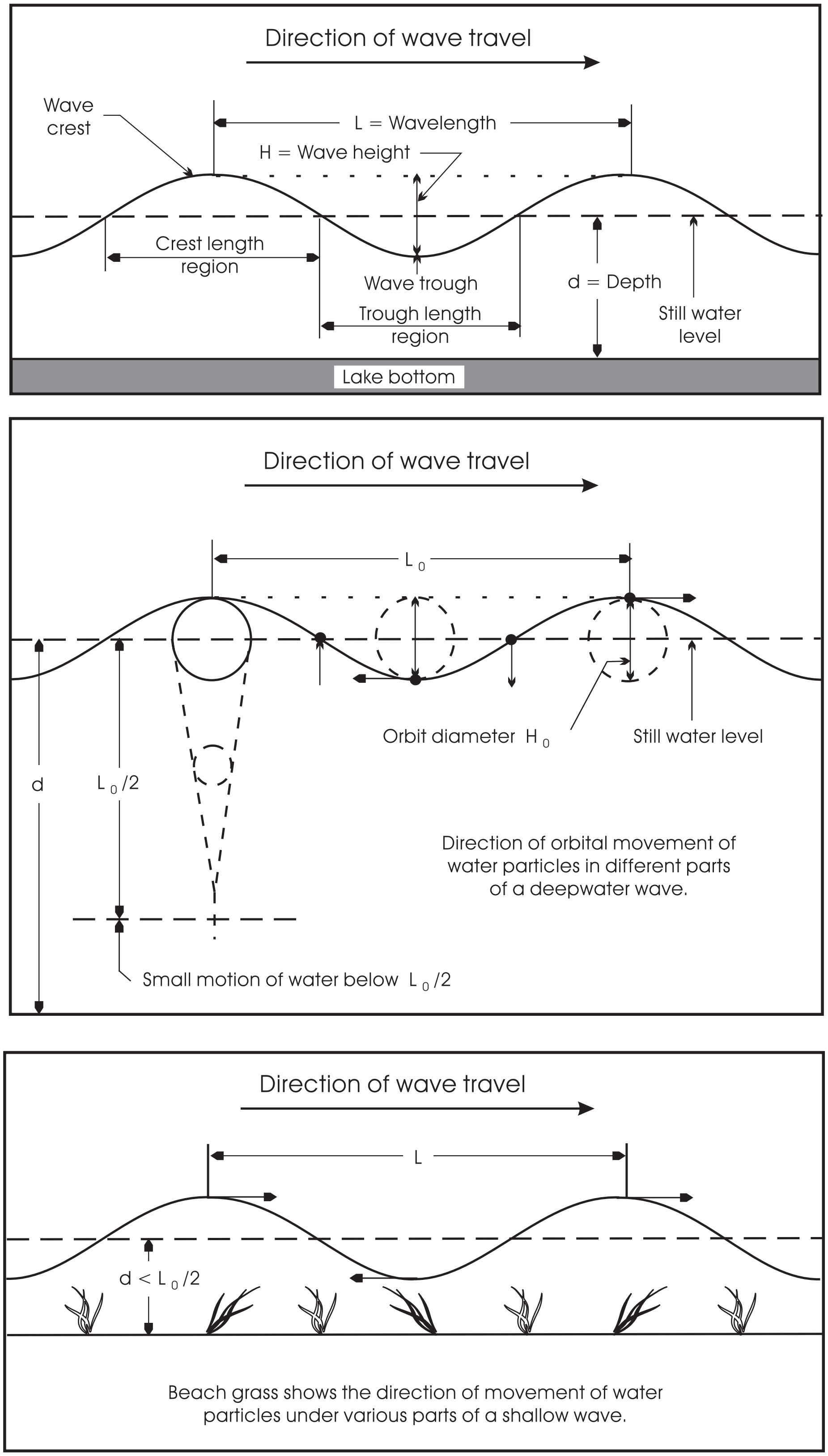
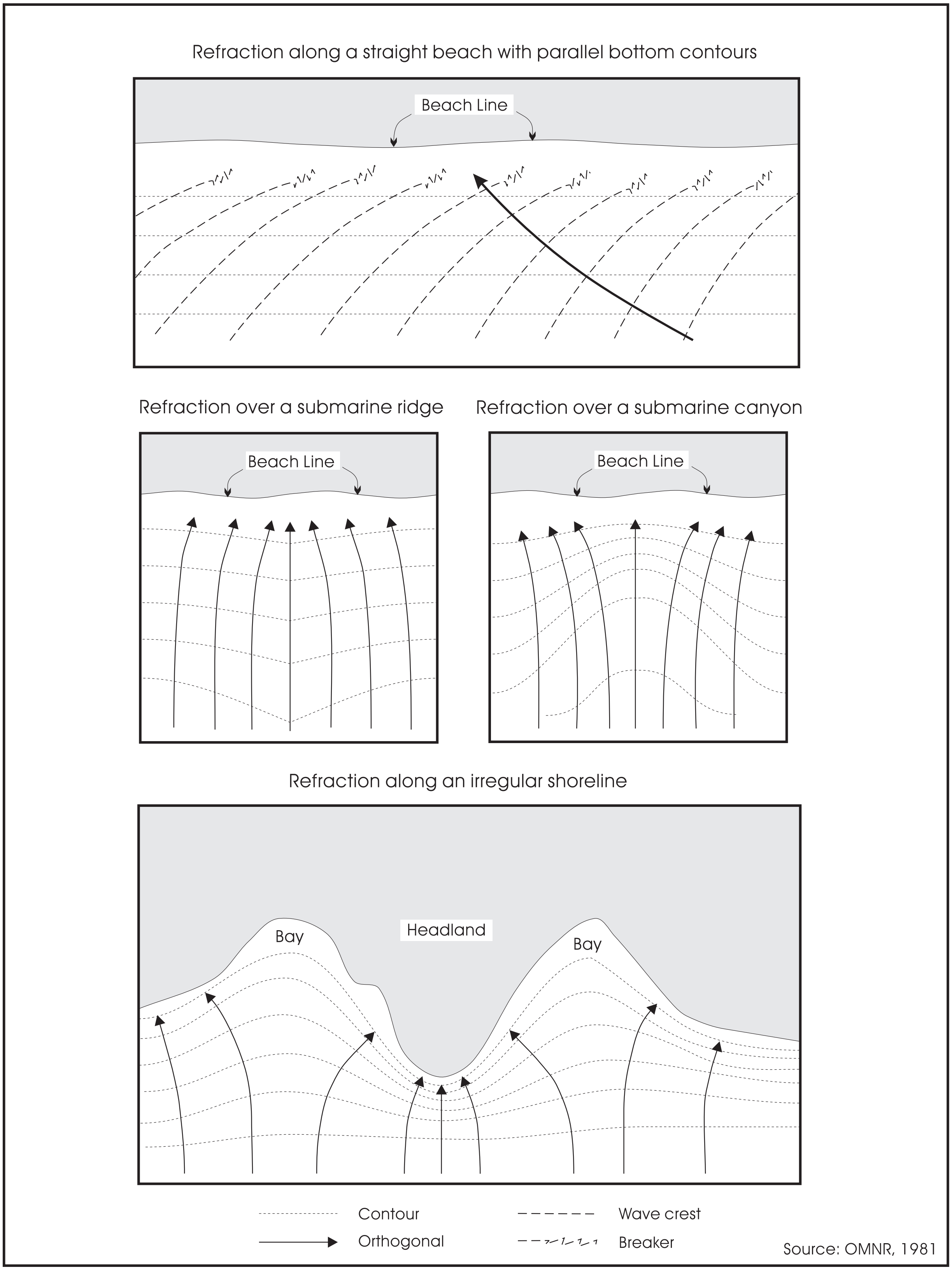


Figure 2.3: Wave Refraction on Simple and Complex Shorelines



The depth of water shallow enough to initiate breaking of a wave is defined as the breaking depth, d_b while the height of the breaking wave is defined as H_b. As a simple guide, waves will break when the ratio of breaking wave height (H_b) to breaking water depth(d_b) is 0.78 or when the water depth is just slightly greater than the wave height.

Turbulence produced by wave breaking can lead to suspension of sand and finer sediments and to the erosion of the beach and nearshore profile on cohesive shorelines.

When waves break at the shoreline, or when a wave that has already broken reaches the shoreline, the forward momentum of the wave results in wave uprush, or runup of the water onto the beach and backshore area. As such, this wave uprush ,or runup, extends the effects of the waves both inland and to higher elevations than the shoreline. Detailed explanations of wave uprush and the methods for calculating wave uprush are provided in Section 4: Flood Hazard of this Technical Guide and in supporting technical reports (e.g., Wave Uprush and Overtopping: Methodologies and Applications, Atria 1997).

e) Nearshore Currents

Currents in *large inland lakes* occur as a result of the inflow and outflow of water within the system, wind blowing over the surface of the lakes and, at the shoreline, the process of wave breaking. Lake currents vary from lake to lake and location to location and can be influenced by factors such as the direction of flow through the lakes and the direction of the predominant or prevailing winds.

Nearshore currents in the littoral zone are predominantly wind and wave-induced motions (i.e., alongshore currents and rip currents) superimposed on the wave-induced oscillatory motion of the water (i.e., mass transport or shore-directed currents).

Alongshore currents flow parallel to the shoreline and are mostly generated by the alongshore component of motion in waves that obliquely approach the shoreline. However, waves approaching parallel to the beach will also generate a current from areas of higher wave height to areas of lower wave height. Wind-generated currents can also be important in the nearshore.

Other significant currents in the nearshore zone can be those generated by the momentum of the waves themselves. The momentum and excess water mass carried into the surf zone by breaking waves results in the set-up of water close to the shoreline. This in turn drives an offshore return flow which may occur either as a uniform "undertow" at mid-depth or as a more complex three-dimensional rip cell.

f) Erosion by Waves

Wherever consolidated material such as bedrock or cohesive material is exposed to wave action, erosion of the nearshore and backshore profile may take place as a result of fluid stresses generated by the wave orbital motion, turbulence due to wave breaking and the direct impact pressures generated by waves breaking at the toe of the bluff. Where sediments are present on the bed, much of the erosion can take place as a result of abrasion by the impact of particles being rolled across or hurled against the underlying substrate. The rate of erosion is dependant on the relative weakness/strength of the shore material and the presence of vegetation. Recession is the landward retreat of the shoreline by erosion of the shoreline material. Along bedrock and cohesive shorelines, the erosion is irreversible.

A detailed explanation of erosion is provided in Section 5: Erosion Hazard of this Technical Guide and in supporting technical reports (e.g., Geotechnical Principles for Stable Slopes, Great Lakes - St. Lawrence River Shoreline, Terraprobe 1997).

g) Sediment Transport

Wave motion and wave-generated currents are the primary processes resulting in sediment erosion, transport and deposition in the beach and nearshore zone. Sediments can be set in motion at the bed by the motion associated with the passage of each wave, by turbulence associated with wave breaking and by the action of swash and backwash on the beach. As waves shoal and break, the wave motion on the bed leading to the suspension of the finer sediment. The presence of any nearshore currents then results in net transport of the sediment in the direction of the nearshore current flow, whether onshore-offshore or alongshore. Ice can also be a factor in sediment transport and is discussed in a later.

h) Wind and Wave Climate

The wave energy (i.e., wave height and period) reaching a given point on the shoreline is determined by the wind climate (i.e., hourly wind speed and direction), by the fetch lengths in each direction, and by the effect of limiting factors such as winter ice cover on the lakes which tends to restrict wave generation.

Wave heights and periods can vary hourly depending on the wind conditions. Therefore, typically the wave climate can be specified as the average conditions over a specified period and direction. The average conditions at a given location can be defined as the average annual hourly frequency of waves by height, period, and direction. The average is based on measured or estimated wave conditions over a period of time (i.e., 10 or 20 years). The resulting wave climate is often presented as average conditions by direction, by month or season.

In general, sections of shoreline that are exposed to long fetches in the direction of the predominant winds are likely to experience high wave energy on a frequent basis. Conversely, shorelines that are sheltered from waves from the predominant wind directions and from the severe storm wind direction are likely to experience much lower energy conditions.

The offshore wave climate can be defined for a point in deep water just offshore of a given shoreline location or stretch of shoreline. Using historical wind records and measured fetch lengths it is possible to hindcast, the opposite of forecast, a wave climate for any given location of stretch of shoreline.

The nearshore wave climate for a specific location can be determined from the offshore wave climate after the effects of wave refraction, diffraction and shoaling are taken into account. The total wave energy reaching a given location or stretch of shoreline control the potential rates of erosion of rocky and cohesive shorelines, while the magnitude and direction of the net alongshore component of wave energy controls the patterns of littoral sediment transport and potential rates of sediment transport.

i) Wind

Wind action has a strong indirect influence on beach dynamics through its control on the wave climate and related wind setup effects. In addition, wind-driven currents in the lake influence sediment transport patterns, particularly the offshore transport of fine sands. Wind action, as a direct influence on the beach change, is generally defined in terms of aeolian sediment transport. On sand beaches, onshore winds transport sand landward where it may be trapped by vegetation, leading to the formation of naturally protective shoreline dunes.

j) Water Levels

Changes in water levels occur as a result of long-term and short-term factors. Long-term factors generally include precipitation, inflow to the lakes, which is dependent on precipitation, outflow from the lakes, evaporation, and to a slight degree by isostatic adjustments to the earth's crust. Short-term factors generally include oscillations caused either by the wind blowing over the lake for several hours or by atmospheric pressure changes.

Seasonal and long-term changes in lake levels result from variations in the amount of precipitation, evaporation, runoff, storage capacity of the lake and the discharge characteristics of the connecting rivers and streams, including the effects of ice. Seasonal changes follow an annual cycle with peaks in the late spring or early summer and lows in the late fall or winter. Historical records of long-term variations does not exist for most of the *large inland lakes*. However some of the larger *large inland lakes*, particularly those that are regulated, do have some historical records.

Short-term fluctuations are generally produced by the influence of the wind and by changes in atmospheric pressure. Atmospheric pressure differences between the opposite sides or ends of lakes can produce fluctuations in water levels. When winds continue to blow over the lake surface in one direction for a number of hours, an increase in the water level against the downwind shoreline is produced, referred to as "wind setup" or "storm surge" (Figure 2.4). A similar "wind setdown" is produced at the upwind end of the lake. With the same wind speed and duration, the setup increases with decreased water depth and nearshore slope.

Another phenomena influencing lake levels is known as seiche effect. Factors influencing or causing seiche effect include both atmospheric pressure and wind-induced water level changes. The return flow of water from the end with an elevated level to the depressed end can result in oscillations of lake levels similar to the sloshing action that occurs in an enclosed tank of water.

The water level elevation determines the portion of the nearshore zone over which breaking waves expend their energy. During periods of elevated lake levels, a portion of the wave energy may reach the toe of bluffs or sand dunes, and some washover of low-lying beach areas may occur. It is during these events that rapid erosion of the bluffs and dunes occurs.

In addition to the natural factors, various artificial changes have been made in this century that have had an influence on the levels and flows within the *large inland lakes*. The most significant is the regulation of lake levels for hydro-electric power generation, recreation and flood control using control structures (e.g., dams and weirs).

2.3.4 Other Physical, Biological or Human-Related Processes

Aside from the shoreline processes described previously there are a number of other important physical processes acting in the coastal zone that are not shoreline processes per se, yet they can influence erosion and recession of the shoreline. These are briefly described and include the following physical, biological or human-related processes.

a) Groundwater

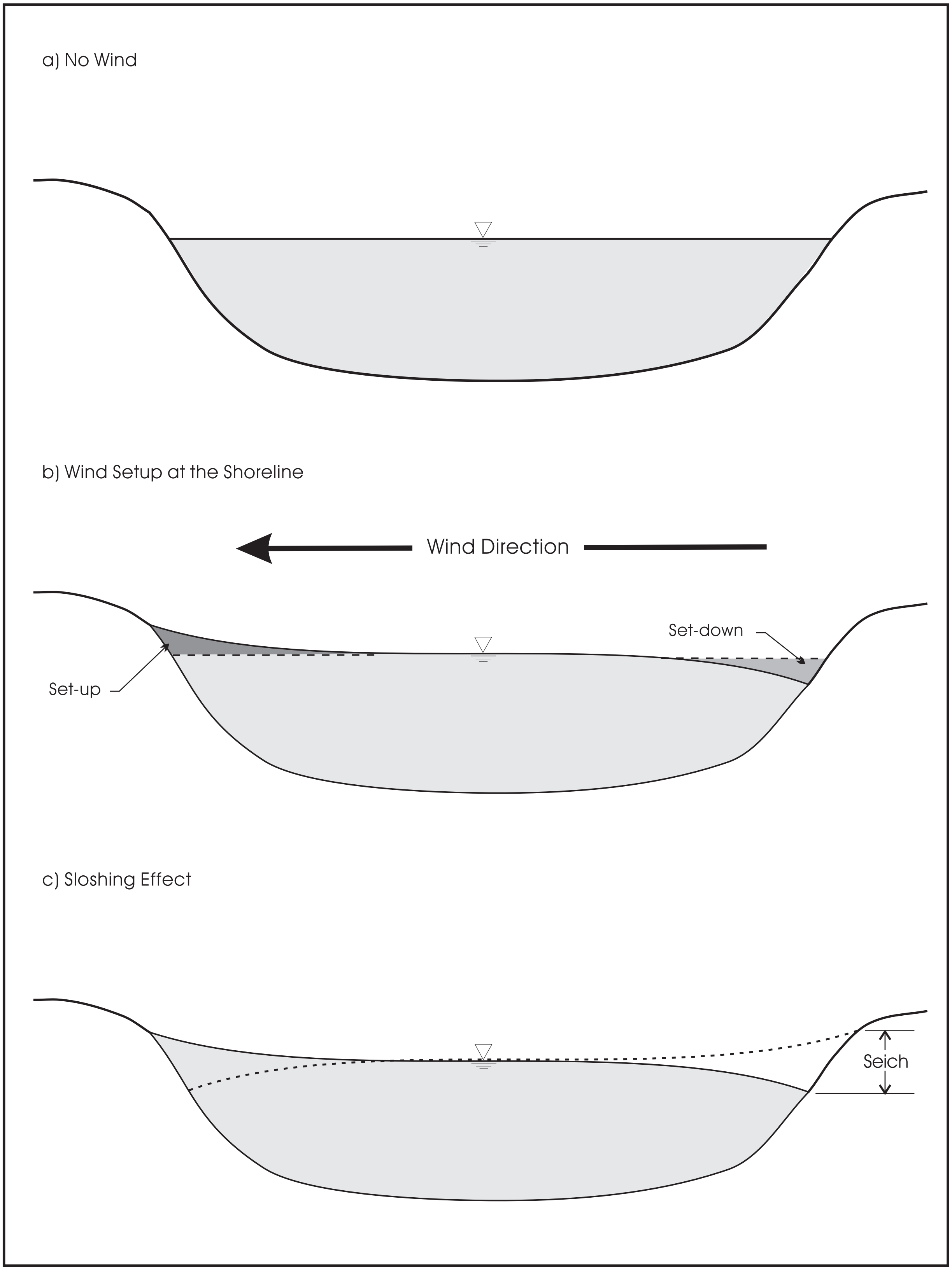
In bluff areas the movement of groundwater can be a major factor in the erosion processes. Many bluffs consist of layers of different types of material of varying thicknesses and permeability. The ability of surface water to flow or infiltrate vertically downward through the bluff structure depends on the types of material from which it is composed. For example, water passes quickly and easily through a layer of sand, but if the sand is underlain by a layer of impervious clay, then the vertical movement of groundwater is halted and the groundwater then moves horizontally along the sand-clay boundary to the bluff face. The groundwater then exits through the face of the bluff at the sand-clay boundary and runs down the bluff face causing erosion of the sand layer, the bluff face, and over time, leads to the landward recession of the bluff.

The presence of groundwater in a bluff reduces its ability to resist collapse or bluff failure. This is due to the lubricating effect that a high water content has on the soil. A collapse or bluff failure of this type is most likely to occur when the soil is saturated with water. Soil saturation may be caused by natural influences such as in the spring snowmelt period or after an extended period of heavy rain, or by human-related structures or activities, such as a leaking swimming pool.

b) Surface Water

The flow of surface water down the face of a bluff can lead to erosion of a bluff face and ultimately to varying degrees of bluff failure or collapse. Frequently, concentration of surface water flows on a given shoreline bluff feature leads to the formation of gullies along the bluff face. As a gully grows, it may become the route for surface water drainage from an increasing tableland area, thereby increasing both the volume of water flow and the rates of gully growth. The creation of tableland water drainage networks, such as field tiles or drainage ditches, are typically the forms of surface water concentration that have led to the formation and growth of shoreline gullies.

Figure 2.4: Wind Setup



c) Ice

The formation of ice during winter months affects shoreline processes in all the lakes in two ways. The formation of shorefast ice in combination with an "ice foot" protects the shoreline area landward of the ice from wave action even when the main body of the lake is ice free. As ice forms first along the shoreline, shorefast ice often persists for several days or weeks after ice on the main body of the lake has melted, protecting the shoreline feature. However, local scouring can result from waves breaking directly against the ice foot, and sediments incorporated in the ice may be transported and deposited offshore.

The second main form of ice, that being ice formed within the main body of the lake, has the effect of reducing wave generation during the winter months and as such, reduces the potential erosion and the volume of sediment transport. During the spring months, as the ice begins to breakup, ice jams, ice piling or ridging may result in flooding or erosion problems along the shoreline and particularly at the outlets of lakes into their connecting channels. Along a river or connecting channel ice breakup occurs as the channel snow and ice cover melts. As the melting process continues, water flows in the channel increase, water levels rise, fracturing the ice cover, and ultimately leading to the formation of ice floes.

Within lake environments, spring breakup typically begins with the ice first melting along the shoreline where the ground is warmed by the sun and the ice is thinner. The ice then becomes detached from the shoreline (i.e., ice floe) and may be further broken up by the actions of winds and currents. Ice detached from the shoreline or lake ice that is piled up by wind action against the shoreline can often scour sections of the beach and nearshore as well as damage and destroy structures close to shoreline. It can also remove boulders from the shallow areas, reducing their protective effect, particularly along cohesive bluff shorelines.

d) Weathering

Two typical forms of weathering along *large inland lake* shorelines are physical weathering, such as a repeated freezing and thawing action within the shoreline structure itself, and chemical weathering, involving a breakdown of the chemical structure or strength of a shoreline bluff or feature.

During the winter months, repeated freezing and thawing of soils within the bluff face reduces the strength of the soil and makes it more prone to erosion from surface and groundwater flows. This process is most prevalent on bluffs with a southerly exposure, where the sun's rays are concentrated on the bluff face and thawing may occur. Then alternately, when the air temperature falls several degrees below freezing, either during the night hours or during days with little or no sunshine, the moisture within the soil structure on the bluff face again freezes.

Similarly, a reduction in the strength of cohesive and over-consolidated bluff sediments can be caused by expansion and contraction due to wetting and drying of the bluff face or by the various processes of chemical weathering of the rock and bluff materials.

e) Human Activities

Beaches, dune complexes, and low lying shoreline bluffs and banks are often directly and indirectly affected by a wide range of human activities. These may range from the stripping of vegetation, increasing intensity of storm water runoff, removing of sediments cobbles and boulders from the beach and nearshore area, nourishment of beaches, and the effects of structures on the beach itself and on the supply of sediment from updrift source areas.

2.3.5 Source, Transport and Deposition of Sediment Supplies

The number, magnitude and influence of sediment sources to beach environments are varied and may change over time. The primary sources include sediment derived from the erosion of cohesive bluffs and sedimentary bedrock, riverine deposition, glacial and glacio-fluvial deposition from post-glacial lakes, and lastly, from biological or human-related activities.

A source of the sediment supply is derived from wave action eroding cohesive bluffs and relatively weak sedimentary bedrock. This material is eroded not only from the bluff or cliff itself but from the whole shoreline profile extending lakeward out to the limit of wave action on the lakebed. These sediments may be retained locally, transported for a distance alongshore to form a beach depositional features.

Fine sediment materials (i.e., silts, clays) are not stable in the beach environment and are usually removed in suspension to be deposited offshore in the lake basins or in enclosed bays. Only that fraction of sediment supplied that is sand size or greater is taken as contributing to the beach environment.

A second source of sediments is from rivers emptying into the lake.

A third source of sediment supply is the volume of sediment in, and adjacent to, beaches which were derived initially from the reworking of glacial and glacio-fluvial sediments by post-glacial lakes. Enhancing this process are the sediment supplies resulting from the large changes in lake levels and accompanying shoreline regressions and transgressions. The result of these processes is that in some areas there are quite large beach deposits which are currently receiving very little new sediments. In areas where isostatic uplift is resulting in shoreline regression, sediments are being stranded in the form of dunes and beach ridges above the reach of modern shoreline processes and as a result reducing the thickness and extent of the modern beach.

Additional sources of sediment supplies to the beach profile can include a number of natural processes such as carbonate material from shellfish and aeolian transport of sediment from sand dunes, although these types of sediment supplies are generally of minor significance. Sediment may also be supplied by human-related activities, either in the form of material dumped over eroding bluffs and cliffs in an attempt to halt or reduce recession, or where sediment is brought into or added to the beach profile to create or nourish the existing beaches. In these areas care must be taken to evaluate the effects of artificial sediment supply on the stability of these beaches.

Information on the source of sediments for beach deposits, on the post-glacial lake level history, and on the current sediment budget is of extreme importance in assessing the stability and dynamic behaviour of beaches. Managers should ensure that this information is available and properly assessed as part of the studies carried out in the development of a shoreline management plan. In many areas these will be evaluated within the framework of littoral cells and sediment budget analysis.

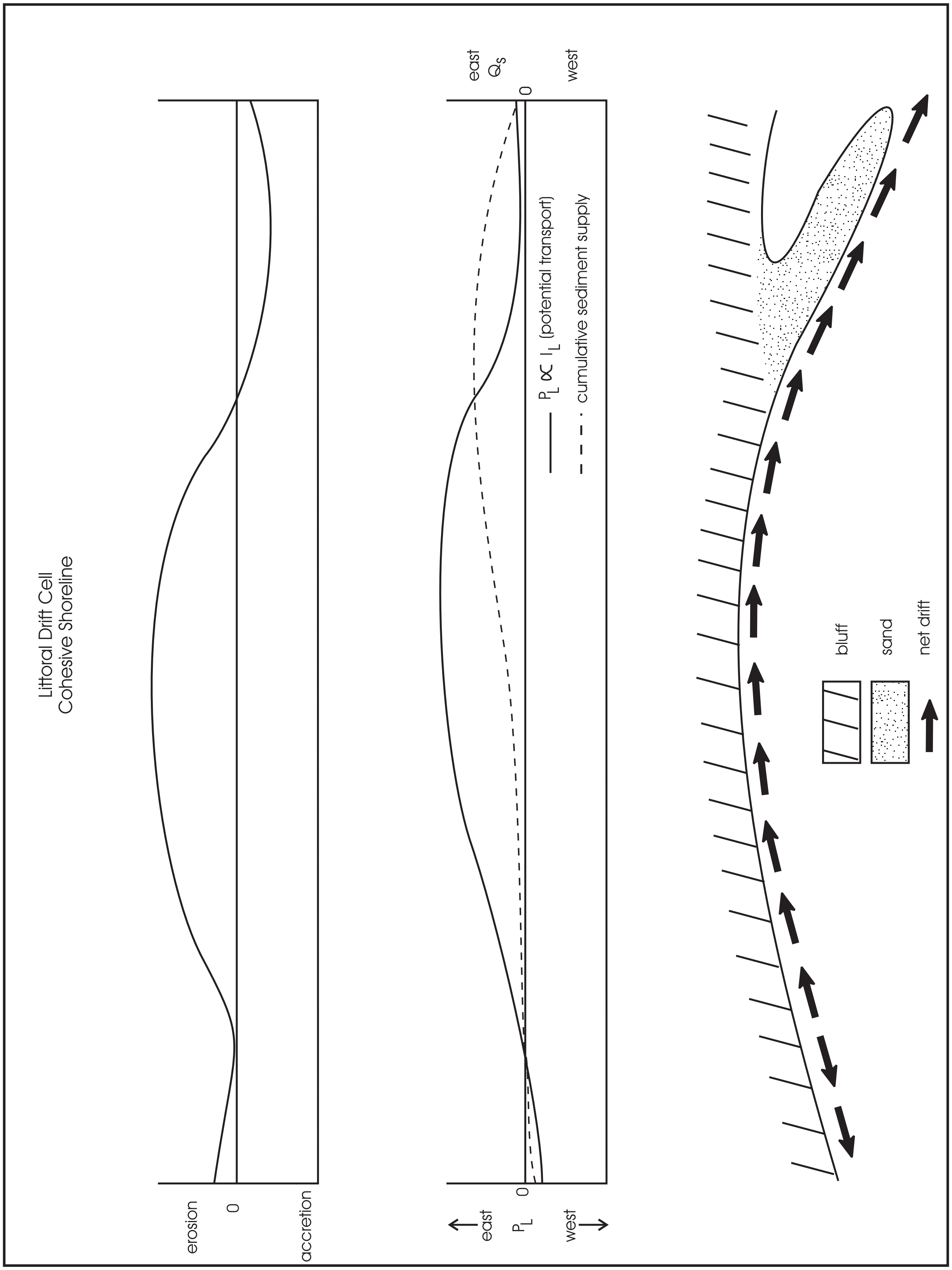
a) Littoral Cells

In developing and assessing shoreline management options, managers need to ensure that selected management alternatives, particularly those involving issues of sediment supplies, erosion, sediment transport, beach maintenance and enhancement, and the installation of onshore-offshore structures which may impact on sediment supplies and transport, are assessed within the framework of littoral cells, including sources and sinks, and sediment budget analysis.

The term littoral drift cell is used to define a length of shoreline within which there is an uninterrupted net transport of sediment alongshore in one direction, with boundaries across which there is little or no exchange of sediment with adjacent cells. Characteristically littoral cells consist of an updrift source area where sediment is supplied to the littoral system, and a downdrift sink area where there is net deposition. The cell boundaries may be relatively sharply defined by a headland or an artificial barrier, such as a jetty at a harbour entrance, or they may be transitional in nature so that it may only be possible to define a zone separating two systems.

For discussion purposes, an idealized littoral cell on a cohesive shoreline is illustrated in Figure 2.5. In this example, the updrift cell boundary occurs at a drift divide where sediment is transported to the right into one cell and to the left into another cell. The average location of the divide is a reflection of changes in the relative fetch lengths as one moves from one end of the lake to another, and of the wind climate. The precise location of the divide may vary as wind and wave conditions change and as such, the divide extends over a length of shoreline from which sediment may be transported in either direction.

Figure 2.5: Idealized Littoral Cell on a Cohesive Shoreline



Within the idealized littoral cell on a cohesive shoreline (see Figure 2.5) sediment is supplied to the littoral system directly by wave erosion of the bluff and underwater profile and by sediments delivered through gully erosion. In combination, these sources form a line source, as compared to the point source formed by a major river. Sediment is then transported alongshore at a rate that is limited by either the amount of sediment actually supplied to the shoreline or by the potential ability of the waves. There are stretches of the shoreline where the volume of sediment supply is much less than the capacity of the alongshore transport system referred to as "supply limited". Within the littoral cell, the sink area is typically located at the downdrift end of the cell and may exist as a baymouth barrier, spit or cuspate foreland, the head of a large bay, or as an artificial barrier.

The material eroded directly by wave action or brought to the littoral zone by rivers and by slumping of bluffs is generally eroded away by wave action. As a result of this action, the fines, generally less than 0.06 millimetres, are dispersed offshore and deposited in the deep lake basins, while the coarser sediments are retained in the littoral zone the beach and nearshore zone. The thickness and extent of the beach and nearshore sediments depend on the magnitude of sediment supplied from wave erosion and land sources and on whether the sediment is retained in place or removed alongshore to some other location by alongshore sediment transport.

To provide a more detailed assessment of the dynamics within the littoral cell, the sources and sinks, and beach sediment budget warrant additional discussion.

i) Sources and Sinks

A "source" is a supply of littoral drift material to the shoreline. This sediment supply may be either a line source (i.e., erosion of the shoreline or bluffs), or a point source (i.e., material supplied to the shoreline by rivers and streams). Artificial nourishment, deposition of material by humans from inland sources or from dredging outside the littoral drift zone, are also considered sediment sources.

A "sink" is a loss of littoral drift material from the littoral transport zone. This loss may be a line sink (i.e., offshore loss to deep water), a point sink (i.e., loss into an offshore canyon), or deposition on a shoal. Losses of material to accretion and deposition areas (e.g., shoals, aggrading beaches, spits) are considered to be sinks. In addition, any removal of sediment supplies through dredging is considered to be a sink.

ii) Beach Sediment Budget

Beach sediment budget provides information on the sediment transport process into and out of a section of shoreline and on the volumes of sediment involved.

The gross sediment budget is the cumulative total sediment volume of all sediment transfers into and out of the defined littoral cell through processes such as bluff recession, alongshore sediment transport, and transport/deposition into the dune complexes. The greater the gross sediment budget the greater the dynamic range of the beach.

The net sediment budget or sediment balance is obtained by subtracting all sediment outputs from the inputs to the defined littoral cell. It is described as positive when sediment inputs exceed outputs, as neutral when inputs and outputs are approximately equal, and as negative when outputs exceed inputs. In practise, the sediment budget identifies sediment inputs from updrift sources and outputs at downdrift locations.

The net sediment budget can be viewed as an indicator of the long-term stability of the shoreline. If the sediment budget is positive then the beach will increase in size or prograde, if the sediment budget is neutral then the shoreline will remain stationary, and if the sediment budget is negative then shoreline erosion and recession will take place. Under conditions of negative sediment budgets, the rate of erosion and recession will be determined by the resistance of the material forming the shoreline to erosion and by the magnitude of the deficit.

b) Shoreline Changes

In analysing the factors interacting within a littoral cell (i.e., sources, sinks, sediment budgets) examination of shoreline forms and features can provide valuable clues to the nature and character of shoreline processes, and identification of the erosional and depositional sections of the shoreline.

Assessing changes in shoreline form can generally be described using four basic terms: erosion, accretion, recession, and progradation. For discussion purposes, these terms are usually defined as follows:

- Erosion is a volumetric reduction of shoreline material by natural processes. It involves the removal and transport of soil, surficial deposits or rock from any part of the shore form.
- Accretion is a volumetric accumulation of shoreline material by natural deposition.
- Recession is the landward retreat (i.e., measured in terms of a linear distance) of the shoreline due to erosion.
- Progradation is the accretional and lakeward advance of a depositional landform (i.e., measured in terms of a linear distance).

Within a defined littoral cell or comprehensive stretch of shoreline, the shoreline may be segmented into "shoreline reaches". These are basically defined as segments of shoreline having similar physical characteristics (i.e., soil composition, orientation, etc.). Shoreline reaches can be classified as progradational, or recessional, depending on whether accretion or erosion is taking place. On any shoreline, the erosional and depositional features may alternate spatially (i.e., size, dimension, location) and/or temporally (i.e., over time).

With respect to its horizontal position, a particular section of the shoreline may be experiencing stability, transgression (i.e., shoreline moving landward), or regression (i.e., shoreline moving offshore).

Isostatic rebound also has an impact on relative shoreline displacement (i.e., horizontal position), particularly where there are differences in the rate of isostatic rebound between the lake outlets and shorelines.

Setting aside the effects that the relative movement of land and water have on a shoreline, shorelines can be divided into three basic types: stable, accreting and eroding. Within these three basic shoreline types, stable shorelines can be further subdivided into two distinct types: static and dynamic.

Static stable shorelines generally occur where erosion is negligible due to very low wave energy (e.g., in protected bays and connecting channels) or on bedrock shorelines where the rock is extremely resistant to erosion.

In contrast, dynamic stable shorelines generally occur where there is a neutral net sediment budget and where a full sediment prism is developed and where the wave energy is being dissipated over the beach and nearshore profile. During periods of low wave energy, sediment is stored in the beach and foredune areas, and then, during storm events these sediments are eroded and transported offshore, forming a wide beach and surf zone.

In shorelines where a negative sediment budget exists, there is insufficient sediment to absorb all the wave energy and an erosional shoreline develops with the rate of erosion determined by the extent/magnitude of the sediment deficiency. Conversely, where there is a positive sediment budget, such as the downdrift end of littoral cells, the excess sediment inputs from updrift sources will tend to lead to progradation of the shoreline.

A typical phenomena in the natural development of a shoreline feature is that the shoreline will naturally tend to "face" the waves so as to minimize alongshore transport and/or satisfy the continuity of the relationship between wave action and littoral transport. In essence, there is a strong relationship between littoral transport, direction of wave action and the resultant type of equilibrium shoreline form. Understanding this unique relationship, enables the shoreline manager, having first identified the type(s) of equilibrium shoreline forms within a defined stretch of shoreline, to then interpret or make an assessment on the littoral transport patterns and on the direction of predominant wave attack based on the type, location and/or size of particular shoreline forms. This assessment may be based on a review of either charts or aerial photographs of the beach/shoreline forms within the defined stretch of shoreline. Conversely, the current and potential future geometry of shoreline forms can be determined from an understanding of the relationship between littoral drift capacity and the direction of wave action.

Headland-bays are a common shoreline feature between headlands or hardpoints on natural shorelines formed in unconsolidated deposits. Bay shapes have received various names: crenulate bays, headland-bay beaches, spiral beaches and zeta bays. Stable headland-bays have a straight segment downdrift, nearly tangential to the downdrift headland, followed by curved section of logarithmic spiral form which is then connected to an almost circular section behind the updrift headland. The straighter downdrift section is parallel to the dominant wave crests. Over time, assuming fixed headlands, a headland-bay will approach an ultimate or static equilibrium shape. This occurs when the shoreline has adjusted so that the dominant waves arrive at right angles to the entire periphery with the result that there is no littoral drift within the bay. Evidence suggests that these bays maintain a relatively stable shape and recede mainly due to recession of the headlands.

The shorelines of unregulated lakes (i.e., those undergoing natural lake level fluctuations) respond to the natural forces of the waves, currents, ice and winds and typically reach a state of dynamic equilibrium. The shorelines of regulated lakes may be still undergoing a period of relatively rapid adjustment as the shoreline profile adjusts to the new lake level regime.

3.0 RECOMMENDED SHORELINE CLASSIFICATION SCHEME TO DETERMINE SHORELINE REACHES

Crucial to the implementation of the flood, erosion and dynamic beach hazard policies is the proper identification and classification of the shoreline based on a consistent, technically sound and functional set of procedures.

The purpose of Section 3 is to describe the recommended shoreline classification scheme (based on the classification scheme outlined in the Technical Guide for Great Lakes - St. Lawrence River Shorelines (1996) intended to support the definition and implementation of the *flooding*, *erosion*, and *dynamic beach hazards* for *large inland lakes*. The criteria and procedures for the definition and calculation of each of these hazards are provided in Sections 4, 5 and 6 of this Technical Guide.

3.1 Criteria For Classification Of Large Inland Lakes Shorelines

The objective of any shoreline classification scheme is to provide a consistent, technically sound and viable mechanism for dividing a given stretch of shoreline into manageable units. The recommended shoreline classification scheme described in the following sections is based on "shoreline reaches", which by definition, are unique segments of shoreline having common physical characteristics.

The primary purpose of the recommended shoreline classification scheme is to aid in the identification of unique segments of shoreline (i.e., based on shore type), to highlight those factors and processes within each shore type that are considered significant controls on *flooding*, *erosion* and *dynamic beach hazards*, and ultimately, to facilitate the identification of shoreline hazards.

Application of the recommended shoreline classification scheme requires that one first understand the principles on which the classification scheme are based:

- that shorelines are normally considered to be bedrock, cohesive, or "dynamic beaches", based on the "controlling" substrate in the nearshore;

- the majority of shoreline areas with small beach deposits (i.e., surficial deposits) should not be classified as "dynamic beaches"; they should be first classified according to the controlling nearshore substrate (i.e., predominant underlying material) followed by subclassifications according to "surficial" nearshore substrate and the general onshore/backshore shoreline type.

- "dynamic beaches" are only those shorelines having beach/dune deposits that are a minimum of 0.3 metres thick, 100 metres long and 10 metres wide and where the maximum fetch distance measured over an arc extending 60 degrees on either side of a line perpendicular to the shoreline is greater than 5 km (this normally does not occur where beach or dune deposits are found in embayments, along connecting channels and in other areas of restricted wave action where wave related processes are too slight to alter the beach profile landward of the waterline; given the significant amount of beach/dune sediment materials involved in these areas, the sediment then becomes the "controlling nearshore substrate"

3.2 Steps for Shoreline Classification

Given these guiding principles, the recommended shoreline classification scheme involves four distinct steps of site evaluation and classification:

- Step 1 controlling nearshore substrate;
- Step 2 general shoreline type;
- Step 3 surficial nearshore substrate; and
- Step 4 shoreline exposure and planform.

These steps are discussed in the following sub-sections.

3.2.1 Step 1: Classification of Controlling Nearshore Substrate

The purpose of Step 1 of the recommended shoreline classification scheme is to identify the most critical factor influencing the physical processes impacting on land/water interface along a particular stretch of shoreline, namely the "controlling nearshore substrate". Controlling substrate was defined as the dominant underlying material which makes up the main body of the lakebed. For bedrock and cohesive shorelines, there are three types of controlling nearshore substrate (see Figure 3.1a):

- bedrock;
- cobble/boulder till (cohesive material); and
- fine-grained cohesive material.

The two controlling nearshore substrate types for dynamic beaches are (see Figure 3.1b):

- gravel/cobble/boulder; and
- sand.

a) Bedrock Shorelines

Bedrock shorlines include all shorelines where the nearshore and part or all of the backshore consists primarily of bedrock. The nearshore is characterized by bedrock and boulders exposed in many places along the shoreline, extensive rock outcrops in the nearshore, or limited amounts of surficial sand or cobbles overlying the bedrock.

In general, bedrock shorelines are more resistant to erosion than cohesive shorelines. The degree of bedrock strength, defined in terms of resistance to erosion by wave action and weathering processes, varies with rock type and structure (i.e., bedrock consisting of ingneous and metamorphic, and limestone and dolomite compared with sedimentary materials).

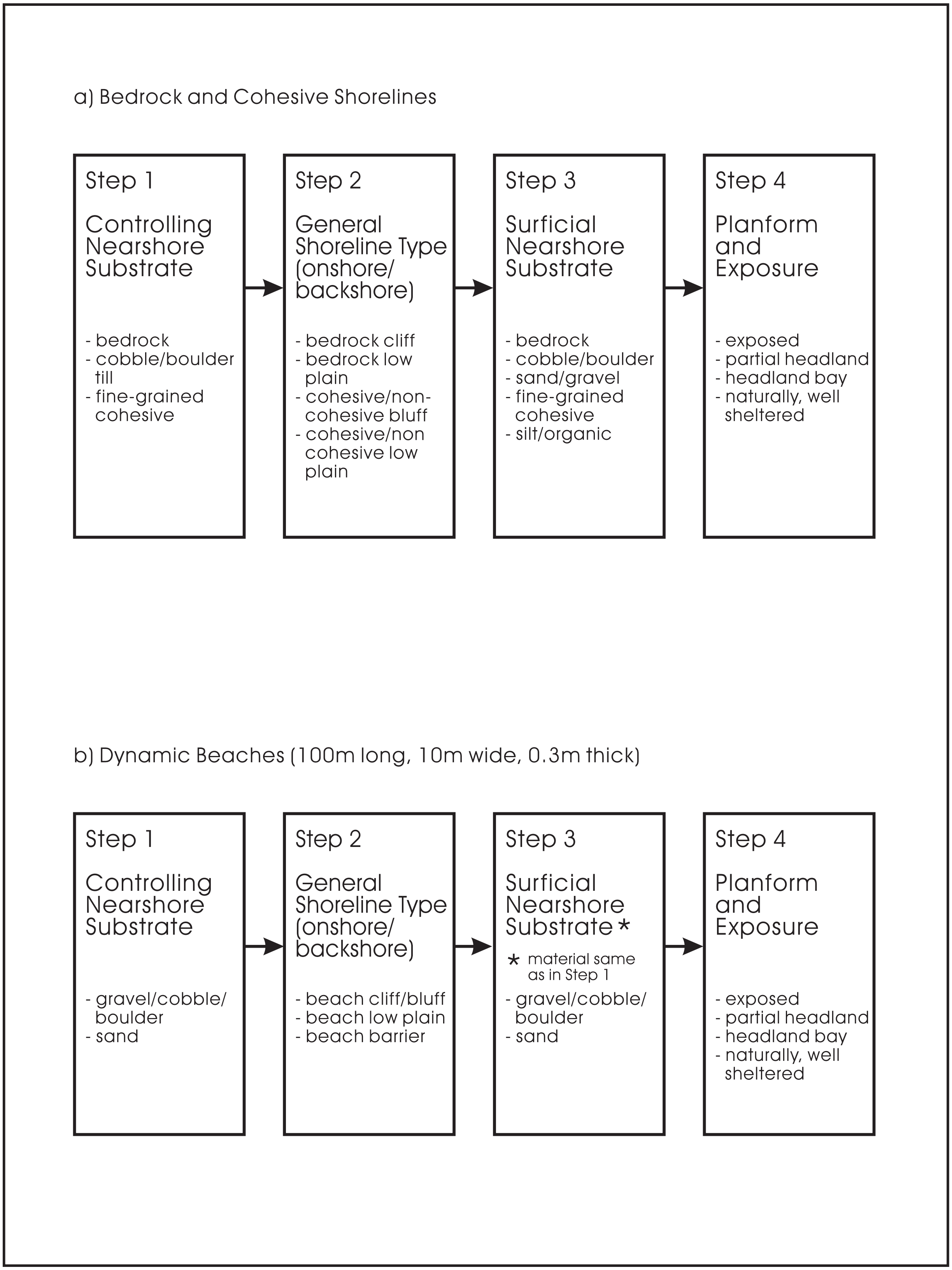
Igneous and metamorphic rock generally are considered extremely resistant to erosion by waves with recession rates in most of these areas being so small that they are virtually immeasurable. Thickly-bedded limestone and dolomite bedrock outcrops are considered to be quite resistant to erosional forces (i.e., low recession rates). Sedimentary rocks such as sandstones, shales and thinly-bedded limestones are often much less resistant to wave action and to weathering and experience low recession rates. The resulting nearshore profiles, characteristic of these softer bedrock types, may be similar in shape to the erosion-resistant cobble/boulder till.

b) Cohesive Shorelines

Cohesive shoreline includes all shorelines developed in sedimentary deposits that contain some fine sediments, such as silts and clays, and which may possess some degree of strength as a result of the cohesion forces associated with the clays within the stratigraphic structure of the shore face. The sediments were deposited by glaciers, in glacial lakes, or by rivers flowing from glacial ice sheets. While glacial deposits possess some strength due to cohesion, a large part of their initial strength is derived from over-consolidation due to the weight of overlying glacier ice during, or subsequent to, deposition. In some areas, shorelines may consist of cohesive sediments of relatively recent alluvial sediments deposited by river or lake currents, which possess some strength due to cohesion but not due to over-consolidation.

The erosion of the cohesive material which comprises the controlling substrate is irreversible. The recession rates and the resulting nearshore profiles can differ depending on the nature of the cohesive material. For the purpose of this classification scheme, cohesive shorelines (i.e., the controlling substrate) have been subdivided into two groups:

Figure 3.1: Recommended Shoreline Classification Scheme



- **Cobble/boulder till** is a cohesive material (e.g., glacial till) with a high content of cobbles and boulders. Washing away of the fines, by wave action in the nearshore, and erosion of onshore bluffs with a high content of cobbles and boulders produces a cobble/boulder lag deposit which protects the nearshore. This results in a convex, shelf-type profile. In other instances, the cobble/boulder material in the nearshore may have originated from other sources other than from the underlying material. Resulting recession rates tend to be moderate to high.

- **Fine-grained cohesive** material contains a relatively small percentage by volume of coarser grained material especially cobbles and boulders. As such, no protective lag deposit is able to build up in the nearshore. Ongoing downward erosion of the nearshore results in a convex-shaped profile with the highest rate of downcutting closest to the shore. The downcutting rate diminishes as one proceeds offshore. Over time, the profile shape tends to remain constant and is merely translated shoreward. Resulting recession rates tend to be high to severe.

c) Dynamic Beaches

In general, the term "beach" applies to any accumulation of sediments that have been transported by wave action and deposited along the shoreline. These include, sediment accumulations or pockets of sediment material that are found along many of the bedrock and bluff shorelines of Ontario’s inland lakes.

For the purposes of the recommended shoreline classification scheme, the term dynamic beach will be applied only to those areas where beach deposits are greater than 10 metres in width, 0.3 metres in thickness and 100 metres in length and where the beach deposits are not located in embayments or in other areas of restricted wave action. Under these criteria, there is a sufficient volume of sediment such that significant changes in the profile of the beach can take place as a result of wave action and water level fluctuations. More detailed information on dynamic beaches is presented in Section 6: Dynamic Beach Hazard of this Technical Guide.

d) Other Features

It should be noted that river mouths may be treated as special cases as required. Some river mouths are drowned river valleys (i.e., rivers existed at earlier glacial times, under much lower lake levels). Not only does the submergence of the old river valley result in an embayment feature, but the lakebed within the drowned river valley may be significantly modified by fluvial sediments deposited over the lakebed. This may result in isolated locations of sandy or silty lakebed conditions along shorelines that are otherwise cohesive or bedrock.

3.2.2 Step 2: General Shoreline Type Classification

The topography and geology of the onshore area have an important modifying influence on the shoreline features. The steepness and height of onshore area factors in determining the terrestrial habitat characteristics, the limit of shoreline flooding hazards, the landward limits to dynamic beaches, and the accessibility of the water's edge. Material eroded from shoreline bluffs contributes to the littoral budget.

Terrestrial habitat considerations are discussed in Section 9: Environmentally Sound Management Within the Hazardous Lands of this Technical Guide.

Onshore flooding concerns decrease as the height of the bluff or cliff increases. Conversely, onshore flooding concerns may pose a significant hazard along low plain shorelines.

The sand and gravel component of cohesive bluffs or the sand and gravel from non-cohesive bluffs provides a supply of beach material. Erosion of softer bedrock cliffs (e.g., shale), along with erosion of the nearshore, provides the material that forms shingle beaches. Where the bluff material has a significant cobble/boulder content, recession of the bluff can result in lag deposit of cobbles and boulders along the shore and on the nearshore profile. The waves remove the finer materials (i.e., silts, clays, sands and gravel) but are unable to transport the larger material away. The higher the bluff, the larger the quantity of cobbles and boulders "left behind" to protect the shore and reduce recession rates. Along shorelines where the topography is undulating, high bluffs are located adjacent to low plains. The lag protected high bluffs form headlands while the more erosion prone low plain shoreline due to lesser available quantity of cobbles/boulders form embayments. Where creeks or streams outlet to the lake at these embayments, barrier beaches may form.

Within Step 2, there are three basic shoreline types (i.e., bedrock, cohesive/non-cohesive, and dynamic beach) which are based on the nature of the material forming the onshore/backshore (a fourth shorline type - artificial beach - also exits, but with minimal occurance and is therfore not discussed in detail in this Technical Guide). The onshore/backshore material can differ from the controlling substrate material in the nearshore (i.e., Step 1). These three basic types are then further subdivided based on the relief/slope and physical characteristics of the shoreline to form the seven general shoreline type classifications:

- Bedrock
    - a) Bedrock Cliff
    - b) Bedrock Low Plain
- Cohesive/Non-Cohesive
    - a) Cohesive/Non-Cohesive Bluff
    - b) Cohesive/Non-Cohesive Low Plain
- Dynamic Beach
    - a) Dynamic Beach Backed by Cliff/Bluff
    - b) Dynamic Beach Low Plain (mainland dune)
    - c) Dynamic Beach Barrier

In addition to differentiating shore types based on physical attributes, recognition of the dynamic response of these shore types should also be documented. The range of dynamic response is usually determined by the influence or impact of coastal processes on the shore type (i.e., wave climate, wind setup potential, nearshore downcutting, alongshore sediment transport patterns and beach sediment budgets, and post-glacial lake history). Human-related activities, such as the placement of fill and the installation of shoreline protection works, also have an impact on shoreline type and should be duly recognized in any determination of shoreline type.

a) Bedrock Shorelines

Bedrock shorelines include all shorelines where the backshore and onshore, or area above the waterline, consists primarily of bedrock. These areas may be characterized by bedrock and boulders exposed in many places along the shoreline (see Step 1).

Under the recommended shoreline classification scheme, bedrock shorelines are subdivided into two separate shoreline bedrock environments:

- **Bedrock cliff** which generally consist of bedrock features that rise steeply (steeper than 1:3, vertical:horizontal) from the shoreline to elevations exceeding 2 metres in height, and as such, have only a very narrow zone at the base of the structure that is subject to flooding and/or wave action.

- **Bedrock low plain** which generally have a gentle slope (flatter than 1:3) inland from the shoreline with a relief of less than 2 metres in height (Figure 3.2). This type of shoreline structure permits wave action to extend some distance inland usually exposing the shorelines to flooding during storms and/or high water periods.

Figure 3.2: Bedrock Low Plain

Figure 3.3: Cohesive/Non-Cohesive Low Plain

b) Cohesive/Non-cohesive Shorelines

The onshore, and at least part of the backshore, of cohesive/non-cohesive shorelines can consist of different sedimentary materials. It is evident that "cohesive" shorelines are developed in sediments with a variety of compositions, often with some till units and varying degrees of cohesion. A significant proportion of the composition will consist of fine sediments, such as silts and clays. "Non-cohesive" shorelines predominantly consist of sands and gravels with only some or trace amounts of silt and clay.

The shoreline may consist of sediments deposited by glaciers, in glacial lakes, or by rivers flowing from ice sheets. While glacial deposits possess some strength due to cohesion, a large part of their initial strength is derived from over-consolidation due to the weight of overlying glacier ice during, or subsequent to, deposition. Once these sediments are exposed at or near the surface, they may lose much of their strength due to weathering processes such as repeated wetting and drying, freezing and thawing and to positive pore water pressures.
The shoreline may consist of cohesive sediments of relatively recent alluvial sediments deposited by river or lake currents, which possess some strength due to conhesion but not due to over-consolidation.

Under the recommended shoreline classification scheme, cohesive/non-cohesive general shoreline types are sub-divided into two separate sub-classifications:

- **Cohesive/non-cohesive bluff** which are a steeply sloping (steeper than 1:3, vertical:horizontal) shoreline with backshore elevations greater than 2 metres developed in sedimentary deposits. With bluff shorelines, wave action and flooding are generally confined to the area between the base of the bluff and the lake.

- **Cohesive/non-cohesive low plain** which are defined as areas with a gentle inland slope from the shoreline (flatter than 1:3) or where the relief is less than 2 metres (see Figure 3.3). Along low plain shorelines, wave action and flooding may extend a considerable distance inland. Cohesive/non-cohesive shorelines exposed to wave action are very prone to erosion.

c) Dynamic Beaches

Under the recommended shoreline classification scheme, on the basis of shoreline slope and elevation, dynamic beaches are divided into three major sub-classifications:

- **Dynamic beach backed by a cliff or bluff** which are essentially beaches that are backed by either a bedrock cliff or a cohesive/non-cohesive bluff and as such, the landward extent and the effect of wave action and flooding are limited.

- **Dynamic beach low plain(mainland dune)** which have a gently sloping shoreline and as such, are subject to wave action and flooding (Figure 3.4). However, the slope is dependent on the underlying bedrock or cohesive material on which the beach is developed. For example, on sandy beach shorelines, sand dunes may develop landward of the beach. The dunes can erode rapidly during a storm event.

- **Dynamic beach barrier** which are essentially beaches and any associated dune complexes which are separated from the mainland by a bay, lagoon or marsh. Barrier beaches are extremely dynamic and may be completely overwashed during storm events.

Unlike bedrock and cohesive shorelines, sand beaches present little resistance to wave action. They may, however, exist in equilibrium with wave action depending on the input and outputs of sediment within a particular shoreline length.

Figure 3.4 Low Plain Beach

3.2.3 Step 3: Classification of Surficial Nearshore Substrate

The primary purpose of Step 3 of the recommended shoreline classification scheme is to recognize the integral importance and need to properly identify the surficial substrate and the role that nearshore surficial sediments have in determining the range of biological or environmental processes occurring on a particular stretch of shoreline.

To ensure proper recognition of the range of biological processes and potential environmental impacts, Step 3 involves the further subdivision of the controlling nearshore substrate identified in Step 1 and the general shoreline types, identified in Step 2, based on the surficial sediments found in the nearshore.

In Step 3 there are five surficial nearshore substrate within bedrock and cohesive/non-cohesive general shoreline types depending on the type of controlling nearshore substrate:

- **Bedrock** consisting of exposed bedrock with a relatively smooth and monolithic surface. Bedrock which is significantly fractured, with many crevices and loose pieces, may be better classified as cobble/boulder. A bedrock surficial substrate can only occur when the controlling substrate is bedrock.

- **Cobble/boulder** consists of the coarser, larger stone material and may include gravel-sized material (i.e., gravel/cobble/boulder, dynamic beach classification). According to the Wentworth scale, gravel is material larger than 2 mm in diameter while cobbles are larger than 64 mm in diameter. Shingle material may be considered as cobble/boulder material. Shingles are defined as water-worn, rounded stones which are usually flat and larger than 16 mm and relatively uniform in size. The larger diameter cobble/boulder material results in greater interstitial spaces than smaller diameter sand/gravel material. It is unlikely to have gravel/cobble/boulder surficial substrate on a fine-grained cohesive controlling substrate.

- **Sand/gravel** consists of small cohesionless particles commonly associated with beaches. Sand and gravel is relatively mobile under the action of waves. While the Wentworth sand scale includes material as fine as 0.062 mm in diameter (i.e., "very fine sand"), material this fine may not be stable on a beach environment.

- **Fine-grained cohesive** is a hard packed (consolidated), fine-grained material with a significant proportion of clay and silt material as well as sand and gravel.

- **Silt/organic** generally consists of loose, fine materials which are not consolidated. Typically silt/organic material is found in sheltered or deeper waters where sediments are allowed to settle. The Wentworth system classifies silt as material finer than 0.062 mm. Where physical conditions are suitable, aquatic plants may become established in these areas.

There are two surficial nearshore substrates in "dynamic beach" shorelines, gravel/cobble/boulder and sand. For "dynamic beaches", the surficial nearshore substrate material will be the same as the underlying controlling substrate.

The distinction between the various surficial substrate types is based on size, interstitial spaces and consolidation. Terms such as "clay", "silt", "sand", "gravel" and "cobble/boulder" are used as descriptive terms to suggest a certain size of material. The actual size limits of the various terms vary according to the classification system used. Table 6.2, in Section 6: Dynamic Beach Hazard of this Technical Guide, provides a description of the various size ranges based on the Wentworth and Unified Soils classification systems.

3.2.4 Step 4: Classification of Shoreline Exposure and Planform

The purpose of Step 4 of the recommended shoreline classification scheme is to describe in further detail the exposure the shoreline to wave action and the physical characteristics described in terms of its "planform". The exposure and planform helps to define the littoral transport characteristics and are indicators of the long-term stability or evolution of the shoreline.

Step 4 results in the description of a shoreline as exposed, partial headland, headland bay, and naturally, well sheltered. The four exposure and planform classifications are applied in bedrock, cohesive (i.e., cobble/boulder till and fine-grained cohesive) and "dynamic beach" shoreline environments. Section 6.3.3, in Section 6: Dynamic Beach Hazard of this Technical Guide, provides more detailed information on the planform of shorelines.

The wave energy reaching the shoreline (i.e., the "exposure") can be described in a relative sense as follows:

Wave Exposure	Fetch Length
. exposed; high wave energy	- greater than ±20 km
. moderate to high wave energy	- ±5 km to 20 km
. low to moderate wave energy	- ±1.6 km to 5 km
. sheltered: low wave energy	- less than 1.6 km

The various shoreline classes are subject to different levels of flooding, erosion and dynamic beach hazards. As previously noted, the flooding hazard is a function of the height and steepness of the onshore area (see Section 4: Flooding Hazard of this Technical Guide). Erosion processes are described in Section 5: Erosion Hazard. For descriptive purposes, erosion hazards can be rated as follows:

Average Annual Recession Rate (m/yr)	Erosion Hazard Rating
<0.0 to 0.0	accreting or stable
0.0 to 0.3	low
0.3 to 0.7	moderate
0.7 to 1.2	high
1.2 to 2.0	very high
>2.0	severe

3.2.5 Summary

The four steps of the recommended shoreline classification results in a range of shoreline types that are summarized in Table 3.1. Table 3.1 also indicates whether or not the different shoreline types are prone to *flooding*, *erosion* and *dynamic beach hazards*. The actual extent of the hazard will of course depend on the site specific conditions.

As a result of the dynamic beach classification process, a total of eighteen (18) general beach types or classes are developed. Under the recommended shoreline classification scheme, each of these beach classes is differentiated by name and number. For more information, a detailed description of each beach class is provided in Section 6: Dynamic Beach Hazard in this Technical Guide.

Figure 3.6 provides schematic illustrations of some example shoreline classifications.

3.3 Procedure For Classifying And Mapping Shoreline Reaches

Classifications, or definitions of shore type, and the subsequent mapping of these shore classifications are usually based on a defined length of shoreline unit, usually referred to as a shoreline reach. Under the recommended shoreline classification scheme, a shoreline reach is defined as a stretch of shoreline where the onshore/backshore/nearshore consists of a single class (i.e., non-cohesive bluff with a bedrock (erodible) controlling substrate and cobble/boulder (shingle) surficial sediments in the nearshore, see Figure 3.6a) and where the shoreline has relatively uniform physical characteristics.

The alongshore boundaries of the shoreline reach are defined by either a transition to a different shore type (i.e., from a non-cohesive bluff to a low plain cohesive shoreline, or from a low plain beach to a barrier beach), or a change in some significant shoreline characteristic within one shore type (i.e., a change in direction of net sediment transport, presence of a complete natural or artificial (i.e., large harbour jetty) littoral barrier, a significant change in bluff or cliff height, or a significant change in land use (i.e., urban to rural)).

In the initial stage of shoreline assessment, maps at a scale of 1:50,000 or 1:100,000 will probably prove most useful for actual boundary definition. However, as the need for a more definitive delineation and assessment of shoreline reaches is required other sources of mapped information may be utilized. These may include 1:10,000 OBM mapping, accurate municipal mapping, consultants reports, vertical aerial photographs, topographic maps, surficial and bedrock geology maps, and local knowledge or information bases.

As with any classification scheme, there will be some locations which will be difficult to classify using the recommended shoreline classification scheme and which can be considered on a site specific basis. For example, a relatively sheltered section of lake shoreline which is a depositional zone for silts and mud carried to the lake by a river may be difficult to classify according to its controlling substrate. In this case the shoreline may simply be classified by the surficial substrate with the controlling substrate considered to be not applicable.

The first step involves the delineation of boundaries between the controlling nearshore substrate and general shoreline types. This initial identification of broad or somewhat general shoreline segments is best approached by the mapper first examining the characteristics of the central part of what is thought to be a shoreline segment, rather than focussing on where the boundaries should be placed. In other words, the boundaries are most easily determined if the mapper works along the shore in both directions from the central portion of the segment. Verification of the shore type can only be obtained by cross-referencing all collated background information, with the ultimate determination being achieved through a field inspection, where warranted.

The final determination of the exact location of the boundaries between shoreline segments and to further subdivide the shoreline segments is best obtained through a site investigation and subsequent field mapping.

Table 3.1 Summary of Shoreline Classes

Shoreline Class[1]			Typical Hazard(s)
General Shoreline Type Onshore/ Backshore (composition and profile)	**Controlling Substrate** Nearshore (predominant underlying material)	**Surficial Substrate** Nearshore (can appear above water as a beach)[5]	• Prone to Flooding • Prone to Erosion • Prone to Influence of Dynamic Beach
Bedrock Cliff[2]	bedrock	bedrock	Typically not prone to flooding and erosion hazards. (Softer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)
		cobble/boulder	
		sand/gravel	
		silt/organic[4]	
Bedrock Low Plain[3]	bedrock	bedrock	Prone to flooding. Typically not prone to erosion. (Softer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)
		cobble/boulder	
		sand/gravel	
		silt/organic[4]	
Cohesive/Non-cohesive Bluff[2]	bedrock	bedrock	Not prone to flooding. Typically prone to low to moderate erosion. (Softer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)
		cobble/boulder	
		sand/gravel	
		silt/organic[4]	
	cobble/boulder till	cobble/boulder	Not prone to flooding. Typically prone to moderate to high erosion.
		sand/gravel	
		silt/organic[4]	
	fine-grained cohesive	cobble/boulder	Not prone to flooding. Typically prone to high to severe erosion.
		sand/gravel	
		fine-grained cohesive	
		silt/organic[4]	
Cohesive/Non-cohesive Low Plain[3]	bedrock	bedrock	Prone to flooding & typically low to moderate erosion. (Softer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)
		cobble/boulder	
		sand/gravel	
		silt/organic[4]	
	cobble/boulder till	cobble/boulder	Prone to flooding & typically moderate to high erosion.
		sand/gravel	
		silt/organic[4]	
	fine-grained cohesive	cobble/boulder	Prone to flooding & typically high to severe erosion.
		sand/gravel	
		fine-grained cohesive	
		silt/organic[4]	
Dynamic Beach Backed by Cliff/Bluff[5]	gravel/cobble/boulder	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach.
	sand	sand	
Dynamic Beach Low Plain[5] (mainland dune)	gravel/cobble/boulder	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach.
	sand	sand	
Dynamic Beach Barrier[5]	gravel/cobble/boulder	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach.
	sand	sand	

LEGEND

1 - This Table does not include classification of shoreline exposure and planform (exposed, partial headland, headland-bay, well sheltered).

2 - Cliff/bluff - steeper than 1:3 (vert:horz) and >2 m high.

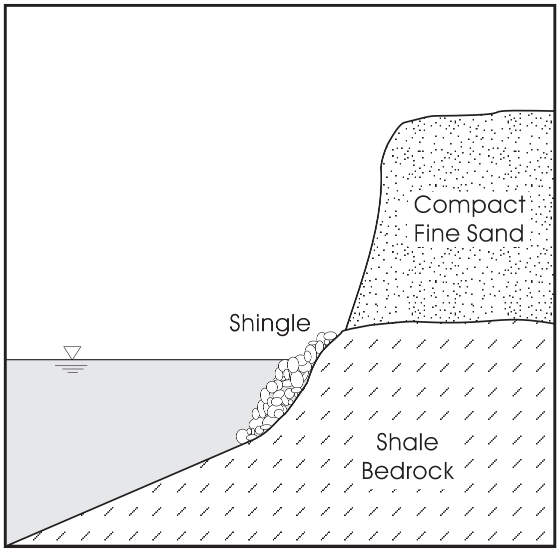
3 - Low plain - landward slope flatter than 1:3 (vert:horz) or <2 m high.

4 - Typically only found in naturally well-sheltered areas where controlling substrate may not be applicable.

5 - a beach is <u>not</u> classified as a *dynamic beach*, where: 1) beach or dune deposits do not exist landward of the stillwater line; 2) beach or dune deposits overlying bedrock or cohesive material are generally less than 0.3 metres in thickness, 10 metres in width and 100 metres in length; or 3) beach or dune deposits are located in embayments, along connecting channels or in other areas of restricted wave action.

Table must be read in conjunction with accompanying Technical Guide text.

Figure 3.5: Schematic Illustrations of Some Example Shoreline Classifications

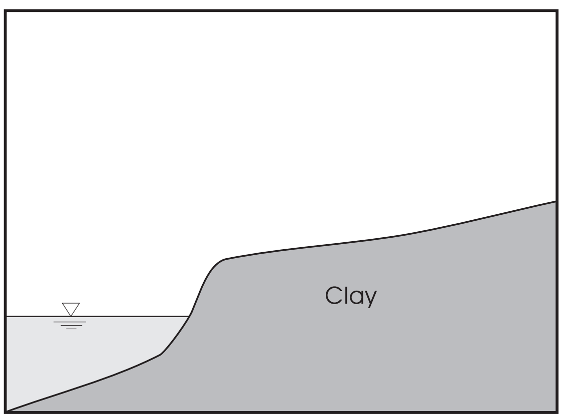


Example (a)

Controlling Substrate - Nearshore bedrock (shale bedrock is erodible; resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till).

General Shoreline Type - Onshore/Backshore non-cohesive bluff.

Surficial Substrate - Nearshore cobble/boulder (shingle falls within size class for cobble/boulder).

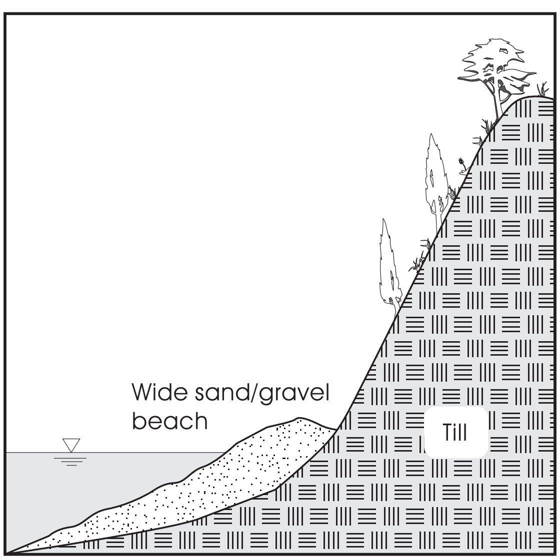


Example (b)

Controlling Substrate - Nearshore fine-grained cohesive.

General Shoreline Type - Onshore/Backshore cohesive low plain.

Surficial Substrate - Nearshore fine-grained cohesive.



Example (c)

Controlling Substrate - Nearshore sand/gravel (till material not exposed) (beach deposit >10m wide and >0.3m thick).

General Shoreline Type - Onshore/Backshore dynamic beach backed by bluff.

Surficial Substrate - Nearshore sand/gravel (for dynamic beaches, surficial substrate is the same as controlling nearshore substrate.

3.4 Sources Of Information

Integral to the initiation of any mapping process is the collection of background information, particularly those related to the physical characteristics of the shoreline and to the processes affecting the shoreline. This, combined with information obtained from field inspections, will generally provide the foundation for the determination of the classification of each shoreline reach, its alongshore boundaries, and ultimately, the definition and delineation of the Hazard Lands along the shoreline of *large inland lakes*.

For most *large inland lakes* there is very little documented background information, some potential sources of information may be as follows:

- Quaternary Geology Mapping - various, Ontario Geological Survey.
- Chapman, L.J. and Putman, D.F., 1951. The Physiography of Southern Ontario: 2nd ed. 1966, University of Toronto Press, 385pp.
- Local offices of the Ministry of Natural Resources, Conservation Authorities, local lake or cottagers associations, other lake residents or boat operators.

In collating general background material, a number of other information sources should be consulted including:

- reports from various government ministries and agencies which deal with the sections of the shoreline under review
- papers published in journals, university theses and any other documents dealing with various aspects of the shoreline and the processes affecting various shorelines
- aerial photographs from several different years, where possible, should be examined to determine changes in the shoreline through time. Of particular interest should be changes in the beach width over time (i.e., when using these sources, one should note that oblique aerial photographs and colour slides often provide better detail than black and white verticals)
- videotapes of the shoreline from a helicopter or small plane can often provide useful information, particularly where coverage over different periods in time are available.

In developing and collating background information, prior to initiating the mapping process, several key pieces of information or data should be compiled, where possible, including:

- fetch window or the range of directions from which waves approach and affect the shoreline unit;
- fetch lengths at 22.5^{o} angles for that fetch window;
- wind speed and direction to determine wave climate and wind setup;
- wave climate, if available;
- gross alongshore sediment transport patterns and the net volume of alongshore sediment transport into and out of the shoreline unit;
- sources of sediment supply to the shoreline unit (e.g., alongshore sediment transport from updrift, gully erosion, nearshore and bluff recession);
- nearshore bathymetry from available hydrographic charts;
- historical rates of shoreline erosion/accretion; and
- the limit of erosion/wave action during high water periods.

4.0 FLOODING HAZARD

Flooding has caused considerable damage along the shorelines of many of the *large inland lakes*. As discussed in Sections 1 to 3, most shorelines of the *large inland lakes* have some degree of flood susceptibility which must be assessed and delineated.

Shoreline *flooding hazards*, as defined in the Provincial Policy Statement (May 1996), consist of three components:

- 100 year flood level;
- wave uprush and overtopping; and
- other water related hazards, such as ice jamming and piling and boat generated waves.

The intent of Section 4 is to provide an in depth analysis of the *flooding hazard* as defined in the Provincial Policy Statement (May 1996). The magnitude, duration and potential impacts associated with flooding and other water related hazards will be examined. A flow chart summary of the procedure for delineating the *flooding hazard* is presented in Figure 4.2. The components of the flooding hazard are discussed in detail in the following sections.

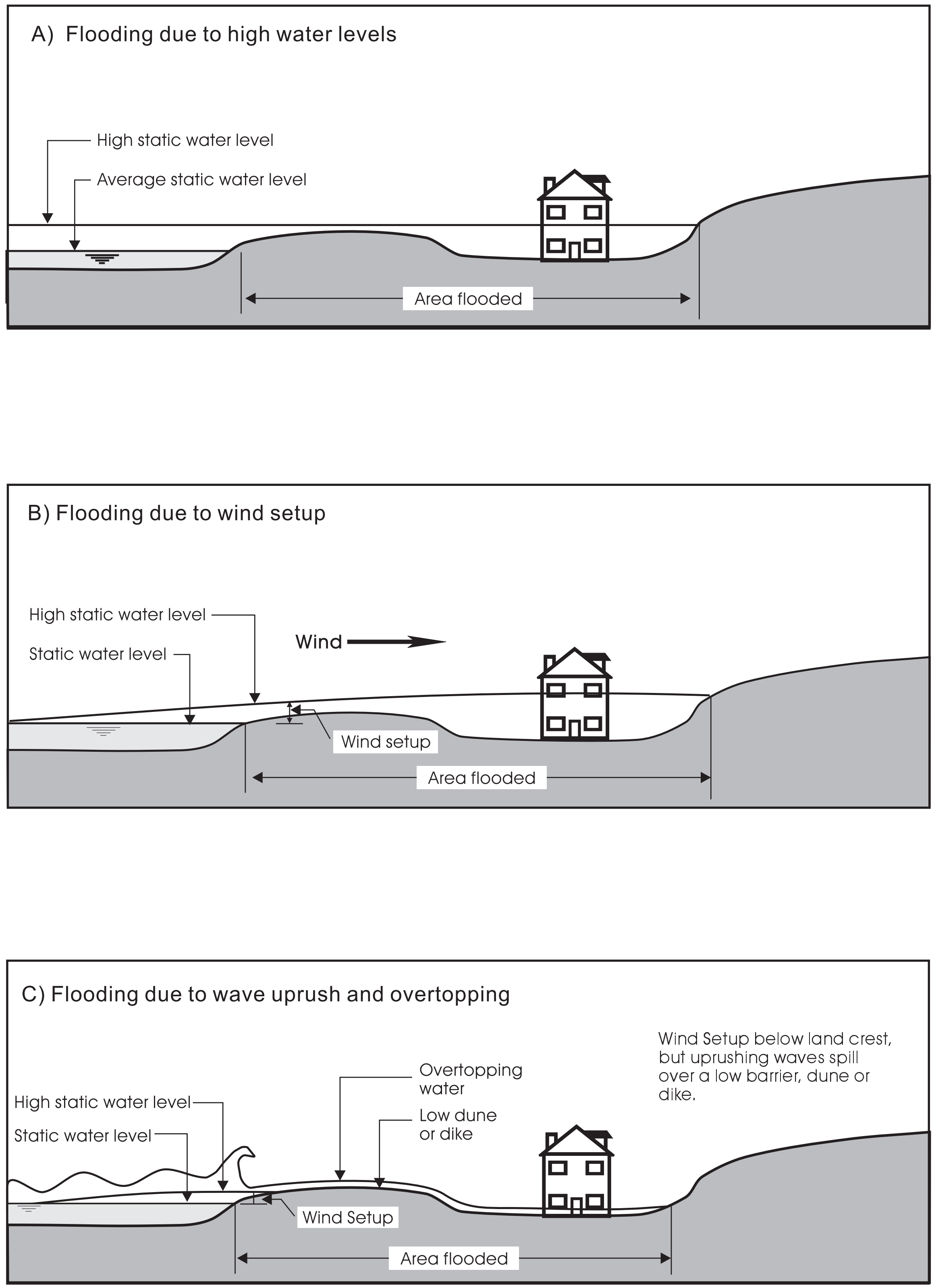
4.1 Provincial Policy: Flooding Hazard

The *flooding hazard* along the shorelines of *large inland lakes*, combines the **100 year flood level** (i.e., static water level and wind setup), and a **flood allowance** for **wave uprush and other water related hazards** (Provincial Policy Statement, May 1996)

The 100 year flood level is a combination of the static water level (see Figure 4.1a) and the wind setup (see Figure 4.1b). High static water levels are the result of a wide range of natural hydrological, physical, geological and human factors. These include seasonal trends in precipitation and evaporation. Longer term changes in water level may also occur as a result of global warming and hydrostatic rebound. Many of the *large inland lakes* are also regulated for navigation and hydro-electric generation. Wind setup is caused by winds blowing across the lake.

Wave uprush or wave runup is essentially the vertical distance reached by the uprushing wave above the stillwater level or flood level. When the height of the natural shoreline or the protection works above the stillwater level is less than the limit of runup, wave overtopping occurs. This can result in backshore flooding (see Figure 4.1c) and can potentially threaten the stability of the overtopped works.

Figure 4.1: Types of Shoreline Flooding



Ice and boat waves constitute other water related hazards which can cause flooding. Ice can cause erosion and flooding of shorelines. On *large inland lakes*, moving ice sheets often cause significant damage to shore structures (e.g., shorewalls, docks, boat ramps). The ice sheets can even ride-up onto the shore and damage buildings. Boat waves can uprush onto the shoreline beyond the defined 100 year flood level.

The 100 year flood level is represented by a contour line or elevation on the shoreline mapping. The flood allowance for wave uprush, unless done on a site specific basis, through a study using accepted engineering principles, is represented by a specified horizontal distance measured landward from the 100 year flood level. The second component of the flood allowance (i.e., the component associated with other water related hazards) must be examined on a site specific basis. In the absence of studies to determine the allowance for wave uprush and other water related hazards, the standard flood allowance is 5 metres (see Figure 4.3).

Where flooding and/or wave action overtops a natural bank or protection works, causing ponding landward of the 100 year flood level, the flood allowance for wave uprush and other water related hazards is to be determined by a study using accepted engineering principles (see Figure 4.4).

4.2 100 Year Flood Level

By definition, the 100 year flood level means, *for large inland lakes*, lake levels and wind setups that have a 1% chance of being equalled or exceeded in any given year, except that where sufficient water level records do not exist, the 100 year flood level is based on the highest known water level and wind setups (Provincial Policy Statement, May 1996).

For many of Ontario's *large inland lakes* there is minimal recorded water level information. For those lakes where there is existing water level data, analysis of the combined probability of static water level and wind setup has usually not been calculated. Therefore, in the absence of statistical water level data, maximum recorded water levels, maximum regulated water levels (e.g., maximum flooding right) or observed high water levels combined with an estimate of wind setup could be used in place of the 100 year flood level. Where no documented information regarding high water levels exists, water level information may be found from local authorities, cottage associations, or other long-time residents of the lake. A field reconnaissance may also provide evidence of past high water levels. Field evidence includes differing vegetation types and erosion or scarping of the backshore. Wave-borne driftwood and debris are indicators of the extent of wave uprush.

In examining shoreline vegetation for clues to previous water levels, one must keep in mind that other factors also play a role in determining vegetation types. These factors include: wave exposure; water currents; water quality; shoreline substrate; topography; latitude; and length of time since most recent high and low water episodes. In general, the onshore (i.e., above the maximum water level) will be dominated by woody perennials intolerant of flooding. Between the maximum level and the typical late spring or early summer water level, the shoreline is characterised by herbaceous species with a wide range of morphologies and life histories and tolerant of occasional flooding. The shoreline between the mean spring to fall range of water levels will be dominated by short-lived weedy plants. Between the average water level and the extreme minimum water level is the zone where shallow marsh vegetation can develop if the other factors, outlined previously, are favourable. Marsh vegetation includes emerged aquatic species. The emergent aquatics can survive continuous flooding but may require occasional low water levels in order for seedlings to establish. Submerged and floating- leaved aquatic species can be found below the minimum low water level. During low water periods, emergents may spread below the minimum water level but they will be killed off again when the water level rises.

One of the factors which influences water level fluctuations and is included in the definition of the 100 year flood level is wind setup. Wind setup, or storm surge, occurs when wind continues to blow over the lake surface in one direction for a number of hours resulting in an increase in the water level against the downwind shoreline.

Figure 4.2: Delineating the Flooding Hazard Limit

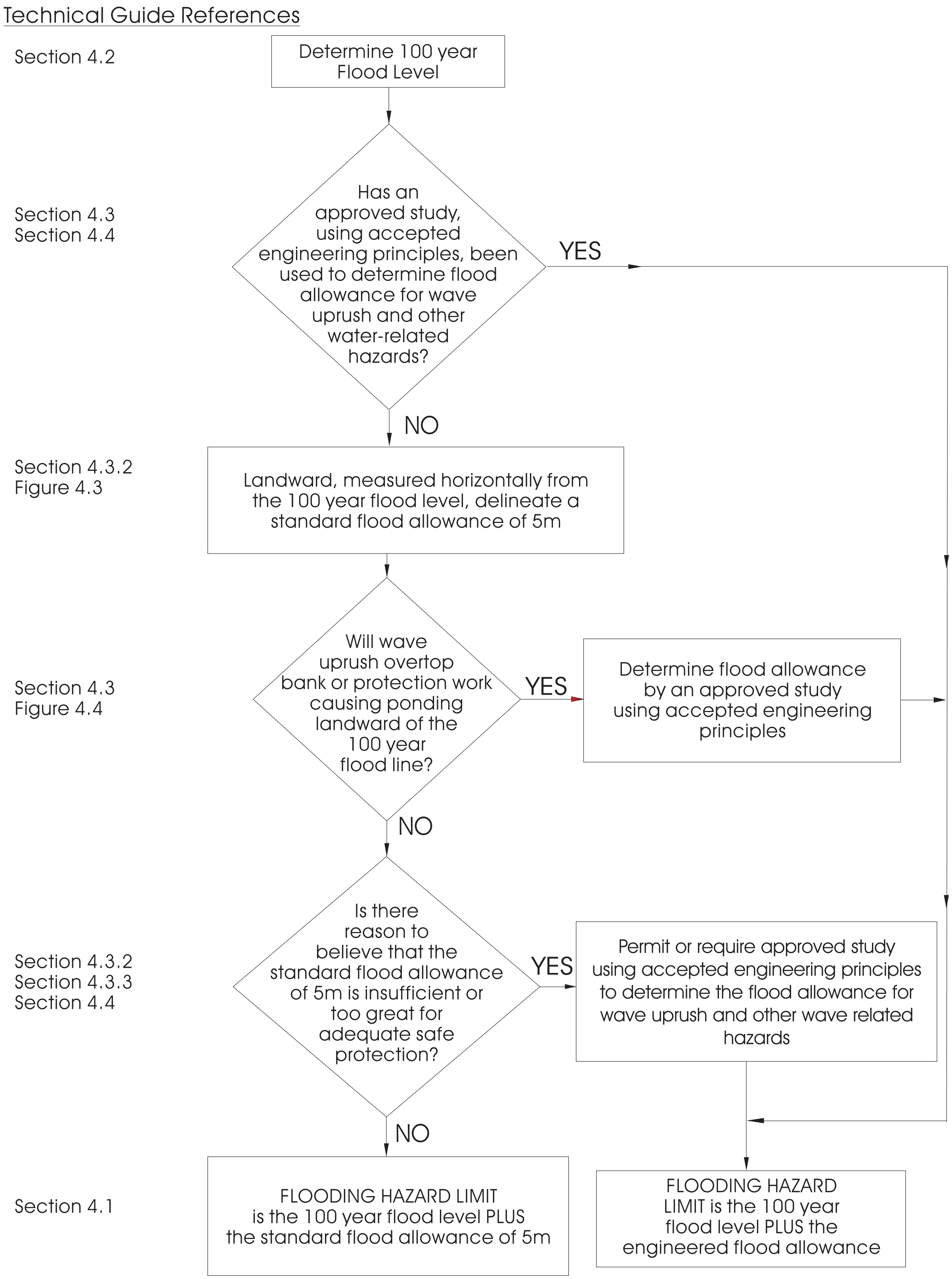


Figure 4.3: Flooding Hazard Limit - Standard 5m Flood Allowance for Large Inland Lakes

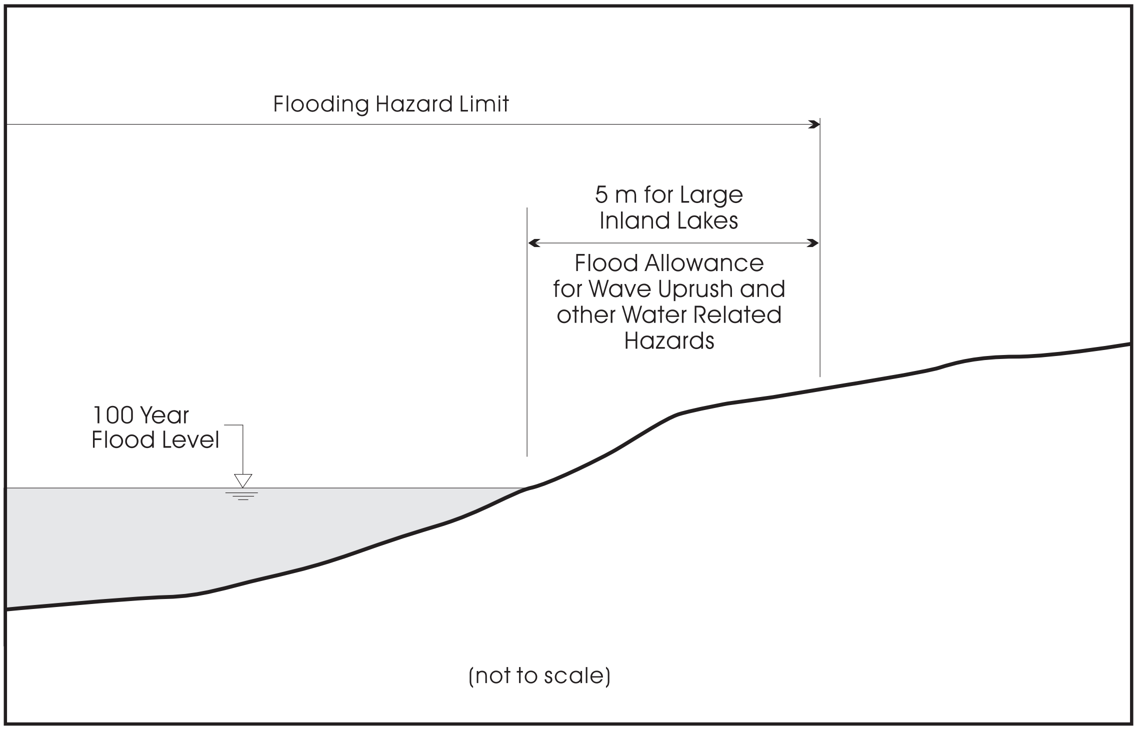
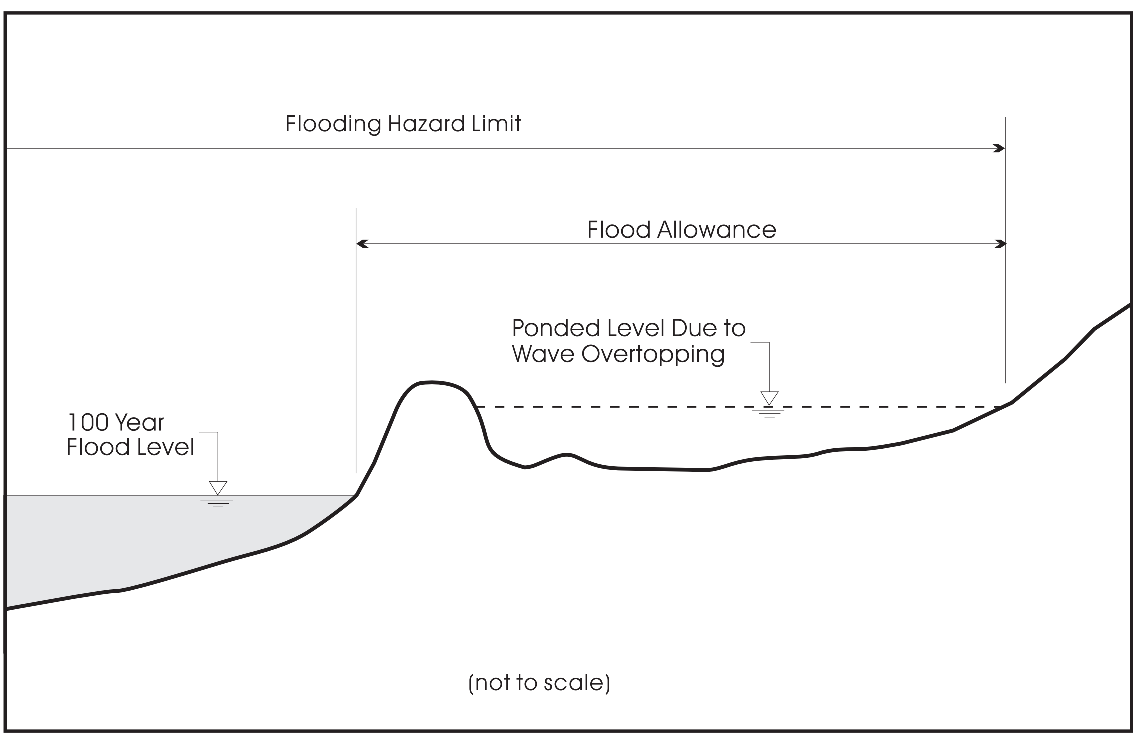


Figure 4.4: Flooding Hazard Limit with Overtopping



Few *large inland lakes* have recorded water level information that could provide an estimate of wind setup. Therefore an estimate of wind setup can be made using the following equation from Silvester (1974) based on wind speed, fetch and depth:

$$S = \frac{kU^2L}{2gd}$$

where
- k = 3.3 x 10^{-6} for lakes,
- g = 9.81 m/s^2
- U = windspeed (overwater; at 10 m height) (m/s),
- L = fetch length (m),
- d = depth (m), and
- S = wind setup or storm surge (height above the stillwater level), (m).

Estimates of wind setup can be made using observed extreme wind speeds. Where this information is unknown, an appropriate wind speed may be found using maps provided by the Atmospheric Environmental Service, Climate Atlas. Figure 4.5 shows the maximum hourly wind speed with an annual probability of 1/30. For southern Ontario the wind speed with an annual probability of 1/30 is 97 km/h (27 m/s)and for northern Ontario 80 km/h (22 m/s). These values represent wind speeds over land and should be adjusted to account for the difference in temperature between the air and the water (i.e., the stability correction, R_T) and the location effect (i.e., the ratio, R_L, of over water windspeed to overland windspeed). Therefore, $U_{water} = U_{land} \times R_L \times R_T$. The stability correction factor, R_T, can be set at 1.1 and the the location factor, R_L, can be assumed to be 1.2. Therefore, as a first approximation, the wind set-up, S, for a relatively exposed *large inland lakes* shoreline can be made as follows:

northern Ontario S (in cm) = $0.014\ L/d$

southern Ontario S (in cm) = $0.021\ L/d$

The shoreline planform (i.e., straight shore, long narrow embayments, etc.) will influence the magnitude of the wind set-up at site specific locations.

Water level and topographic elevations are typically referenced to Geodetic Datum or a municipal or local datum. The differences between the land-based Geodetic Datum and local datums are site specific. It is important to know which datum the elevations are referenced to and how to convert from one datum to another.

4.3 Wave Uprush and Wave Overtopping

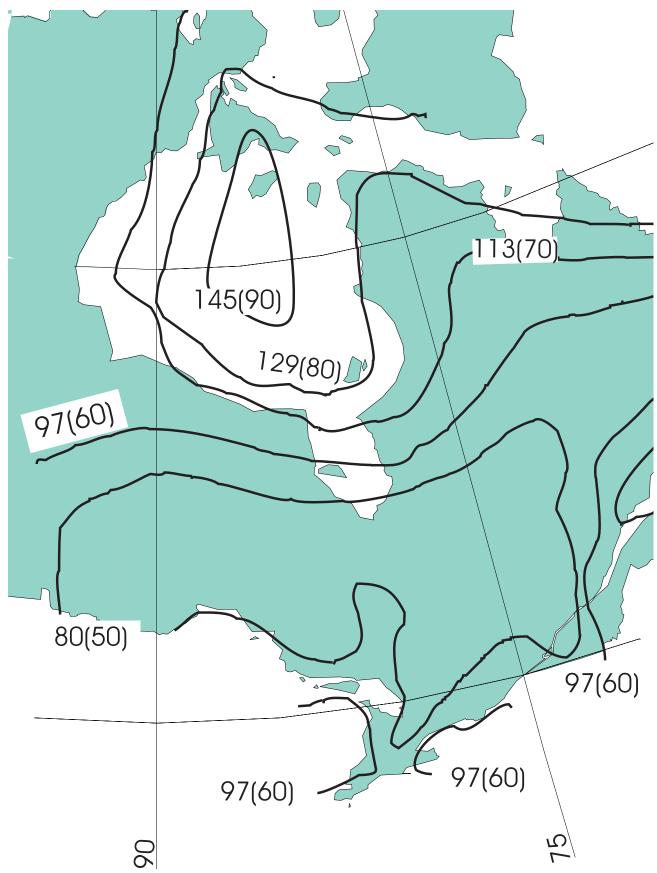
Along shorelines susceptible to wave action, flooding hazard areas extend landward beyond the 100 year flood level to the limit of wave action. All shorelines of *large inland lakes* should be considered to be susceptible to wave action unless site specific study demonstrates that wave action is not significant.

Wave action includes wave uprush, wave setup, wave overtopping and/or wave spray. Wave uprush is the time varying height above the stillwater level that the water runs up the shoreline face, while wave setup is the mean increase in the water level caused by the onshore transport of water due to waves breaking at the shoreline. In general, methods used to estimate wave uprush are measured from the stillwater level and thus inherently include wave setup (see Figure 4.6a). The relationship between the vertical wave uprush/runup value, R, and the horizontal offset for wave runup is shown in Figure 4.7. Wave overtopping occurs when the limit of wave uprush or incident wave action passes over or exceeds the top of a shoreline bank or the top elevation of a shore protection work (see Figure 4.6b). As a result, waves overtopping the protection work can cause flooding of the onshore and can threaten the structural stability of protection works.

Figure 4.5: Windspeed Mapping for Ontario

80(50) KM/H (MPH)

Maximum hourly wind speed
(Annual probability 1/30)



Atmospheric Environment Services
Climate Atlas Climatique-Canada
Vol. 1, Canadian Government
Publishing Centre, Ottawa, 1986

Figure 4.6: Wave Uprush and Wave Overtopping

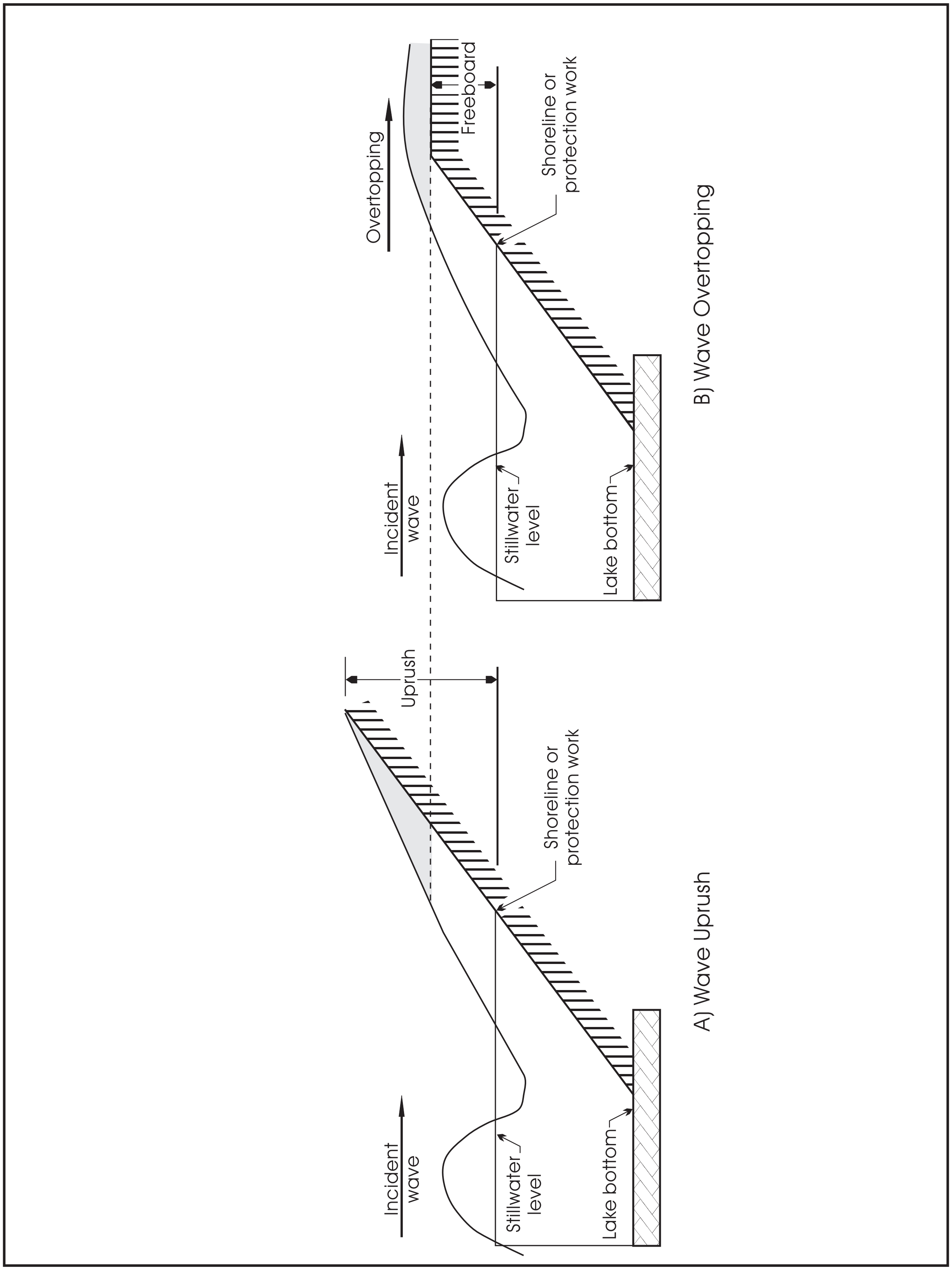
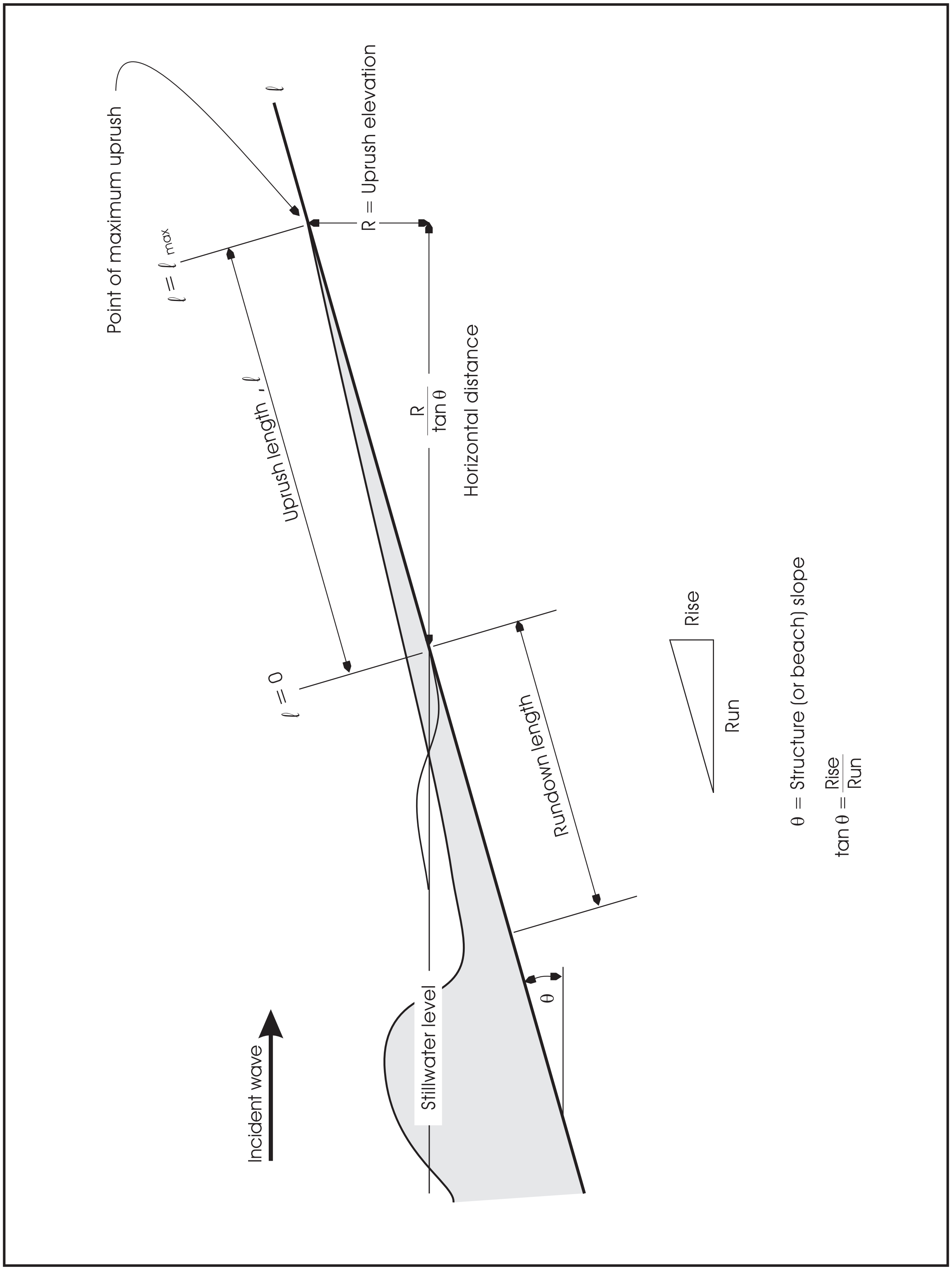


Figure 4.7: Uprush Characteristics for Wave Breaking on Slope



4.3.1 Characteristics of Wave Uprush and Overtopping

The primary controlling parameters for wave uprush are (see Figure 4.8) stillwater level (*SWL*); the incident wave climate (wave height, H, and wave period, T); the beach (or protection work) slope (tan θ); the lake bottom slope (m); the water depth at toe of the protection work's slope or beach slope (d_s); and surface roughness and protection work permeability (Δ_r and P). Other factors such as the local bathymetry (e.g., offshore bars and composite slopes), berms in front of protection works and oblique wave attack may also change the magnitude of the wave uprush/runup. Ice cover of the shore can also influence the wave uprush by making a rough permeable slope into smooth impermeable slope and/or limiting the depth of water (hence limiting the wave action) by the presence of an ice foot.
The basic parameters controlling wave overtopping are essentially those affecting wave uprush.

The commonly accepted measure of overtopping is the mean discharge, Q. The mean discharge is the total volume of overtopping water over a given time period (e.g., one storm of several hours), divided by the length of that time period. The mean discharge, Q, is usually specified in terms of the mean discharge per unit length of shoreline or protection works (i.e., $m^3/s \bullet m$; note that 1000 litres(l) = 1 m^3).

The amount, magnitude, duration and landward extent of overtopping water and wave spray are of direct concern in assessing shoreline flood susceptibility and degree of risk. The degree of risk is measured in terms of:

- risk to the safety of persons and property behind the shoreline protection works (e.g., usage considerations);
- the threat to the stability of the shoreline protection work itself; and
- the magnitude and impact of flooding and ponding behind the protection work (e.g., drainage considerations).

Protection works that permit a safe amount of wave overtopping are not uncommon and their proper design, installation and use is considered to be acceptable practice. Initial costs of protection works that preclude overtopping may be prohibitive and, depending on the proposed land use to the lee of the protection work, a non-overtopping work may not be necessary. The controlling criteria in any decision-making process is whether the intensity and/or the amount of wave overtopping endangers people or property, threatens the structural stability of the protection works and/or permits excessive water to pond in the onshore area.

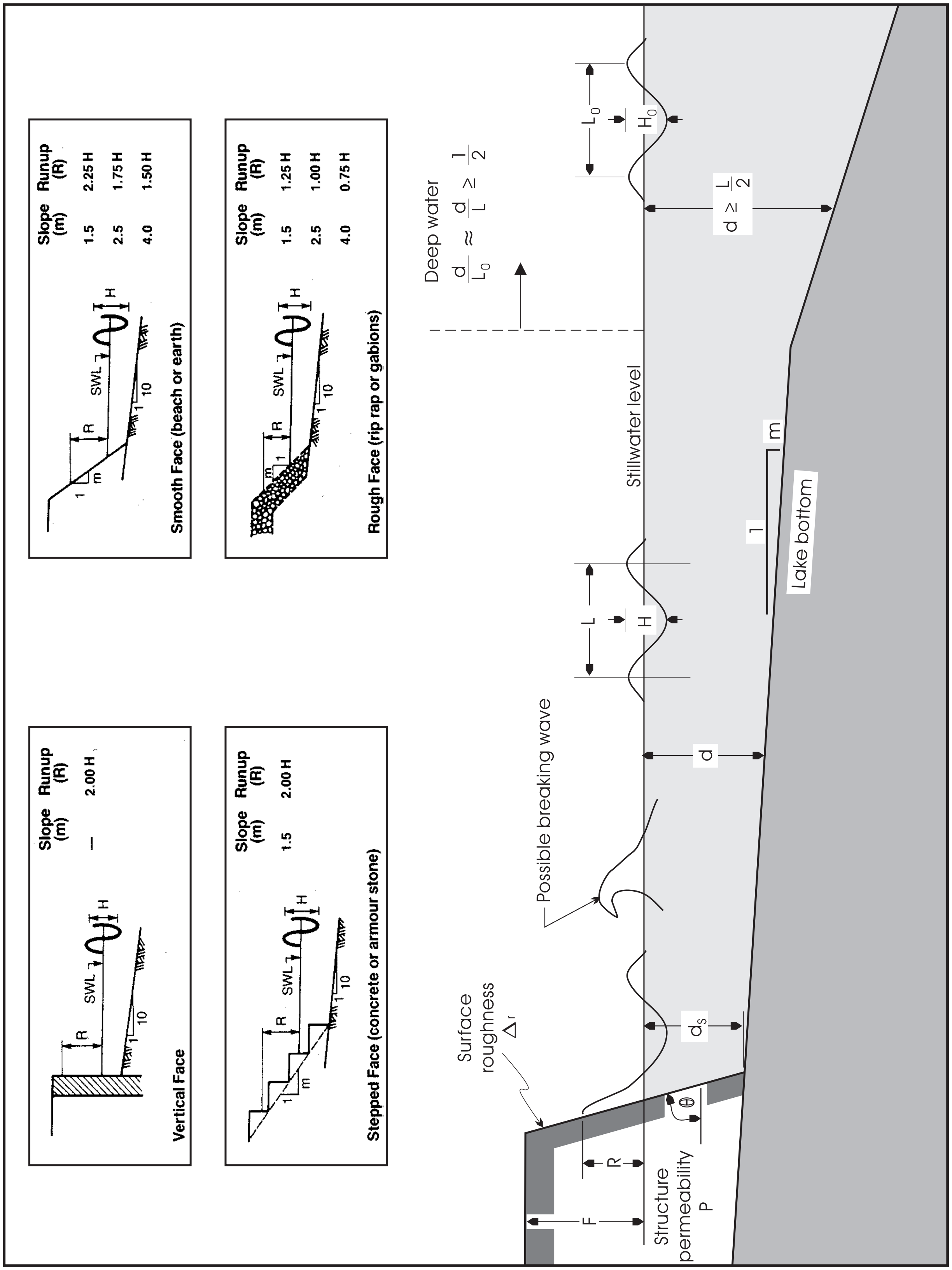
Protection works which are subject to overtopping must be carefully designed to withstand the forces of the overtopping water. Special attention must be given to the details of the crest and backside of the protection works to ensure that its stability is not jeopardized. Proper provisions for the drainage of the overtopping water must be specifically incorporated into the design of the shoreline protection work to prevent onshore flooding and ponding.

Additional supporting information on wave uprush and overtopping, is outlined in a separate report, Wave Uprush and Overtopping: Methodologies and Applications (Atria 1997). It provides a review and summary of accepted practice for determining wave uprush and overtopping, as well as typical examples of application.

4.3.2 Flood Allowance for Wave Uprush and Overtopping

By definition, the *flooding hazard* for *large inland lakes* involves the combined influence of the 100 year lake level and a flood allowance for wave uprush and other water related hazards. In the absence of studies using accepted engineering principles, a standard flood allowance of 5 metres, measured horizontally landward from the 100 year flood level, is to be used to define the *flooding hazard* limit for *large inland lakes* (see Figure 4.3).

Figure 4.8: Definition Sketch for Some Variables Applicable to Wave Uprush



Shoreline managers responsible for determining and applying this standard should note that the 5 m horizontal allowance is not to be interpreted as or used as the required setback for development. The required setback may be further inland due to other hazards (i.e., erosion and dynamic beach; see Section 7) or it may be closer to the water if floodproofing or erosion protection works exist (see Section 8). It should be recognized that the 5 m flood allowance, in the absence of detailed, site-specific studies, is intended only to provide a means of defining the landward extent of the wave uprush and other water related hazards component of the flood hazard on natural unprotected shorelines.

Where municipalities determine that the 5 m standard wave uprush allowance is excessive or not sufficient enough, mechanisms providing the flexibility to undertake a study using accepted engineering principles should be incorporated into the municipal planning process. This flexibility may not be warranted or desired where a more precise definition of the *flooding hazard* is not necessary, where there is sufficient area within the development lot to site any proposed development outside of the *flooding hazard* limit, where development pressure is low and alternative development sites exist, or where staff, administrative and financial resources within the municipality may preclude the ability of the municipality to support such studies.

4.3.3 Using Studies to Determine Wave Uprush and Overtopping

Where the standard 5 m flood allowance is considered to be insufficient or greater than necessary to safely address the wave uprush component of the *flooding hazard* on *large inland lakes*, flexibility is provided to define the limit of wave uprush and other water related hazards through the use of a study using accepted engineering principles.

Field or on-site indicators that the standard flood allowance may be insufficient or too great with respect to wave uprush generally would be based on sound evidence and local knowledge of the limit of wave uprush experienced during periods of high water. The 5 m flood allowance may be insufficient if the following indicators are present landward of the 5 m limit:

- materials washed up by waves (cobbles/shingles/gravel, driftwood, debris);
- the lakeward extent of mature, established vegetation; or
- erosion of the backshore (beach dune, berm or bluff) or a high vertical bluff or cliff.

The presence of materials washed up by waves or evidence of erosion of the backshore, lakeward of the 5 m flood allowance, is not proof of that the flood allowance is too great unless this is supported by information regarding the recent flood levels. Field evidence must be backed up by further analysis of the limit of wave uprush using accepted engineering principles.

a) Accepted Methods for Estimating Wave Uprush

At present, the understanding of wave uprush processes is limited, and there seems to be no generic methodology for the prediction of the limit of wave uprush/runup. Existing guidance is mainly based on empirical research work, carried out in laboratory facilities.

Figure 4.8 provides a first approximation of the wave uprush level at a vertical wall, a smooth, impermeable slope and a rough, permeable slope. These first approximations are based on depth-limited wave conditions in front of the structure (i.e., $H = 0.78d$, where d is the depth of water) and are intended to provide a preliminary understanding of the magnitude of the uprush level.

The technical support document Wave Uprush and Overtopping (Atria 1997) provides several uprush methodologies that may be considered as "accepted engineering principles" provided they are used in the same context for which they are based. Some of the "accepted" methods include: Ahrens and McCartney (1975); Stoa (1978; 1979);Losada and Gimenez-Curto (1981); Ahrens (1981); Ahrens and Heimbaugh (1988a); Walton and Ahrens (1989); Mase (1989); Pilarczyk (1990) ; U.S. Army Corps of Engineers (1990); and van der Meer and Stam (1992).

b) Methods of Calculating Wave Overtopping

The prediction of wave overtopping through an entirely theoretical basis of analysis is not yet possible. The inability to predict wave overtopping is essentially due to the complex processes which govern wave interaction with shorelines and protection works. These processes cannot yet be fully explained and put into the form of mathematical equations. There is, however, some limited guidance in the literature for predicting overtopping rates of some protection works with simple profiles (i.e., uniform vertical seawalls and uniformly sloping armour stone revetments, see Figure 4.9). For these simple protection works, the results of a number of model tests have been assembled and analysed and some predictive empirical wave overtopping methodologies have been developed. Most wave overtopping prediction models include the following input parameters, taken at the toe of the protection work: wave height, H; wave period, T; water depth, d_s; and freeboard, F (distance between the stillwater level and the top of the protection work). Other models require the equivalent unrefracted wave height, H_o'

The accepted wave overtopping methodologies for simple vertical seawalls are Ahrens and Heimbaugh (1988b) and Goda (1985). For sloping armour stone revetments the methodologies are Ahrens and Heimbaugh (1988b), Goda (1985), and Owen (1982). The technical support document Wave Uprush and Overtopping: Methodologies and Applications (Atria 1997) provides further details. Caution must be exercised when applying these methods due to the significant margin of error associated with the results.

c) Upper Limit of Wave Uprush

For the definition and delineation of shoreline flood hazards in *large inland lakes*, an appropriate **upper-bound** curve of the "accepted" uprush procedures for smooth slopes can be used and is given as follows:

$$\frac{R_s}{H_s} = 1.25\,\xi$$

together with and limited by the maximum value as a function of the protection work (or beach) slope

$$\frac{R_s}{H_s} = \sqrt{2\pi}\left(\frac{\pi}{2\theta_r}\right)^{1/4}$$

where:
R_s = the significant uprush (m);
H_s = the significant wave height (m) at d_s;
ξ = the surf similarity parameter; and
θ_r = slope of protection works (in radians).

The surf similarity parameter is as follows

$$\xi = \frac{\tan\theta}{\left(\frac{H_s}{L_o}\right)^{1/2}}$$

where:

θ = slope of protection works (in degrees)
L_o = deep-water wave length (m); $L_o = 1.56T^2$; and T is wave period (s).

Figure 4.9: Application of Wave Overtopping Models

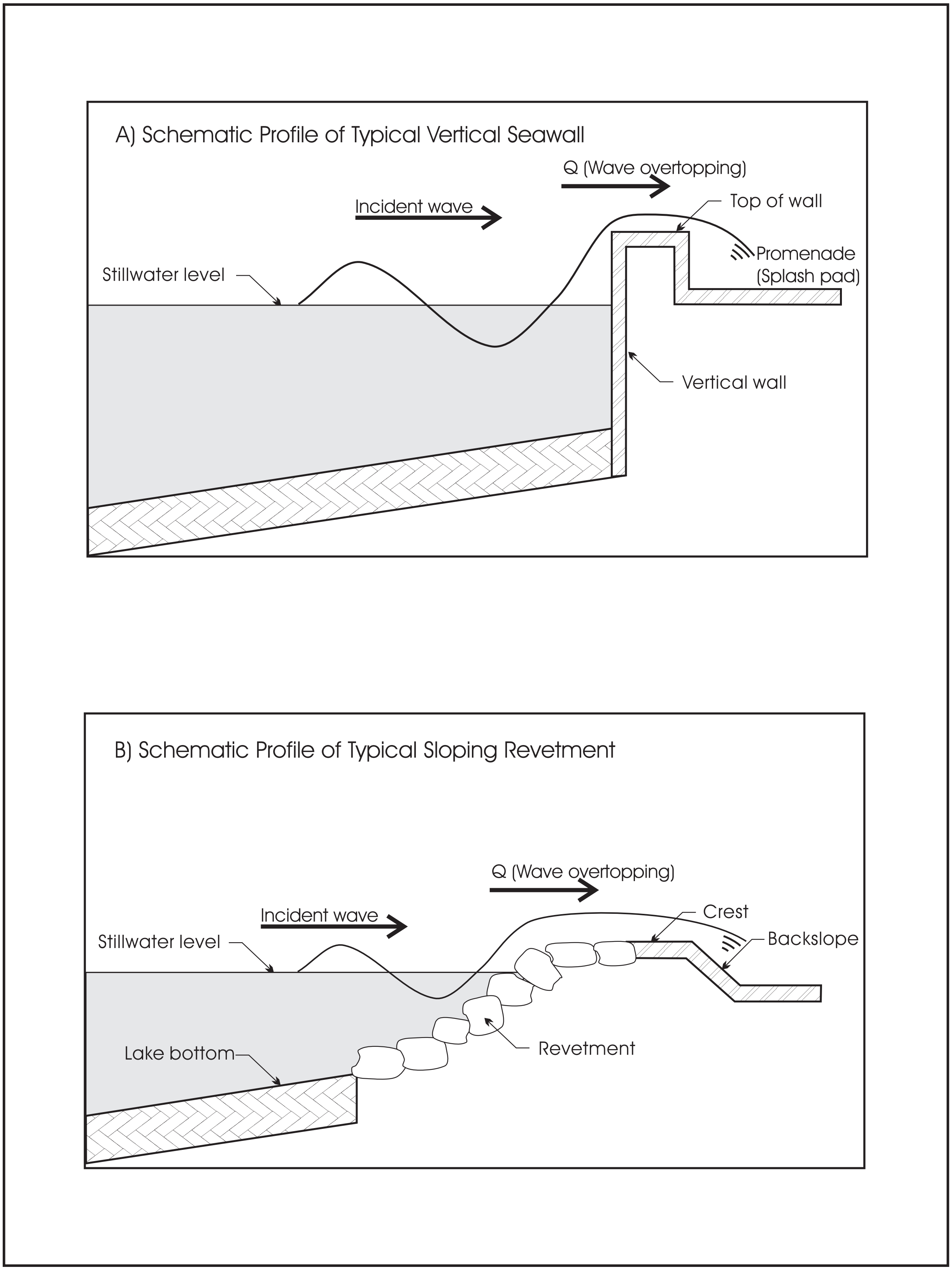


Figure 4.10 graphically shows this upper-bound, smooth slope, uprush method.

For rough slopes, the smooth slope runup values can be modified by the appropriate slope surface reduction factor, *r*, as follows:

$$\left[\frac{R}{H}\right]_{roughslope} = \left[\frac{R}{H}\right]_{smoothslope} * r$$

Table 4.1 provides an upper bound of the slope surface reduction factors, *r*.

Table 4.1: Upper Bound of Slope Surface Reduction Factors

Slope Surface Characteristics	*r*
Smooth	1.0
Concrete or Gobi blocks	0.9
Grass	0.9
Quarrystone, rubble	0.8
Stepped surface	0.8

d) Distribution of Irregular Wave Uprush

During a storm, the maximum limit of wave uprush will exceed the value of uprush determined by R_s/H_s This is because even though the wave conditions during a storm are characterized by the single value, H_s the waves actually vary in height (i.e., they are "irregular"). H_s represents the "significant wave height" and is described as the average of the highest one-third of all the wave heights. It is often assumed that the wave uprush is Rayleigh distributed resulting in

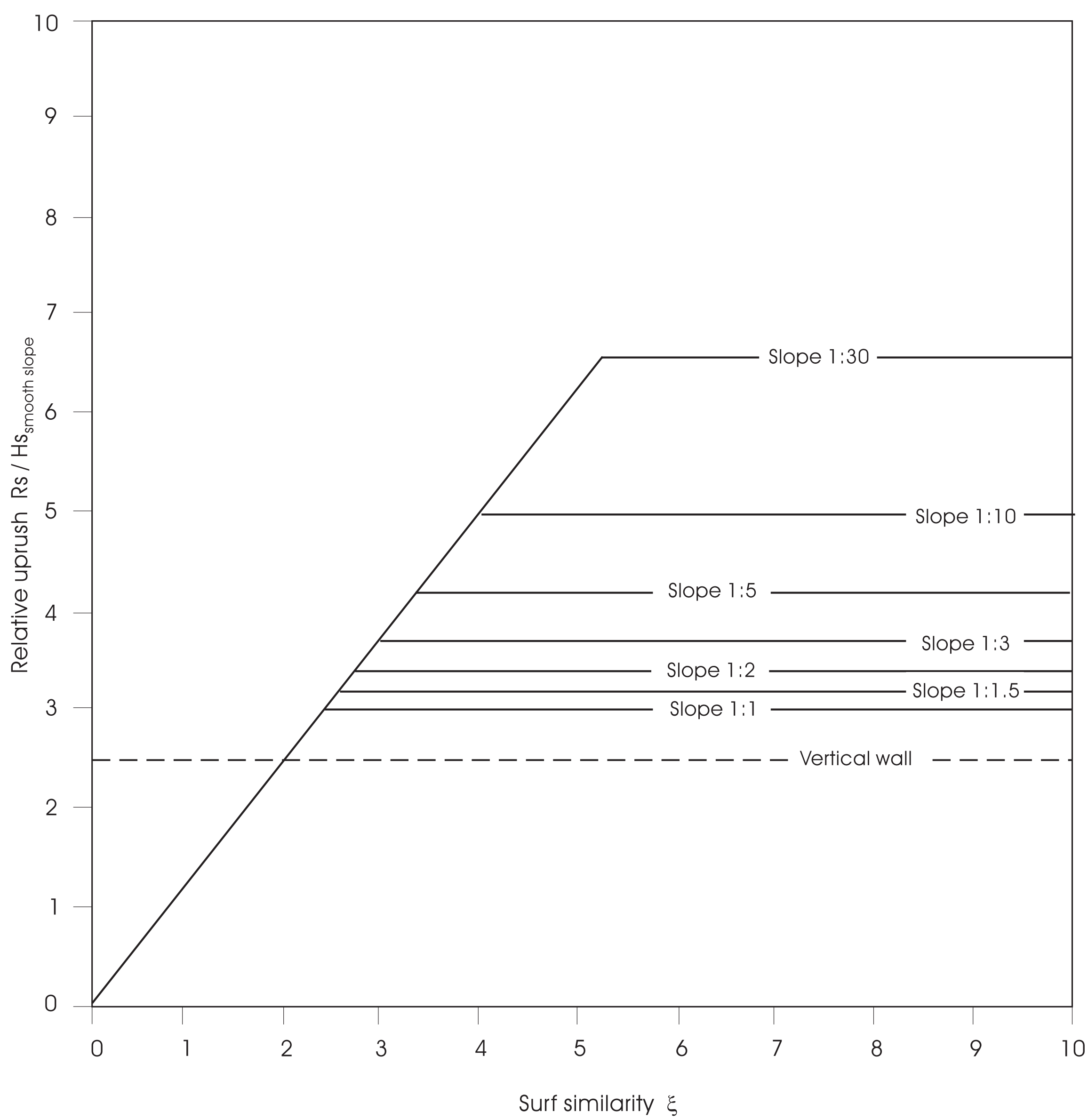
$$R_2 = 1.4\,R_s\,; \qquad R_2 = 2.23\,R_m$$

where:
R_2 = the uprush level exceeded by only 2% of all the uprush levels

The R_2 uprush value could be considered as a reasonable limit for minimal overtopping for shoreline protection works. However, it should be noted that making allowances for safe overtopping is considered to be acceptable engineering design practice. R_m is the mean uprush value. As a general guide, if the freeboard, *F*, is less than 2 times R_m, there may be considerable or excessive overtopping.

To obtain an upper-bound estimate of the R_2/H_s level, the upper-bound curves (Figure 4.10), represented by the equations presented above, could be increased by a factor of 1.4.

Figure 4.10: Relative Uprush and Upper Bound Curves for Smooth Slopes



For rough slopes apply the slope surface reduction factor, r.

$$R/H_{rough\ slope} \approx R/H_{smooth\ slope} * r$$

e) Acceptable Rates of Overtopping

A summary of acceptable mean overtopping rates is presented in Figure 4.11. Further guidance for assessing the acceptable rate of overtopping is provided in Wave Uprush and Overtopping (Atria 1997). The guidance provided by Figure 4.11 is grouped according to three categories:

1) usage considerations;
2) structural stability considerations; and
3) flooding/drainage considerations.

All three considerations must be addressed when assessing the allowable level of overtopping. The usage consideration is further subdivided into "vehicles", "pedestrians" and "buildings". The usage guidelines are generally applicable for situations in close proximity (i.e., less than 10 m) to the shoreline or protection works.

Usage considerations should be evaluated using severe wave and water level conditions that are likely to occur during periods of normal operation. Structural stability and flooding/drainage considerations should be evaluated using the 100 year flood level and the associated wave conditions.

It is important to note that during a storm, overtopping is characterized by sporadic, intense events when the larger waves overtop the shore. It is during these brief, intense moments when most of the overtopping volume takes place. For example, over a period of one hour, approximately one-half of the total overtopping volume may be the result of the single largest overtopping wave. The volume of water in this single overtopping wave, and the rapidness with which it occurs (i.e., of the order of a couple of seconds), will determine the hazard level. As a result, it is not so much the average rate that determines the level of inconvenience or danger, although average rates can be used as criteria for acceptable overtopping (Jenson and Juhl 1987).

Wind can have an important influence on the quantity and extent of wave overtopping. Wave spray can be carried much further inland. Building and structure designers should be made aware of the potential for significant icing during freezing weather.

f) Data Requirements

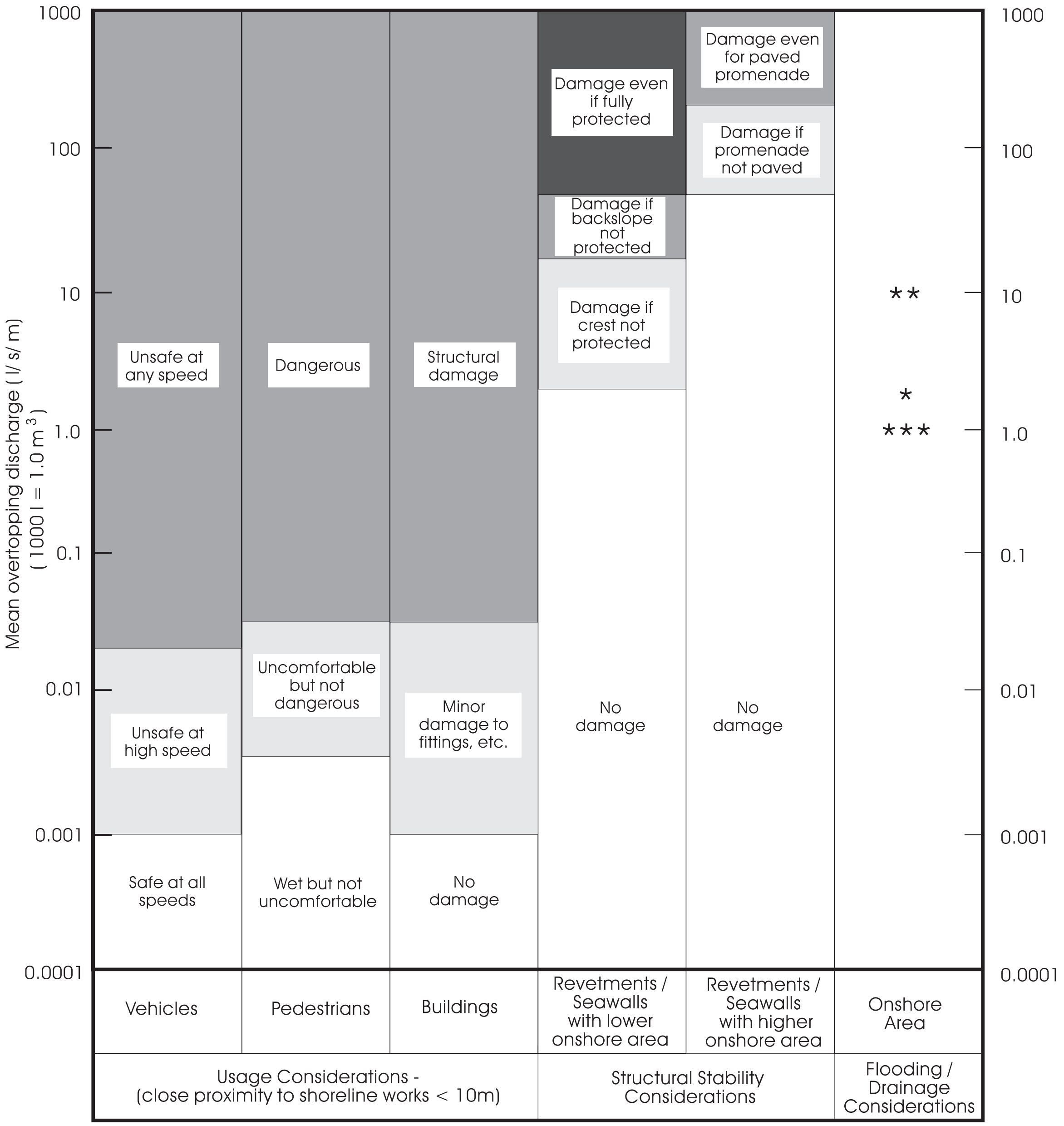
The data required for determining wave uprush and wave overtopping includes:

- the stillwater level (*SWL*);
- the incident wave climate (wave height, H, and wave period, T);
- the beach or protection work slope (tan θ);
- the lake bottom slope (m);
- the water depth at toe of the protection work's slope or beach slope (d_s); and
- surface roughness and protection work permeability (Δ_r and P).

The stillwater level should be the 100 year flood level. The 100 year flood level includes both the mean lake level plus wind setup.

When defining wave conditions, for shoreline reaches with significant fetch areas, wind generated deep-water waves should be calculated, or depth-limited nearshore wave conditions assumed, to determine the wave uprush offset allowance. A fetch is considered to be significant where the maximum fetch distance measured over an arc extending 60° on either side of a line perpendicular to the shoreline is greater than 5 km.

Figure 4.11: Summary of Acceptable Overtopping Rates (adapted from CIRIA / CUR 1991)



* 2 l / s / m considered acceptable for dykes in Holland (Pilarczyk 1990).

** Suggested limit by GODA (1985) for utilization considerations and requires drainage channel of sufficient width (few tens of metres wide) and strong paving to withstand impact of falling water.

*** Suggested limit by GODA (1985) if ground elevation behind structure is lower than flood level or if insufficient facilities for proper drainage. Keillor and Miller (1987) suggest this limit for residential properties.

.   Waves and the Flooding Hazard

Storm surge and wave action are not independent events as both are wind driven phenomena. Further, the 100 year flood level is a combination of mean lake level and storm surge. It follows that the 100 year flood level is not independent of wave action. In order to determine the limit of wave uprush for the purpose of determining the limit of the *flooding hazard*, it is necessary to know the wave conditions which are reasonably likely to accompany the 100 year flood level. There are three approaches that can be used: the first, is based on the appropriate return period of the deep-water waves; the second, is derived from the wave conditions resulting from a maximum sustained wind speed; and the third, is the based on the depth limited wave condition. Both the first and second approaches require transformation of the deep-water waves to the site in the shallow nearshore (i.e. local wave conditions).

With the exception of Lake Simcoe (MMM 1981), there is no available information on deep-water wave conditions which are likely to accompany the 100 year flood level on Ontario's *large inland lakes*.

An estimate of wave height (*H*) and period (*T*) based on wind speed, fetch and depth can be made using the wave prediction methods found in the Shore Protection Manual (USACE 1977). Shallow-water curves should be used to estimate the offshore wave conditions if the average depth of the lake is in the range of 4.5 to 15 m (15 to 50 feet). The deep-water curves should be used where the depth is greater than 15 m (50 feet). For the Great Lakes, FEMA (1991) recommends a maximum sustained wind speed of 65 km/h. For shallower lakes with shorter fetch distances, the appropriate maximum sustained wind speed used should be greater than 65 km/hr. Matheson (1989) reported that the 30 year return maximum hourly wind velocities were found to provide acceptable guidance in determining the significant wave heights with effective fetches up to 10 km. Figure 4.5 shows the maximum hourly wind velocities with an annual return period of 1/30. The values range from 80 km/h for northern Ontario to 97 km/hr for southern Ontario.

If deepwater waves are used, the deepwater waves then have to be transformed to the nearshore to take into account the effects of refraction, shoaling, diffraction and other influences. Simple techniques for estimating refraction, shoaling and diffraction, based on linear wave theory, are available in the Shore Protection Manual (USACE 1984). In practice, most nearshore wave transformation studies carried out at the present involve more sophisticated computerized models. These models must be used and interpreted by qualified coastal engineers.

An alternative approach to determining the deepwater wave conditions and then transforming the waves to the nearshore is to assume depth-limited wave conditions in shallow nearshore waters. Depth-limited simply means that the wave height is physically limited by the depth of the water. That is to say, a given depth of water can only support a certain maximum wave height. The depth-limited wave height condition used in the uprush equations, for protection works in the inner nearshore or backshore, can be approximated as follows:

$$H_s = 0.78\, d_s$$

$$H_{mo} = 0.6\, d_s$$

It is useful to know the deepwater wave height associated with the depth-limited wave height (i.e., what deepwater wave height is necessary to produce the depth-limited wave). Comparison of depth-limited associated deepwater wave height with the actual deepwater wave conditions estimated previously or ,where data exists, the observed wave climate will give some indication of how often the structure would be subject to these waves, if at all.

.   Sensitivity Analysis

A range of wave conditions (i.e., height and period) should be used to determine sensitivity of the wave uprush methodologies. Depending on the site conditions (i.e., slope, approach slope and water depth), the maximum wave height may not necessarily produce the maximum value of wave uprush.

. Incident Versus Transmitted Waves

In instances where a structure, such as a detached breakwater, may act to reduce the incoming, or incident, wave action at a site, it may be necessary to estimate the transmitted wave height (i.e., the wave height on the leeside or shoreward side of the structure) for the purpose of determining the *floodproofing standard*. Estimates of transmitted wave height can be made by qualified coastal engineers using guidance from the literature (i.e., CIRIA/CUR 1991 (see Atria 1997); Allsop 1983; Bremner, Foster, Miller and Wallace 1980; Seelig 1979; van der Meer 1990).

. Shoreline Slope, Approach Slope and Water Depth

Data on the nearshore bathymetry and onshore topography at the study site are needed for evaluations of wave uprush and overtopping. In undertaking these evaluations, it is important to obtain the nearshore bathymetry near the site in order to define the transition from the approach slope (i.e., lake bottom) to the shore or protection works slope and to determine if a composite slope procedure is applicable. A composite slope consists of various slopes as opposed to a single constant slope.

A further complicating factor arises when the extent of the calculated uprush extends past the top of the shore or structure slope such as might occur along a low bluff or bank shoreline. Guidance on the inland extent of the wave uprush is provided in the Technical Guide for Great Lakes - St. Lawrence River Shorelines (MNR 1996).

. Surface Roughness and Structure Permeability

The surface roughness and structure permeability is dependent on the structure type. The surface roughness of various materials is demonstrated in Table 4.1. Saturated sandy beaches are typically assumed to be smooth and impermeable. Permeability of the structure depends on the thickness and number of armour layers, the underlayers and filter. Single layer armour stone revetments with a minimal under layer of rip-rap and a geotextile filter may be considered as a rough impermeable structure for the purpose of wave uprush. This due to the fact that the velocity of the uprushing and downrushing water greatly exceeds the ability of the geotextile filter to pass water. Further information on roughness and permeability is provided in Wave Uprush and Overtopping: Methodologies and Applications (Atria 1997).

. Alongshore Considerations

For isolated protection works (i.e., no protection at adjacent alongshore properties) or for protection works with low level protection at adjacent properties, the provision of adequate wave uprush protection, at the one site only, may be insufficient to protect the property against flooding. Water overtopping the shoreline at the adjacent properties may flow unimpeded onto the subject property. Consideration must be given to the provision of drainage of water from adjacent properties.

. Shoreline Protection Works

The structural stability of protection works can be threatened when they are overtopped by waves. Overtopping can erode the area behind or above the protection work, resulting in the removal of material which supports the structure and may ultimately lead to the potential failure of the protection work.

The effects of overtopping can be reduced by increasing the crest elevation (i.e., increase the freeboard, F) or by protecting the surface area behind the protection work. The protection work can consist of armour stone, rip-rap, concrete or asphalt pavement, proprietary reinforced grass or soil products or other suitable materials. Of primary importance is the provision of a proper bedding and filter for the selected protection works and a continuous connection with the filter of the primary protection. A description of some of the methods for estimating the overtopping protection requirements for shoreline structures are outlined in Atria (1997).

. Drainage Provisions

In the design of seawalls, the drainage system for the overtopped water should be well planned, ensuring that the volume of overtopping water due to storm waves, which can be considerable, is properly calculated and accommodated. The drainage system must ensure rapid drainage otherwise recovery operations may be hampered.

Factors to take into consideration, when designing a proper drainage system for any development, include the following:

- the temporal and spatial distribution of the overtopping water (i.e., most of the water volume is the result of relatively few waves resulting in short periods of high flow with the greatest intensity closest to the protection works);

- while overtopping intensity may decrease as you move away from the shoreline, the increased distance does not diminish the flooding risk due to the total volume of water which comes over the structure;

- the potential for blockage of drains by wave carried sediments and debris; and

- the potential freezing of the drains.

The predictors of wave overtopping can provide estimates of the average overtopping rate. Using established, standard civil engineering drainage design methods as a guide, a designer should then ensure that these factors are incorporated into a drainage system for the selected protection works. The resulting shore drainage should be much larger than typical land-based systems.

Where drainage provisions landward of a protection work are uncertain or are not sufficient, the elevation of the development should be greater than the level of the limit of wave action (i.e., the development must meet the conditions of the *floodproofing standard*).

4.4 Other Water Related Hazards

A number of additional water related influences impact on the landward extent or destructive nature of flood hazards. These include, but are not limited to ice piling, ice jamming and boat generated waves.

4.4.1 Ice

On lakes, ice first starts to melt along the shore because it is thinner there and beacuse more heat comes from the adjoining ground surface. A free water surface appears along the shoreline leaving the main body of ice floating free. At that time the ice cover still has considerable strength (Michel 1971). Significant damage to shore structures (e.g., docks, ramps and shorewalls) can occur along shorelines of *large inland lakes* where a combination of early ice breakup and strong onshore winds results in large pieces of floating ice being driven into the shore. Ice piling occurs when wind or wind driven currents and waves carry ice sheets or flows on top of one another and eventually onto the shore.

Ice jams, usually occurring during spring ice breakup, involves the broken pieces of ice moving to join a stationary piece of ice to form a jam. The most significant impact of ice jams on *large inland lakes*, when they clog the outlet or an inflowing river, is that of shoreline flooding. The ice cover, itself, can also cause changes to the hydraulics of the a lake and/or river system causing local and regional flooding threats. This usually occurs where a portion of the system which is normally open channel flow is restricted or closed resulting in conduit flow and flooding.

While ice piling can damage shoreline structures and erode beaches, ice can also act as a natural protector of shoreline environments. The initial formation of shore ice can reduce the influence and overall destructive impact of wave action by acting as a protective barrier.

Hazards related to ice, including ice jams and ice piling are to be addressed and included in the calculation of the flood allowance for wave uprush and other water related hazards. Where local conditions suggest that the standard flood allowance of 5 metres for *large inland lakes* is not sufficient to address recurring problems associated with ice piling and ice jams, a more detailed engineering study, using accepted engineering principles, should be considered. It should be noted that the present ability to predict the inland extent of ice incursion is limited due to the many variables such as time of year, air temperature, stage of ice decay, wind conditions, ice thickness and strength, snow thickness and strength of ice cohesion to the shoreline.

4.4.2 Boat Generated Waves

Boat generated waves are a familiar and common phenomenon to people living and interacting near harbours, embayments, navigation channels, or other bodies of water on which boats operate. Depending on the shoreline configuration and slope characteristics, boat generated waves can rush up the shoreline past the 100 year flood level. In addition to boat generated wave uprush, the subsequent boat generated wave drawdown can scour and damage a shoreline or protection works.

Local conditions such as bathymetry, water levels, soil conditions, protection works, currents and waves have a direct effect on the degree to which a site is susceptible to boat waves. As such, site specific conditions may require that investigations using acceptable engineering principles be carried out in these and other locations affected by boat generated waves.

By definition, the calculation of the flood allowance for wave uprush and other water related hazards includes the influence of boat generated waves. Where local conditions suggest that the standard flood allowance of 5 metres for *large inland lakes* is not sufficient to address recurring problems associated with boat generated waves, a more detailed engineering study, using accepted engineering principles, should be considered.

At the present time the level of analysis and understanding of the processes related to boat waves is limited. There is no predictive method available for determining the limit of wave uprush due to boat generated waves.

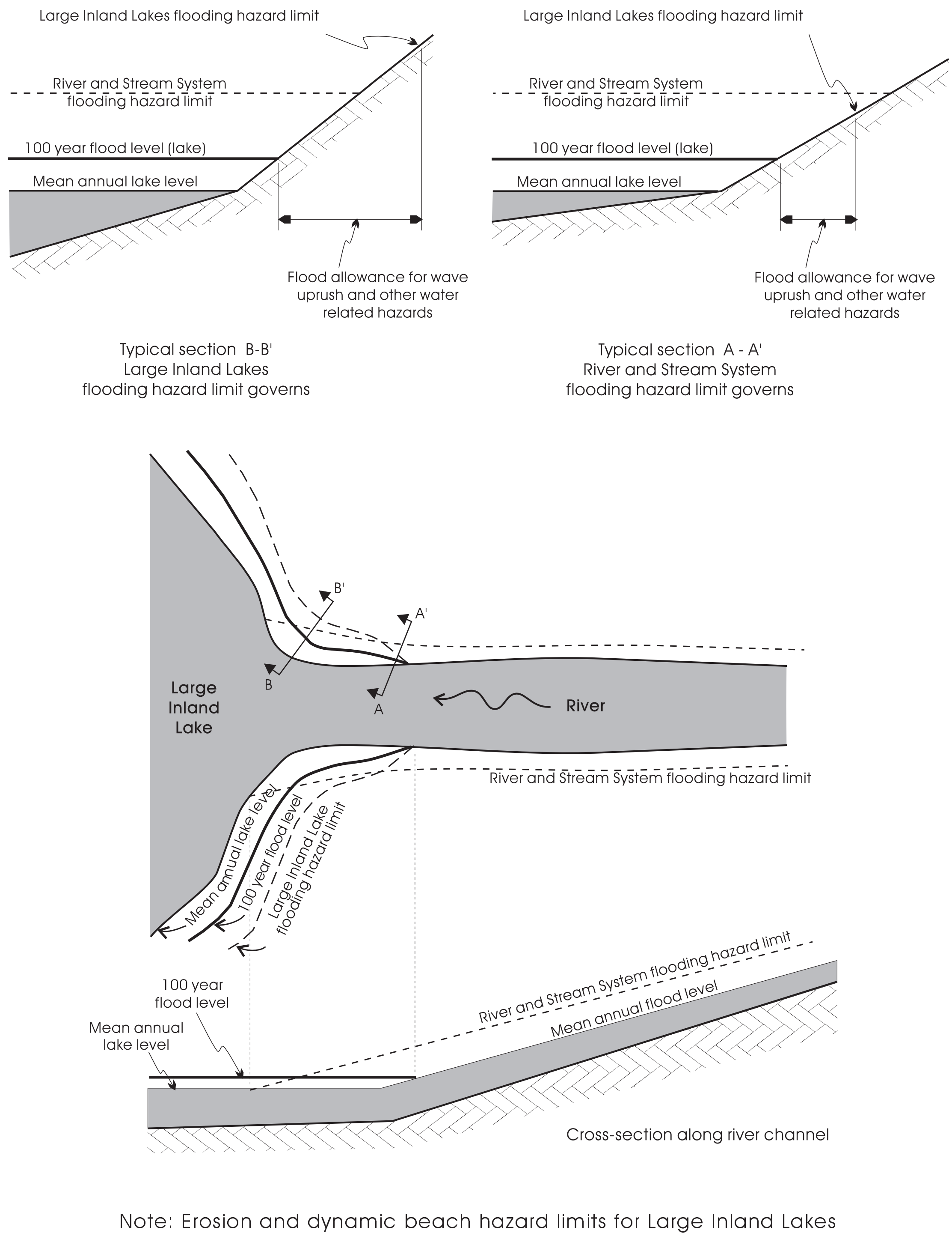
Some work has been done in predicting ship generated waves which may be applicable boat generated waves. Although present techniques do not translate the ship generated wave information into a horizontal distance, they are useful in providing an understanding of some of the processes which are occurring as a result of ship generated wave activity. Appendix A3.6 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines provides a review of ship wave processes.

4.5 Combination of the Flooding Hazards for Large Inland Lakes and River and Stream Systems

Determining the relevant *flooding hazard* limit at the junction of a lake and river or stream is based on an evaluation of which *flooding hazard* limit governs the site, namely the *flooding hazard* limit for *large inland lakes* or the *flooding hazard* limit for *river and stream systems*. In other words, the decision on which limit applies is based on which factors most influence the level of the flood risk or hazard at a given location.

This determination may become particularly difficult at a wide river mouth due to the interaction of lake generated waves with the channel currents and the complex bathymetery at the river mouth, as when waves propagate into the river and stream system. If the currents in the river and stream system are significantly high, the wave propagation pattern (i.e., refraction and diffraction) will be altered and the wave conditions along the connecting channel, which are essential for wave uprush calculation, may be affected.

Figure 4.12: Flooding Hazard Limits at Junction of River and Lake



Note: Erosion and dynamic beach hazard limits for Large Inland Lakes and erosion hazard limits for River and Stream Systems must still be evaluated and applied if further landward.

Determining which *flooding hazard* limit applies is based on the same principles outlined in the Technical Guide for River and Stream Systems (MNR 1996) and are as follows:

> Rivers flowing into *large inland lakes* require an analysis of the respective river and lake flood levels. Where the high water conditions at the junction are generated by two independent flood events, the *flooding hazard* limit should be based on the higher of:
>
> i) mean annual lake level and the river and stream systems *flooding hazard* limit as shown in Figure 4.12, Section A-A';
>
> or
>
> ii) *large inland lakes flooding hazard* limit as shown in Figure 4.12, Section B-B'.

5.0 EROSION HAZARD

Many geological, topographical and meteorological factors determine the erodibility of a shoreline. These include soil type, bluff height, vegetation cover, groundwater seepage, shoreline orientation, wind and wave climate and lake level fluctuations. For the most part, these factors are dictated by natural processes, but in many instances they can be made worse through human intervention (i.e., removal of shoreline vegetation and nearshore boulders and cobbles, altering surface and groundwater drainage, and impounding lake levels).

Although the rate of erosion may be heightened during storm events and the resultant short-term losses of land more readily visible immediately following a major storm event, erosion over the long-term can be a continuous process influenced by lakeside (i.e., wave action, water levels) and landside forces (i.e., surface/subsurface drainage, loading/weight of buildings, removal of surface vegetation).

To slow the erosion of shorelines, structures such as breakwaters, seawalls and revetments have been used. Often these attempts can cause some new problems; such as aggravating hazards at updrift and/or downdrift properties; and causing unacceptable detrimental impacts to a wide array of environmental components of the shoreline ecosystem (i.e., fisheries, wetlands, water quality). When making land management and land use management decisions, there is a need for individuals and implementing agencies to better understand, recognize and adapt to the natural processes at work along their shoreline.

The intent of this section is to provide background information on the *erosion hazard* as defined in the Provincial Policy Statement (May 1996). Further detailed information can be found in the Technical Guide for Great Lakes - St. Lawrence River Shorelines (MNR 1996) and Geotechnical Principles for Stable Slopes, Great Lakes - St. Lawrence System Shorelines, (Terraprobe 1997).

5.1 Shoreline Erosion and Slope Stability Processes

In defining and delineating shorelines susceptible to erosion there first needs to be an understanding of what causes erosion, an identification of those landforms susceptible to erosion and a clarification of general slope failure mechanisms which influence rates and magnitudes of slope recession.

Erosion and slope instability are two different processes which are often associated together (see Figure 5.1). Erosion results from two basic causes: forces of nature acting along the shoreline and the actions of man. The erosion process affects the soils at the particle level, by dislodging and removing the soil particles from the parent mass (see Figure 5.2). Water movement is often the agent commonly occurring in one of the following manners (see Figure 5.3);

- wave action (i.e., shorelines of lakes, bays);
- rainfall or snowmelt and surface run-off (e.g., sheet or rill or gully erosion);
- internal seepage (e.g., springs) and piping; and
- water flow (e.g., banks or base or river, creek, channel).

Other processes such as loss of vegetation, wind, ice and frost may assist in the weathering or dislodging and transport of soil particles. Shore geology, shore orientation and adjacent bathymetry can also influence the erosion.

Slope failures (i.e., instability) consist of the movement of a large mass of soil (see Figure 5.4). Slope movement or instability can occur in many ways but is generally the result of:

- changes in slope configurations, such as steepness or inclination;
- increases in loading on a slope, such as structures or filling near the crest;
- changes in drainage of the soil which create higher water levels or water pressures, such as heavy rainfall, blocked drainage, broken watermains etc.;
- loss of vegetation; and
- erosion of slope toe.

Wave induced toe erosion frequently triggers slope instability, due to steepening or undercutting of the slope. Along cohesive shorelines (i.e., the controlling substrate is composed of cohesive material; see Sections 2 and 3), on the larger of the *large inland lakes* (i.e., long enough fetch to generate sufficient wave action), the downward erosion, or downcutting of the nearshore profile may also be an important consideration. For most of the smaller *large inland lakes*, and those with erosion resistant controlling substrates, downcutting is not likely a significant concern. A more complete discussion of downcutting along cohesive shorelines is provided in Appendix A1.2, Land/Lake Interaction, of the Technical Guide for the Great Lakes - St. Lawrence River Shorelines.

Water seepage or groundwater levels can also affect slope stability since they affect the slope strength. "Piping" on a slope face can be related to "springs" or seepage, where soil erosion occurs in water bearing sands and slopes.

Initial formation of coastal slopes takes place through cycles of water erosion, followed by stabilization and re-vegetation. Stabilization occurs when the slope reaches a stable angle, and soil movement stops. Vegetation then becomes established on the stable slope mass, which provides protection against surface erosion (see Figure 5.5). Sloping surfaces are prone to increased erosion due to the increased flow velocities and to the increased concentration of flow quantity, or duration.

Environmental influences (e.g., climate and heavy rainfall) may interrupt stabilization by causing new erosion that can trigger or re-initiate slope movements. Studies have found that along river valley slopes, low intensity but long duration storms seem to produce more slope failures related to toe erosion (i.e., water flow along toe). Comparatively, along lake shoreline slopes, sustained storms or high lake levels tend to produce more slope failures influenced by toe erosion (i.e., wave attack on toe). Shoreline erosion can also increase when the mean lake level is elevated to accommodate hydro-electric development, recreational and boating needs or flood control works. At the new higher level, shoreline materials previously above water are now subject to water and wave action. There will be a period of time of increased erosion as the shoreline adjusts to the new water level.

Evidence of shoreline erosion may be detected in several ways. Aerial photographs can be a great aid in a preliminary investigation, however, the more direct approach would be to undertake a site visit. Once in the field, a systematic reconnaissance of the entire site and adjacent lands should be conducted. Field notes on pertinent observations should be recorded at the time and place of observation. To further augment and support the field observation, a photographic record can often prove very useful in any subsequent analysis and discussion of management options.

Figure 5.1: Erosion Processes

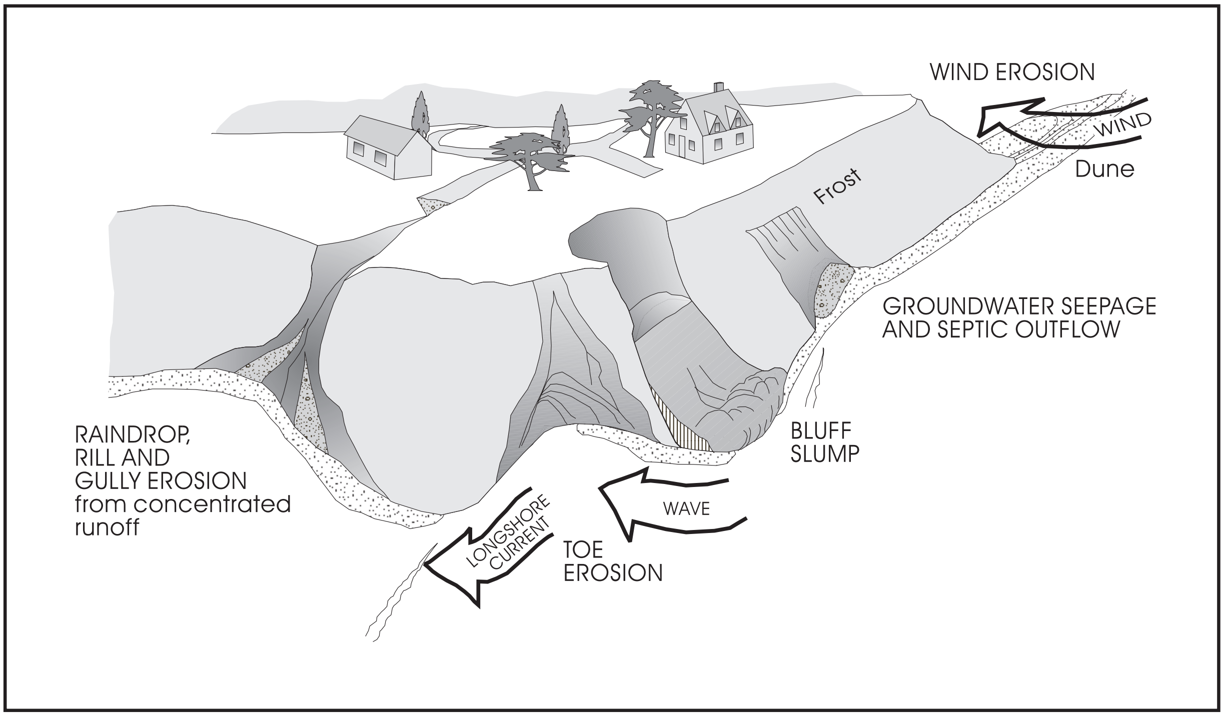


Figure 5.2: Water Action on Soil

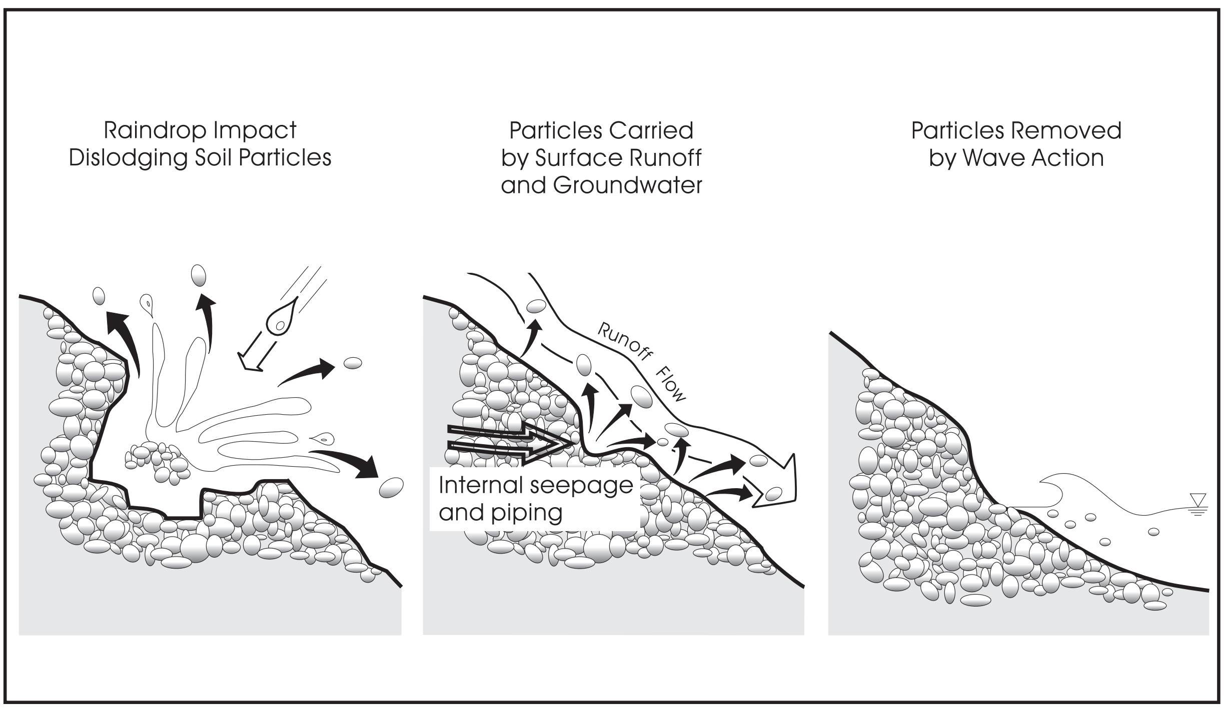


Figure 5.3: Erosion by Waves and Water Flow

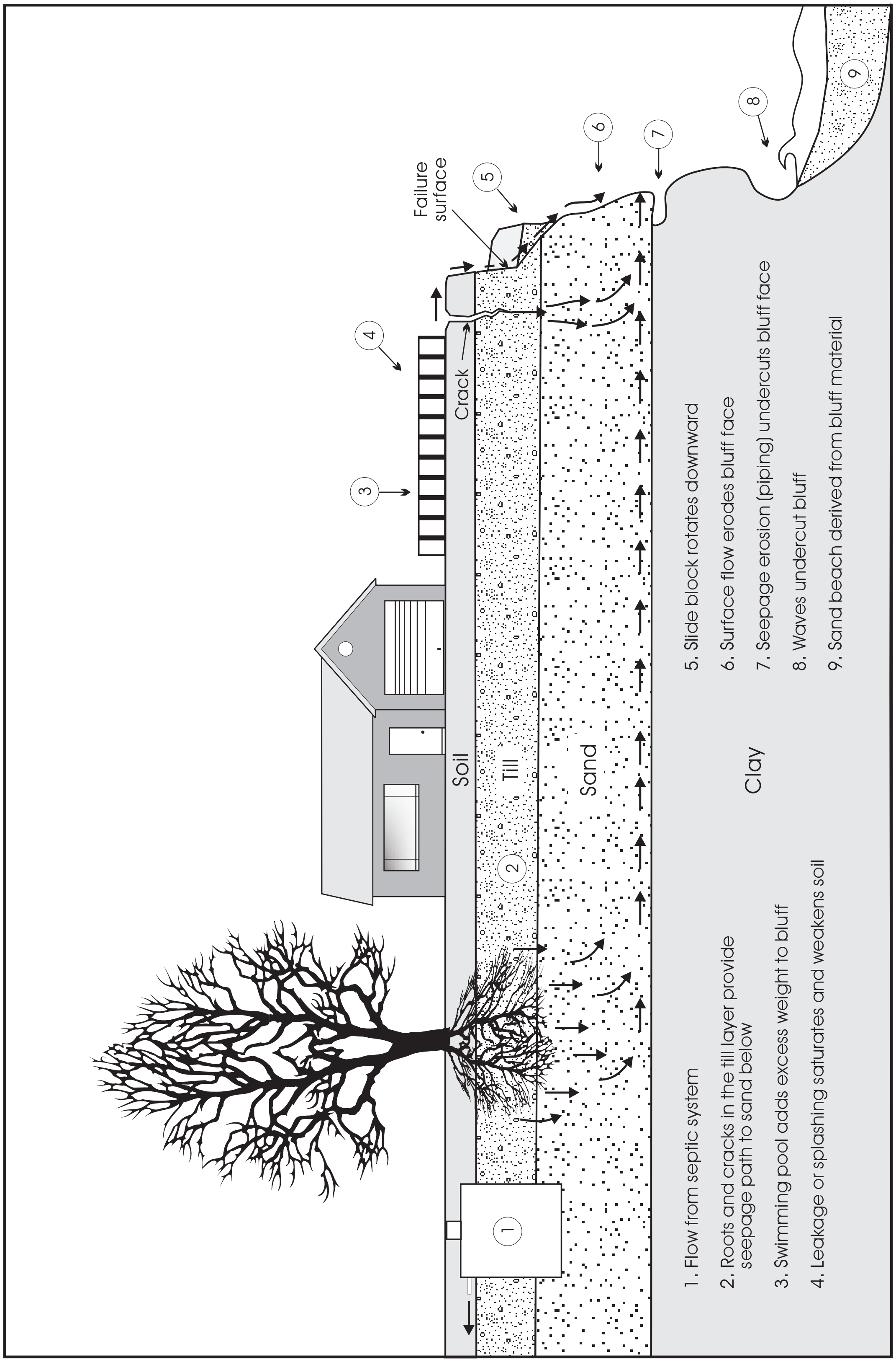


Figure 5.4: Slope Movements

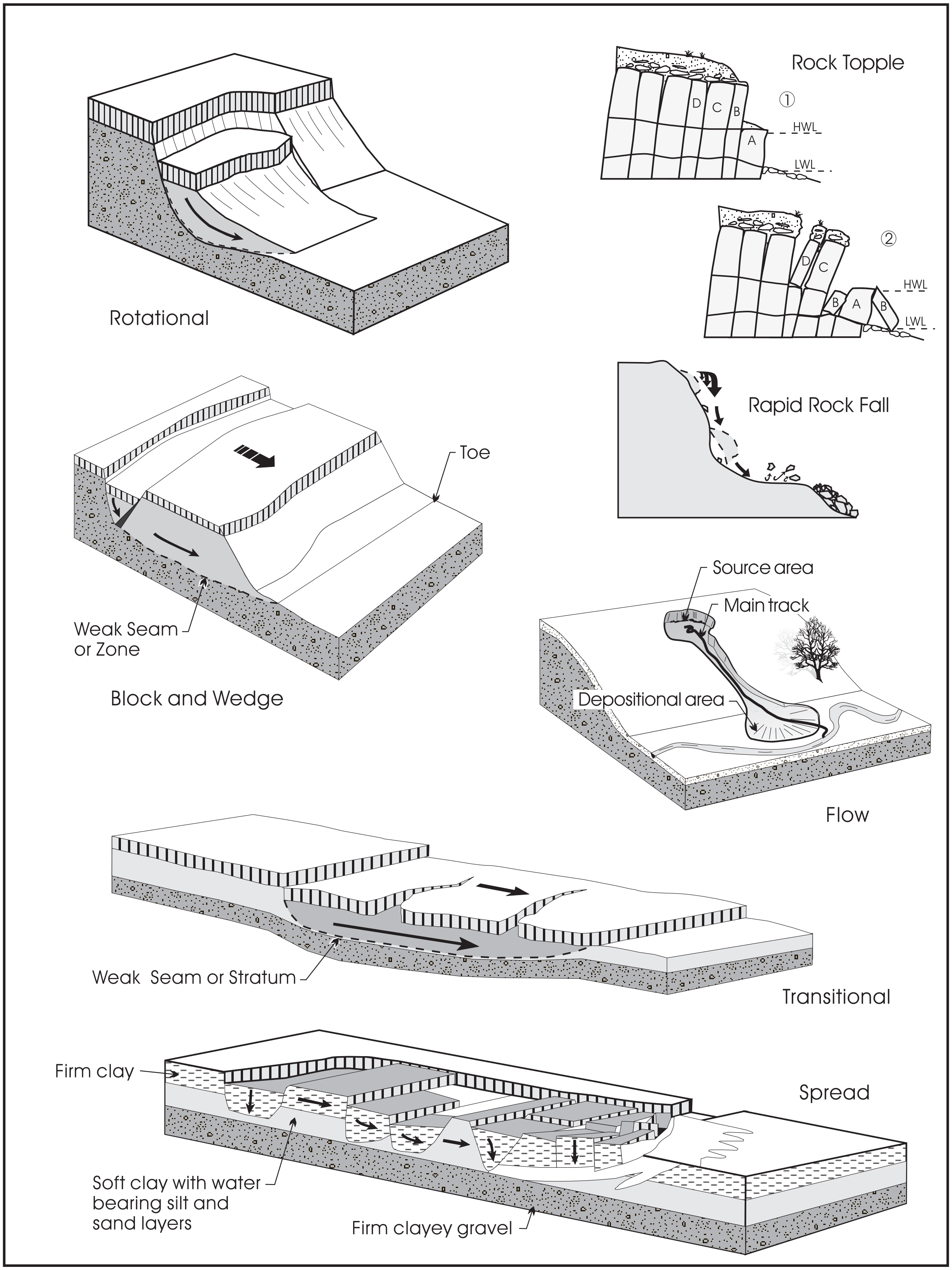
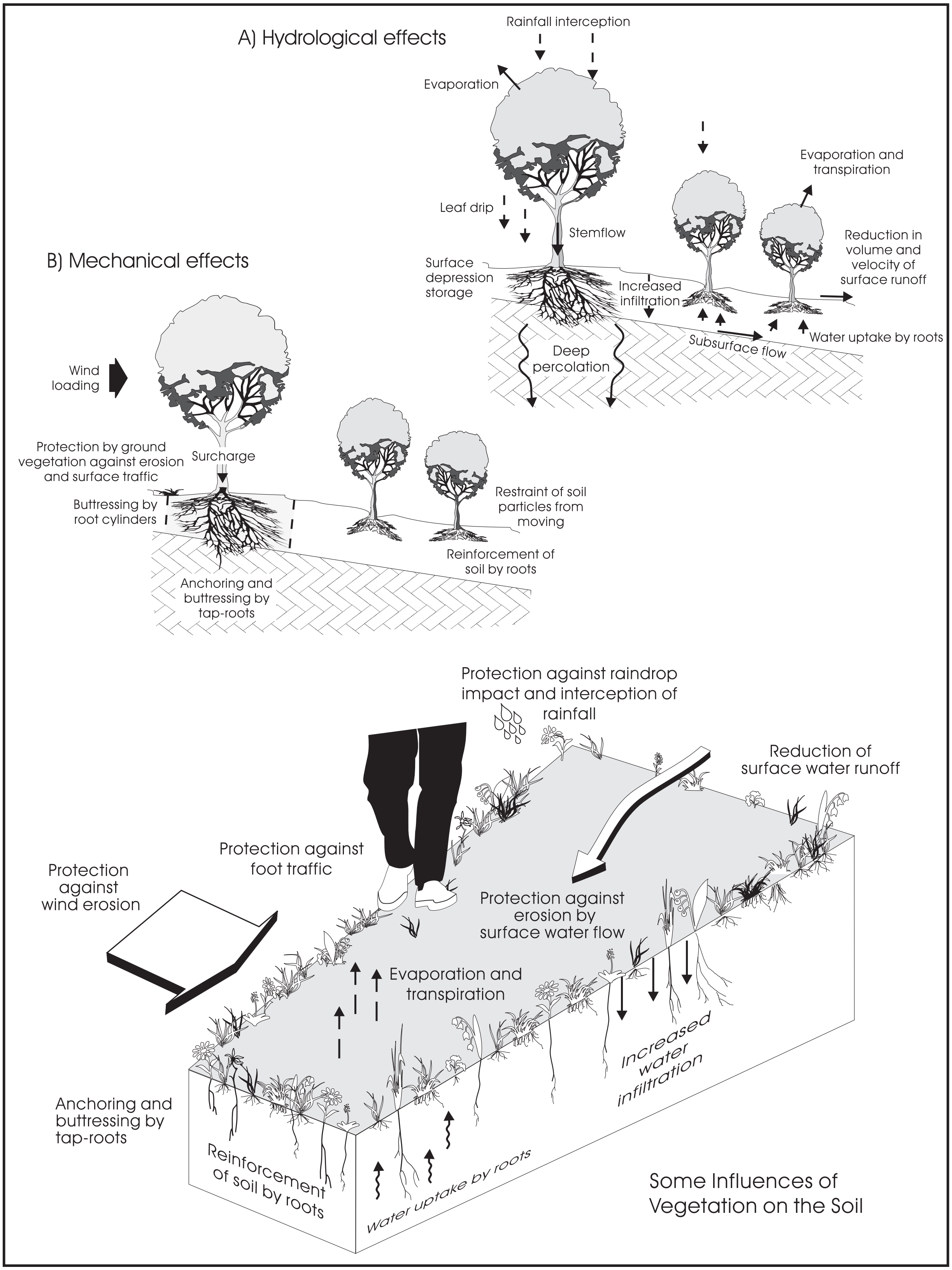


Figure 5.5: Importance of Vegetation in Controlling Surface Erosion

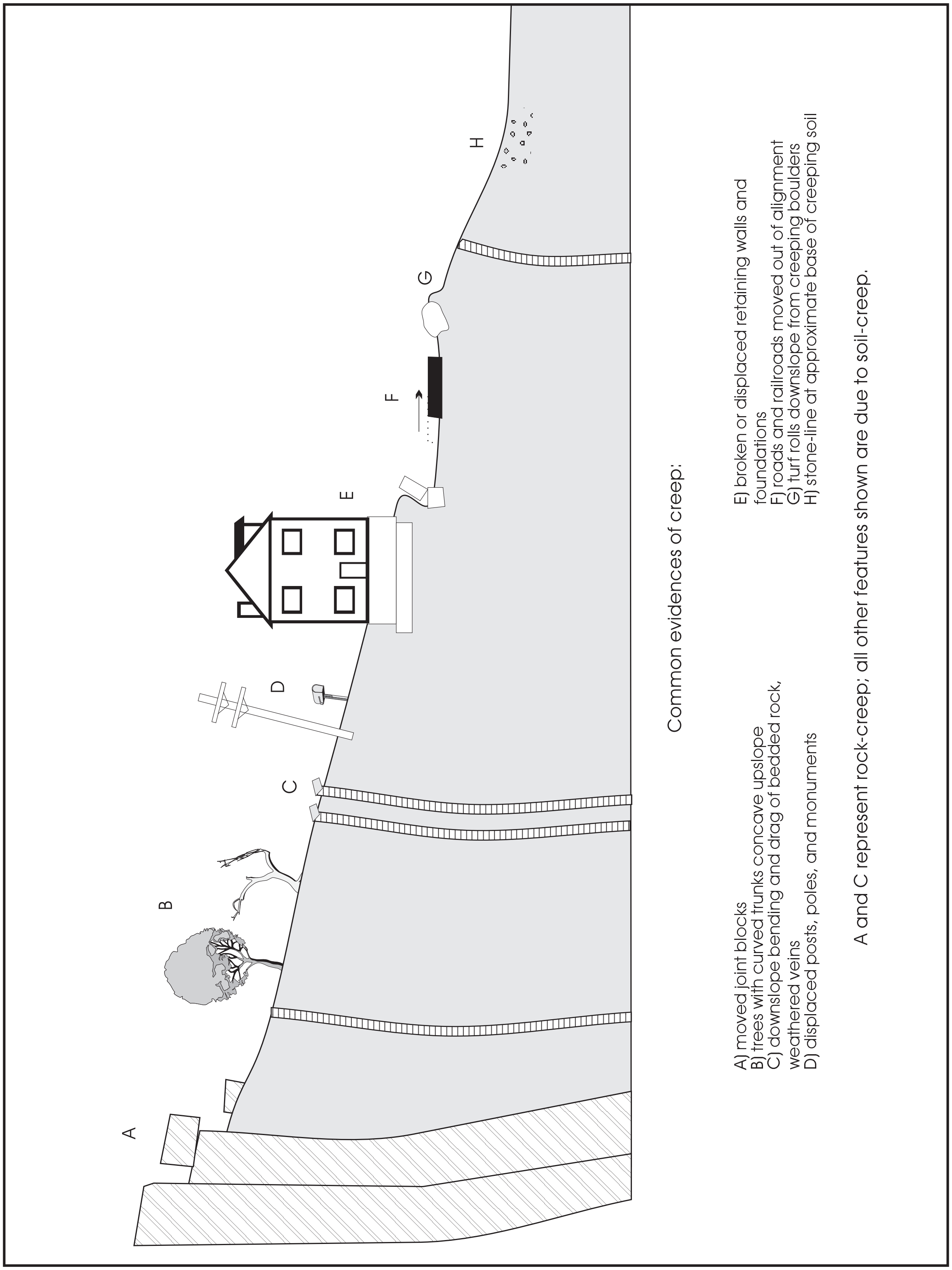


In general, there are a number of visible indicators of erosion which can be determined through a site investigation. A number of the more common visible indicators include (see Figure 5.6):

.	bare slopes	indicates erosion in the area is too rapid for plant growth to take hold
.	hummocks on a bluff slope	indicative of earth flow; look for lumpy, uneven slopes
.	bare scarps	indicative of slumping; look for bare, vertical or near vertical faces on a vegetated slope
.	leaning trees or trees with curved trunks	indicative of soil creep down a slope face; in addition, dead trees near the edge of the bluff often suggests broken roots or loss of root support through soil creep or erosion
.	displaced fence lines or other linear, man-made features	may be indicative of soil creep
.	springs, seeps, or bands of vegetation adapted to wet soils	are generally indicative of a saturated soil or sedimentary layer which may, therefore, be susceptible to landsliding
.	hummocks at the toe of a bluff	can be indicative of an earth flow; look for topographic anomalies
.	soil cracks, tension cracks and separations on top of the bluff or on slope face	may indicate slow mass movement and potential slumping
.	an undercut slope toe	indicates an unstable slope condition
.	leaning or stepped shore protection works	can indicate a lowering of the foreshore which in time could undermine the slope toe creating an unstable condition.
.	presence of slumped material in the nearshore and a scalloped bluff face	is direct evidence of a recent slope failure

In determining the erosion potential of a particular site, consideration must be given to the cyclic nature of shoreline erosion, current potentially hazardous slopes do not always display evidence of past slope failures. In addition, some shoreline locations may not have experienced any recent failures, or conversely, where old failures have occurred they may have been small in magnitude or size and are now disguised by vegetation and surface or toe erosion.

Figure 5.6: Visible Evidence of Shoreline Erosion



5.2 Provincial Policy: Erosion Hazard

Defining the *erosion hazard* involves the calculation of the cumulative impact of stable slope, average annual recession rate, and an erosion allowance (Provincial Policy Statement, May 1996). To address the variable nature of the *large inland lakes* shorelines and to provide flexibility and technical support in the application of the provincial policy, a two step process to define the *erosion hazard* is recommended.

The first step involves the determination of whether or not appropriate erosion or recession information for the particular stretch of shoreline under study is available. It is recommended that **at least 35 years** of sound recession information about the unprotected shoreline should exist before a particular recession rate is adopted for a particular site to provide a measure of reliability in the projection of the average annual recession rate over the planning horizon of 100 years.

Defining the landward limit of the *erosion hazard* first involves the selection of one of the following:

- the **sum of the stable slope allowance <u>plus</u> 100 times the average annual recession rate** (i.e., 100 year recession) measured landward from the toe of the shoreline cliff, bluff, or bank for shorelines **where a minimum of 35 years of recession information is available** (Figure 5.7)

OR

- the **sum of the stable slope allowance <u>plus</u> a 15 metre erosion allowance** measured landward from the toe of the shoreline cliff, bluff, or bank **where there is insufficient recession rate information** (Figure 5.8)

The second step then involves the comparison of the first choice with:

- **a 15 metre erosion allowance** measured landward from the top of the shoreline cliff, bluff, or bank or the first lakeward break in slope (Figure 5.9)

Under the second step, it is the <u>greater</u> of these two measurements (from Step 1 and Step 2) which ultimately determines the landward limit of the *erosion hazard*.

The *erosion hazard* is applied to all shorelines of *large inland lakes* except where dynamic beach shore types exist. Although erosion of cohesionless sediments, such as sands, silts and clays found in beach environments, have a significant influence on the change and configuration of certain shore forms, discussion on this form of erosion is more appropriately and more fully discussed in Section 6, Dynamic Beach Hazard, of this Technical Guide.

The following sections explain in more detail how each of the three contributing factors are determined:

- **stable slope allowance** (Section 5.3 describing the 3:1 stable slope allowance standard, situations where a study using accepted geotechnical principles may be acceptable and applied),

- **average annual recession rate** (Section 5.4 describing the use of the minimum 35 years of record, and the various methods for defining recession rates)

- **15 metre erosion allowance** (Section 5.5 describing shorelines where an adjustment in the 15 metre erosion allowance standard may be considered based on accepted scientific and engineering principles)

Figure 5.7: Erosion Hazard Limit: Stable Slope Allowance plus 100 times the Average Annual Recession Rate

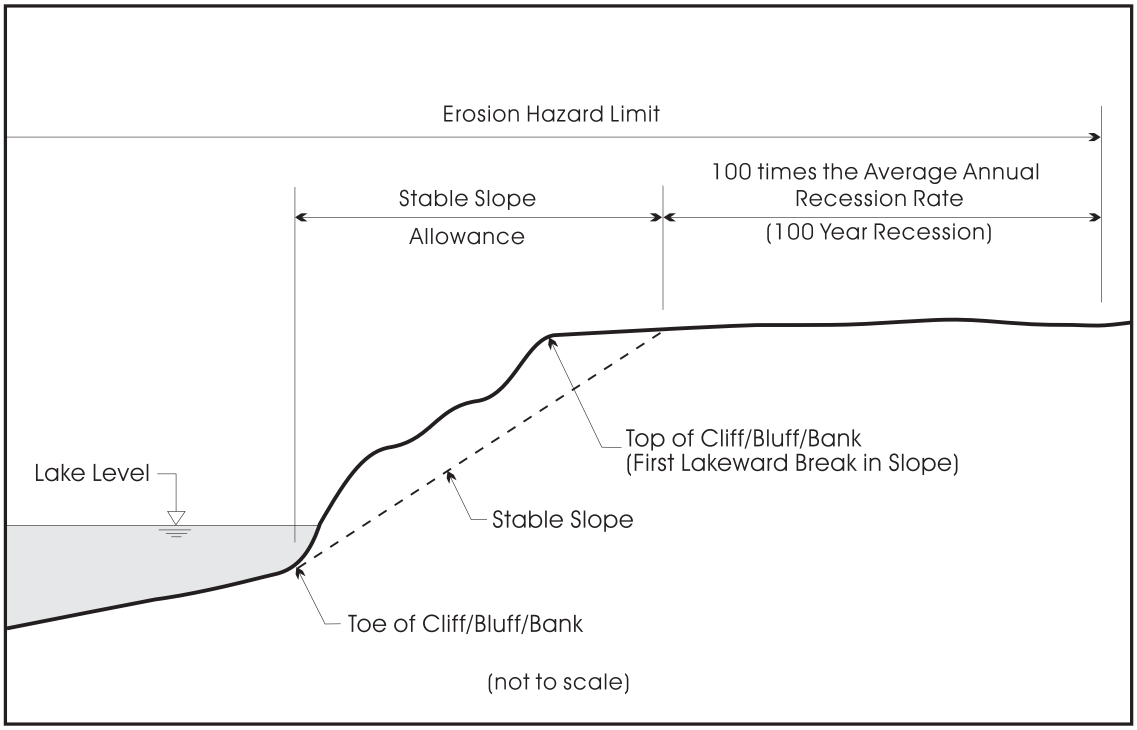


Figure 5.8: Erosion Hazard Limit: Stable Slope Allowance plus 15 metre Erosion Allowance

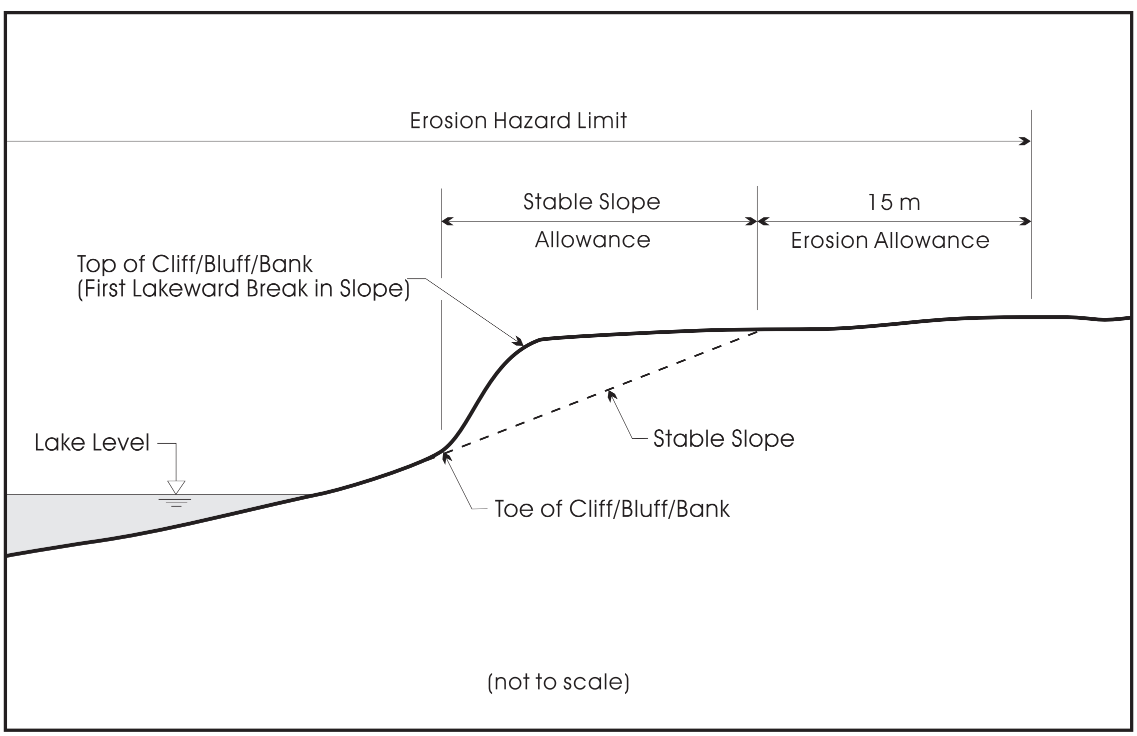


Figure 5.9: Erosion Hazard Limit: 15 Metre Erosion Allowance Measured from Top of Cliff/Bluff/Bank or First Lakeward Break in Slope

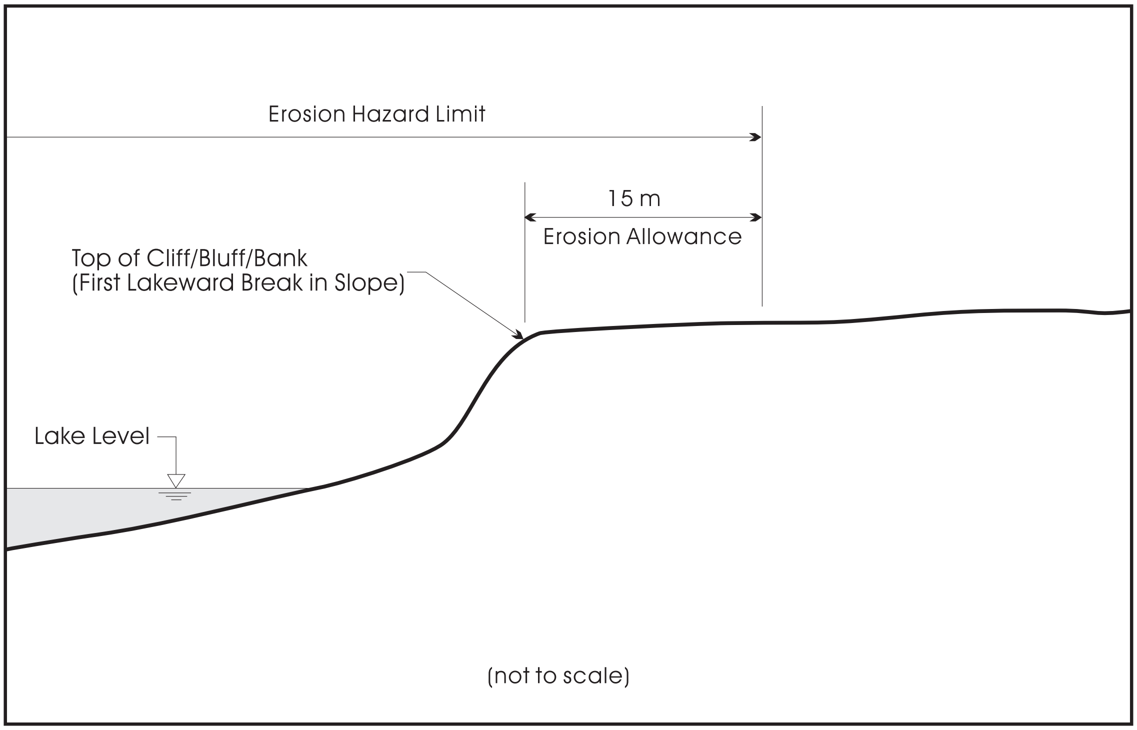
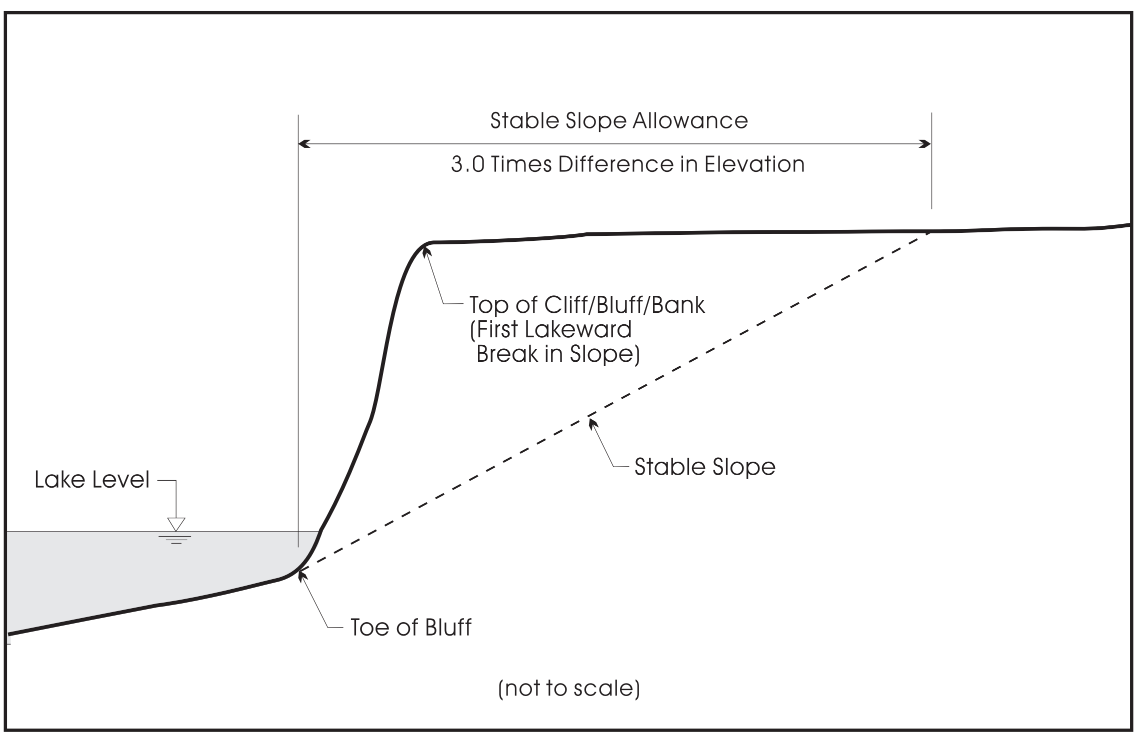


Figure 5.10: Stable Slope Allowance



5.3 Stable Slope Allowance

The stable slope allowance is a horizontal allowance measured landward from the toe of the shoreline cliff, bluff, or bank equivalent to 3.0 times the vertical height of the cliff, bluff, or bank (see Figure 5.10) or a distance determined through a study using accepted geotechnical principles.

A horizontal to vertical ratio of 3:1 is considered to be an acceptable conservative value for most shoreline locations. Identification of the toe and top of cliff/bluff/bank and height of the cliff/bluff/bank must be found to determine the stable slope allowance.

The location of the toe of a cliff/bluff/bank can be either submerged, covered or emerged. The top of the cliff/bluff/bank corresponds with the lakeward edge of the tablelands and is sometimes referred to as the first lakeward break in slope (Figure 5.11a). In some instances, usually in shorelines which have undergone past slides (Figure 5.11b), the top of cliff/bluff/bank may be some distance landward from the lakeward edge of the tablelands. In these instances, experienced judgement in the determination of the top of cliff/bluff/bank is required. The vertical height of a cliff, bluff or bank shore type is simply the vertical difference in elevation between the toe and top (first lakeward break in slope) of the cliff, bluff, or bank.

Where municipalities determine that the 3:1 requirement is excessive or not sufficient enough, mechanisms providing the flexibility to undertake a study using accepted geotechnical principles should be incorporated into the municipal planning process. This flexibility may not be warranted or desired where a more precise definition of the *erosion hazard* is not necessary, where there is sufficient area within the development lot to site any proposed development outside of the *erosion hazard* limit, where development pressure is low and alternative development sites exist, or where the staff, administrative and financial resources within the municipality may preclude the ability of the municipality to support such studies.

Where studies using accepted geotechnical principles are approved by the municipalities or planning boards, the landward limit of the *erosion hazard* will be defined by the engineered stable slope allowance <u>plus either</u> the 100 year recession rate <u>or</u> a 15 metre erosion allowance and applied only in the area studied.

Municipalities, implementing agencies and development proponents should consult the Technical Guide for Great Lakes - St. Lawrence River Shorelines (Part 4: Erosion Hazard) and the technical support document (Terraprobe 1997) for technical direction regarding what constitutes "accepted geotechnical principles" (i.e., what methodologies should be used, where they should be used, and the appropriateness and applicability of study results).

5.4 Average Annual Recession Rate

The average annual recession rate is a representative linear measurement of the annual retreat of the toe or top of cliff, bluff, or bank over time (usually described in metres per year). The average annual recession rate along a given shoreline should be based on the "natural" recession rate (i.e., a rate derived from an unprotected shoreline). This recession rate type of measurement is readily accepted as a form of measuring and expressing the impacts of erosion, which is in reality a volumetric measure, or the loss of the usable, shore tablelands, particularly by local landowners. For descriptive purposes the erosion classification system in Table 5.1 can be used.

In measuring erosion in terms of an average annual recession rate, two specific shore features, the toe and top of the shore cliff/bluff/bank are used. These reference points are generally easily visible or distinguishable on aerial photographs, topographic maps and in the field.

There are two methods recommended for determining average annual recession rates along the shorelines of *large inland lakes*. The first method is to use existing historical recession studies where they exist, and the second is to carry out a comparative analysis of historic and recent shoreline toe and top of the cliff/bluff/bank positions obtained from surveys, maps and/or aerial photographs.

Table 5.1 Erosion Classification System

Recession Rate (m/yr)	Erosion Classification
< 0.0 to 0.0	Stable or accreting
0.0 to 0.3	Low
0.3 to 0.7	Moderate
0.7 to 1.2	High
1.2 to 2.0	Very High
> 2.0	Severe

In determining the recession rate(s) for any shoreline point location, all available information where the shoreline is unprotected should be utilized. Visible evidence of erosion, described Section 5.1, as well as local anecdotal information may also assist in assessing the average annual recession rate or erosion allowance for a site.

5.5 Erosion Allowance

For the purpose of defining the landward limit of the *erosion hazard*, two different situations are compared. The first being the stable slope allowance plus 100 times the average annual recession rate where sufficient recession rate information is available, or 15 metres where there is insufficient recession rate information, measured landward from the toe of the cliff/bluff/bank. The second being 15 metre erosion allowance measure landward of the top of cliff/bluff/bank. The greater of these is the landward limit of the *erosion hazard*.

The 15 metre erosion allowance is considered to be an appropriate minimum distance:

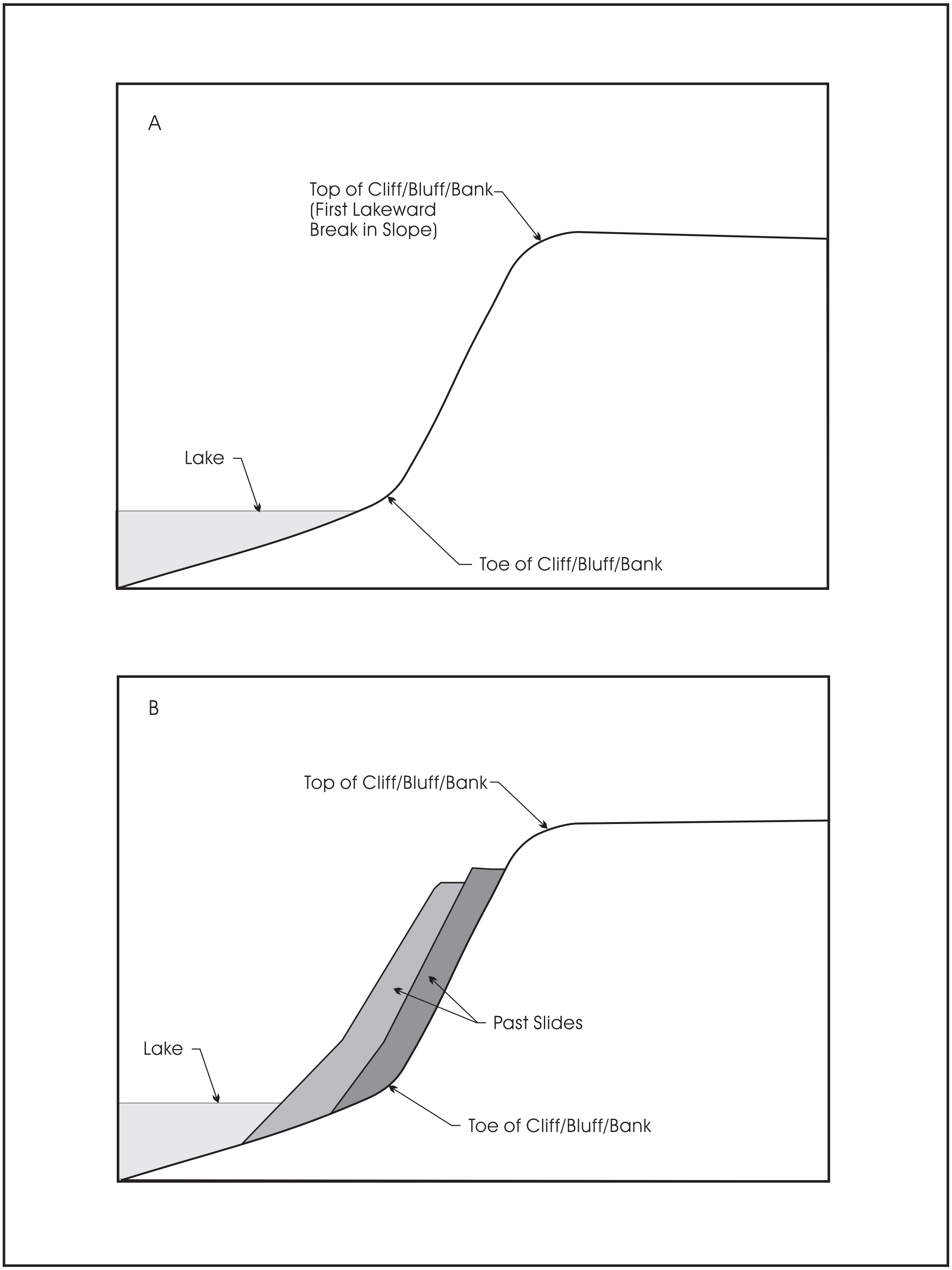
- to address safety issues associated with risks to life and property;
- to account for the uncertainties associated with calculating or not knowing the local recession rates, and the present inability to accurately predict the final form and extent of any surface failure; and
- the potential, yet incalculable, impact on the local recession rates from changes in land use.

Recognizing the variability in the erosion potential throughout the *large inland lakes*, the uncertainties associated with predicting recession rates in the absence of sound historical records, and the complexities associated with determining rates of recession where a wide range of surface, subsurface and lakeside erosive forces are simultaneously acting on a particular shoreline, and in the interest of providing the added flexibility to address this variability, shoreline managers can permit changes to the 15 metre erosion allowance where it is considered to be:

- too onerous in addressing the local erosion potential; or
- not sufficient enough to address the local erosion potential.

Any deviation from the 15 metre erosion allowance standard is to be undertaken only in accordance with accepted scientific and geotechnical engineering principles, as warranted by the site conditions and the size and nature of the proposed *development* and *site alteration*.

Figure 5.11: Toe and Top of Cliff/Bluff/Bank



Of particular concern are shorelines of *large inland lakes* that are undergoing adjustment due to changes in the mean water level as a result of the construction of dams or weirs. The recession rates may be changing depending on the time since the mean level was adjusted. As outlined in Penner (1993), reservoir shore erosion rates generally decline over time. A common assumption is that the erosion rate will decrease exponentially with time (i.e., rapid erosion at the outset, and diminishing as a new shore profile is established). Penner notes that where erosion-resistant rock is buried beneath a thin cover of unconsolidated soil material, the rate is nearly constant until rock is encountered at which point the erosion stops. Factors affecting the recession include the type and density of forest vegetation.

5.5.1 Reduction of the Standard 15 metre Erosion Allowance

An evaluation of the general physiography, post-glacial composition and range of erosion forces impacting on shorelines throughout the *large inland lakes* suggests that there are two general shoreline types or locations where the standard 15 metre erosion allowance standard may be considered too onerous. These include bedrock shorelines; and naturally well-sheltered shorelines. Other shoreline types and location must be further evaluated on a case-by-case basis.

a) Bedrock Shorelines

Bedrock shorelines are defined as those composed of predominantly metamorphic or igneous rock that are not currently being undermined by coastal processes. Although it is recognized that bedrock environments do erode over time, they do so at a very slow rate compared to cohesive shorelines. Where studies are undertaken, using accepted scientific and engineering principles, to determine the erosion allowance in bedrock environments, the scientific/engineered erosion allowance is to be based on a sound knowledge and understanding of the stability of the local bedrock formation.

As a general guideline, the defined erosion allowance should ensure that all proposed shoreline developments are located landward of any obvious tension cracks or surficial jointing which may be indicative of weaknesses in the bedrock structure. Any evidence of block slide events or of boulders and rubble material at the waterline or at the base of a bedrock bluff or cliff shoreline, and the lack of lichens or moss on the face of the bedrock structure are additional indicators of potentially weak rock structures and should be given due consideration through the site evaluation process.

Where development is proposed in areas consisting primarily of bedrock cliffs, recognizing the uncertainties associated with identifying a definitive measure of bedrock stability, the erosion allowance standard determined for the site should be related to cliff height (i.e., the higher the cliff, the greater the erosion allowance).

For bedrock shorelines composed of predominantly shale or sedimentary rock formations, given that these formations can be undermined by coastal processes and that they are considerably weaker than the massive metamorphic and igneous bedrock formations, additional care must be taken in the determination of a reduction in the erosion allowance.

b) Well-Sheltered Shorelines

In determining the erosion allowance along a particular stretch of well-sheltered shoreline, consideration must be given to the erosive potential of the shoreline sediments, impacts of wind and boat generated waves, and ice effects. The erosion allowance may need to be increased where significant wave activity occurs and/or where the shoreline soil structure (based on the nature of the material or on past recession rate information) or backfill material behind the structure is highly erosive.

5.5.2 Increase in the Standard 15 metre Erosion Allowance

In defining the *erosion hazard* limit, it is the intent that the standard 15 metre erosion allowance be considered a minimum value. There is, however, flexibility to address local conditions. As such, where a 15 metre erosion allowance is deemed to be insufficient in addressing the rate of recession along a given shoreline, local municipalities have the option of increasing the erosion allowance requirements in accordance with accepted scientific and engineering principles.

An increase in the 15 metre erosion allowance may be appropriate, but not limited to, actively eroding cohesive bluff shorelines where the average annual recession rate is unknown but considered to be potentially greater than 0.15 metres per year. In these situations, determination of an appropriate erosion allowance standard should be based on a sound understanding of the local wave climate and on the erosive potential of the materials which compose the shore profile.

In shoreline locations consisting of predominantly low-lying cohesive shore profiles, an erosion allowance standard of greater than 15 metres may be warranted. For example, an increase in the erosion allowance standard may be desired near the outlet of a river where the outlet has historically migrated up and down the shoreline area. A second example may include the mouth of a river where the combined hydraulic forces of the river and the lake have the potential to accelerate episodic erosion of the river banks or lake shoreline profile.

In those locations where shore protection works have temporarily arrested erosion for all of the years of available and reliable recession rate records, yet the shoreline is composed of erodible sediments, the erosion allowance standard determined for the site should be based on the erosion potential of the materials at the site (i.e., backfill and natural soil composition). The erosion potential can be determined in several ways, the most common being an examination of nearby unprotected shorelines composed of the same materials, or possibly from an examination of similar materials located elsewhere and exposed to similar site conditions and coastal processes (i.e., fetch, wave height, alongshore sediment transport, etc.).

5.6 Combining the Erosion Hazard Limit for Large Inland Lakes and River and Streams Systems

The *erosion hazard* limit at the junction of a lake and a river is the combination of the *erosion hazard* limit for the *large inland lake*, as defined in this Technical Guide, and the *erosion hazard* limit for *river and stream systems*, as defined in the Technical Guide for River and Stream Systems.

Figure 5.12a shows the location of the *erosion hazard* limits for both the lake and river when the river mouth is narrow. For wide-mouthed rivers, the shoreline manager must first determine the point where the river or stream starts and the lake shoreline ends. The *erosion hazard* limit is then determined for the river or stream system and the *erosion hazard* limit is determined for the lake shoreline. Figure 5.12b illustrates the location of the *erosion hazard* limit for a wide-mouthed river.

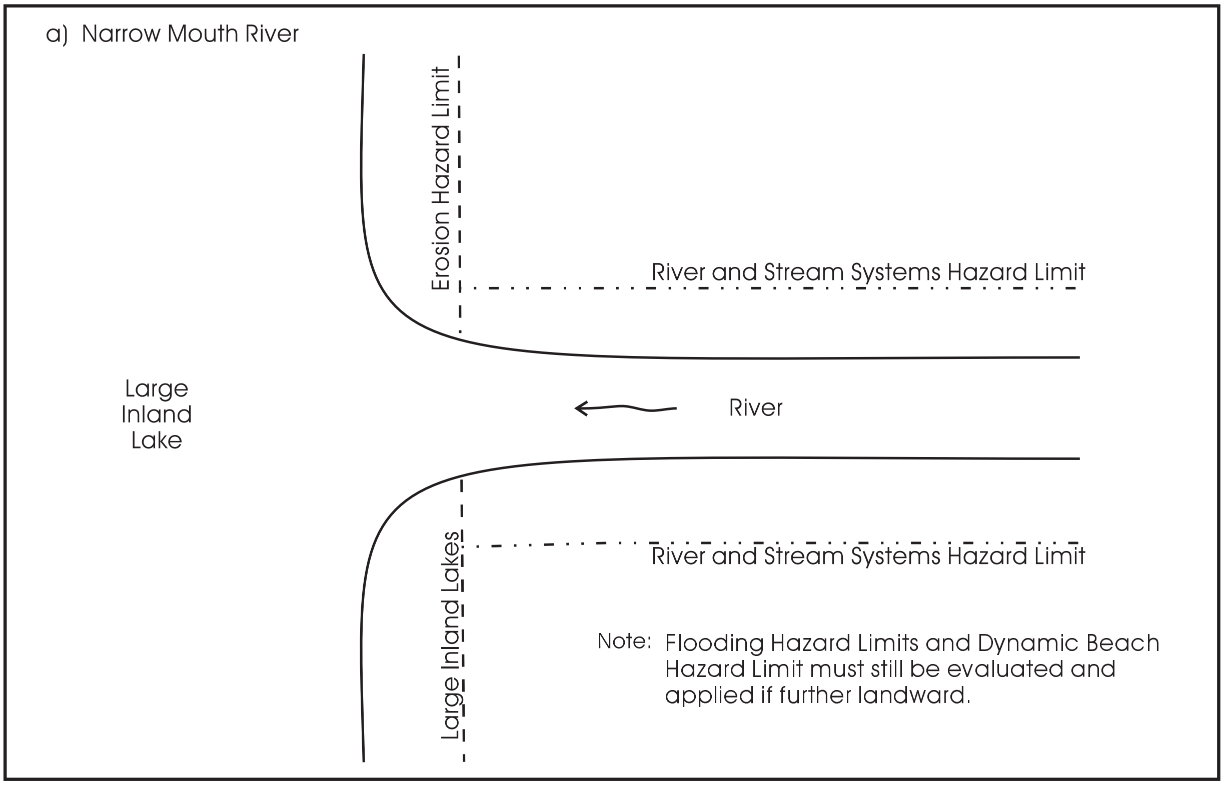
5.7 Historical Maps and Aerial Photographs

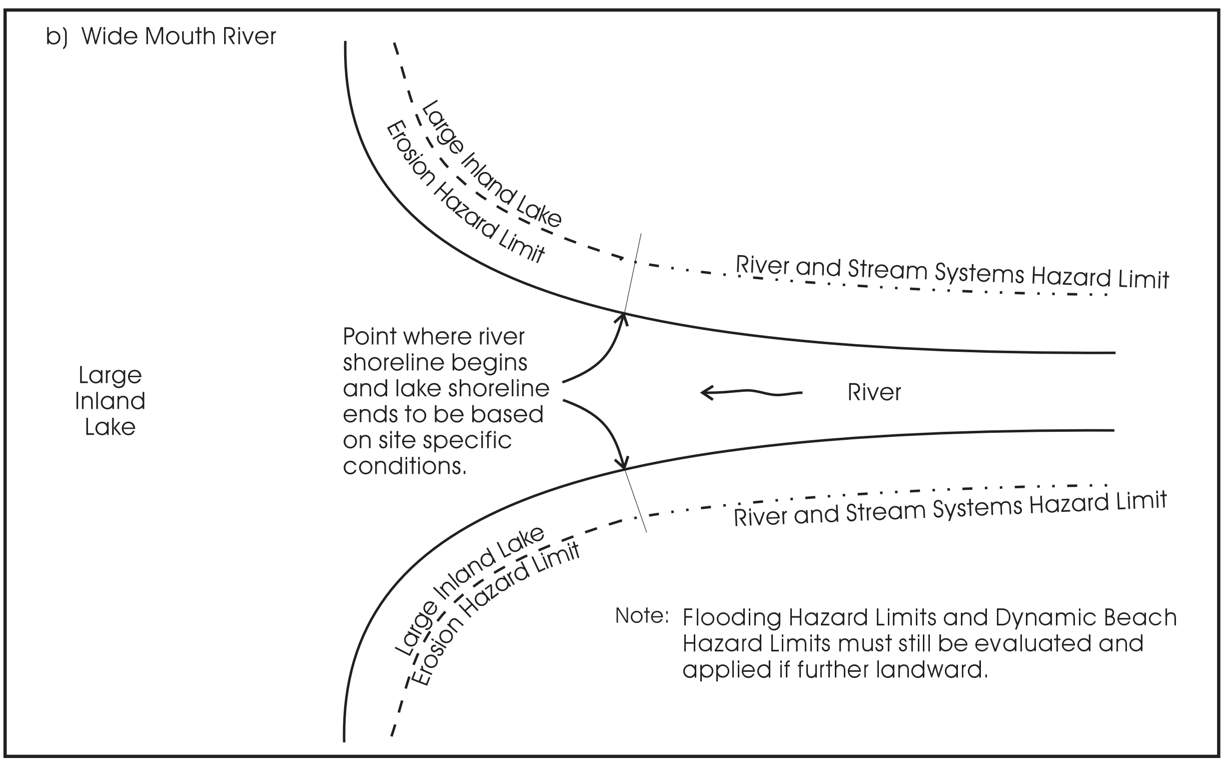
5.7.1 Sources Of Mapped Information

The following section provides a list of potential federal, provincial and public programs offering access to map and aerial photograph information. In addition to identifying map and aerial photograph programs that may be applicable to the shoreline of Ontario's *large inland lakes*. This listing is not intended to be comprehensive.

- Ontario Basic Mapping Program: Ontario Ministry of Natural Resources
  - Large Scale (1:2000) and Medium Scale Mapping (1:10,000; 1:20,000)
- Ontario Hydro
- National Topographic Series (NTS) Mapping
  - Topographic coverage of entire landbase of Canada (1:50,000, 1:250,000, and 1:1,000,000)
- Canadian Hydrographic Service Charts (CHS Charts of navigable waters various scales).

Figure 5.12: Erosion Hazard Limit at Junction of River and Lake





For more information regarding these programs including, program overview, content, coverage(s) and scale(s) available, procedures for conversion to digital files and/or availability of digital information where available and direction on ordering procedures consult the Technical Guide for Great Lakes - St. Lawrence River Shorelines, Appendix A4.3: Historical Maps and Aerial Photographs.

5.7.2 Sources of Aerial Photographs

In selecting aerial photographs for use in calculating an average annual recession rate, remember that photos scaled at 1:20,000 or larger are most appropriate. Photos of this scale are required so that the precise location of features including roads, buildings and toe and top of bluff (where present) can be identified. The following is a list of aerial photograph sources:

- National Air Photo Library - Department of Energy, Mines and Resources (EMR), Ottawa
  - various scale, age and quality
- Ontario Ministry of Natural Resources (MNR)
  - Forest Resource Inventory (FRI) photo coverage
  - Ontario Basic Mapping Program (OBM) photo coverage
- Ontario Hydro

For more information regarding these programs consult the Technical Guide for Great Lakes - St. Lawrence River Shorelines, Appendix A4.3: Historical Maps and Aerial Photographs.

5.8 Creating Historic-Recent Shoreline Position Maps

A method for creating a historic-recent shoreline position map is outlined in Appendices A4.4 and A4.5 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines. Specifically, it provides the following: identifies relevant shoreline data required to create a historic-recent shoreline position map; evaluates the availability of pertinent historic-recent information sources and the issues associated with using map and aerial photography in creating historic-recent shoreline position maps; recommends procedures to create a historic-recent shoreline position map; and develops a step-by-step procedure to determine the average annual recession rate from a historic-recent shoreline position map for natural shorelines and altered shorelines.

5.9 Methodologies to Monitor Shoreline Recession

The purpose of this section is to provide a description of suggested procedures for measuring shore profiles or cross-sections from ground measurements, which, when done annually, can provide valuable information on the erosion/recession rates and contributing processes at the monitoring sites. The two primary methodologies involve the use of a: 1) field monitoring program; or 2) photogrammetric monitoring program.

5.9.1 Field Monitoring Program

A field monitoring program requires a representative cross-shore profile to be located such that it can re-established at subsequent time intervals (e.g., annually) and the profile measurements repeated. The profile location could, for example, extend along a property boundary, across the tableland, down the bluff face, across the beach, and along the lake bottom to some desired distance offshore. As a general rule, it is recommended that measurements be made at locations where erosion is visibly occurring (Section 5.1). This representative cross-shore profile is then surveyed and plotted. When the exact same location is surveyed and plotted on, say an annual basis, the volumetric amount and rate of erosion can be determined. In addition, the linear recession rate of the shoreline can also be calculated.

Ideally, the measurements should be done about the same time each year. The month of July or August, is the recommended period for monitoring since the summer months tend to represent a quiescent erosion period and generally provides similar environmental conditions. In addition to the summer survey, some may wish to replicate the measurements after major storm events to assess the catastrophic nature of erosion and/or to obtain an understanding of the magnitude of damage done by various intensities of storms in their region. Monitoring of this type of information will aid in the development and selection of appropriate shoreline management options to address existing shoreline erosion concerns.

There are essentially two types of measurement sites that can exist. The first involves the shore profile, consisting of a bluff feature, where measurements are taken across a portion of the tableland (e.g., on top and landward of the edge of the bluff), down the bluff face, across the beach fronting the bluff and out into the offshore. The second general shore form involves beach environments where the beach may be backed by a dune complex. In this latter situation, measurements should begin in the backshore area where little change in shore profile has been observed over time (e.g., leeward toe of first main foredune) and then extend the measurements lakeward across the beach and into the lake.

Although annual measurements are recommended, economics may limit the frequency and the extent that measurements are taken. Where only landside measurements are taken, they should extend lakeward to a depth where an individual is able to safely wade. It is recommended that shoreline managers obtain profile measurements of the nearshore zone at least every 5 years to provide sufficient information to understand the processes and potential impacts that nearshore lowering may have on any particular shoreline reach.

Survey methods and equipment available for monitoring shoreline erosion vary from simple (e.g., tape measure and hand level) to sophisticated (total station equipment).

The various methods and steps involved in undertaking shore profile surveys can best be described by differentiating between those steps involving onshore and then offshore measurements.

Onshore Measurements and Tasks

. **Step 1** Determine the water level information for the time period in which the surveying will be undertaken, if available. Obtain the elevation of a known benchmark or reference point.

. **Step 2** Locate the site and establish the base profile line from a fixed reference point (i.e., stakes, iron bars, house corners). As the landward retreat or recession of the shore profile reaches the defined reference points, these reference points may need to be re-established and/or replaced.

. **Step 3** Set up a theodolite or similar equipment on the base profile line near the bluff crest to view backsights and downslope. Starting well enough back from the crest of the bluff/bank to be in an area of little change, place markers on the base profile line at points where major slope changes occur on the tableland, at the top of the bluff/bank, down the bluff/bank slope, at the toe of the bluff/bank and across the beach to the water line.

Care should be taken to ensure that the selected survey points are representative of any major changes in slope so that the drawing of straight lines between survey points will represent a true cross-section or profile of the existing bluff/bank or beach. When these points are not obvious then a survey point about every 3 metres vertical and/or 2 to 3 metres horizontal would provide a rough guide, with some exceptions. On a beach profile the survey points should be taken at any visible changes in slope and/or every 5 metres, with additional survey shots being taken near the water's edge.

. **Step 4** Set up a level or similar equipment and establish the elevation of the level by reading the elevation from the bench mark. Determine the ground elevations at the marked survey points. For offshore points to waist or shoulder deep water, the rod person must ensure than they position themselves on the base profile line by aligning with the markers. In doing so, care should be taken to pin the measuring chain to a known point on the beach to simultaneously measure this distance with the measurement of the beach/offshore elevation, or by using stadia.

. **Step 5** Determine the water level elevation. This can be done by placing rod on a rock, or about a foot into the water and, while the rod person reads the average water level on the rod (i.e., between wave crests and troughs) the level operator reads elevation. Subtract one reading from the other, record the time, and water condition. This may be substituted for re-levelling up the bluff/bank to close the traverse and/or re-level to close.

. **Step 6** Measure the horizontal distances between the marked survey points. Collate and record the measurements and confirm the measurement in the survey record/notes.

. **Step 7** Take a picture of the site and record any additional comments for future reference.

Offshore Measurements and Tasks

. **Step 8** For the offshore work, the base profile line can be sounded by a depth recorder, mounted in a small boat, positioned on line by the theodolite and walkie-talkies, with the distance measured electronically. The cost of this process may prove prohibitive where only a small number of sites are being measured.

A simple alternative to the use of a depth recorder would be to use a sounder, or lead line, with a small boat kept on line by marker poles, with the distance measured by a pre-marked stretch line or by theodolite triangulation. The aim of this method would be to survey to a few hundred metres offshore and/or to a three or four metre depth.

Calculation of nearshore depth can then be done using timely lake water level data.

Compilation of the Surveyed Information

. **Step 9** Reduction and plotting of the information in the office.

5.9.2 Photogrammetric Monitoring Program

A field program for monitoring erosion is considered to be superior to the implementation of a photogrammetric program since photogrammetric work does not yield underwater information and is subject to scaling errors. Photogrammetric programs can, however, efficiently process greater lengths of shoreline. Field survey measurements yield information from a limited number of select locations while photogrammetric monitoring programs provide continuous coverage along the shoreline. For more detailed information regrading photogrammetric monitoring see the Technical Guide for Great Lakes - St. Lawrence River System, Appendix A4.6.

6.0 DYNAMIC BEACH HAZARD

Low-lying shoreline environments generally tend to undergo a continuous or "dynamic" change of form and configuration due to the natural processes of erosion and accretion. These processes can broadly be defined as the removal, movement and deposition of material in the onshore and offshore areas by wave action and currents. Depending on their magnitude and the sediment supply in the nearshore, the turbulence of breaking waves uprushing onshore can build or destroy shoreline beach environments.

On hard rock shorelines, these changes are so slow that they can only be detected when measured in geological time. On shorelines of unconsolidated materials (gravels, sands, silts and clays) significant changes, either a partial or entire loss of the beach, may be observed following a severe storm event or a series of storms, only to reappear days, months or years later.

In many cases, the existing land form and its natural physical and biological features offer a high degree of natural protection against flood and erosion damages. For instance, dunes or sand ridges that lie landward of beaches absorb the energy of large storm waves thereby protecting inland areas from flood and erosion damage. In addition, they provide a valuable reservoir of sand to replace beach material that is carried off during severe storm events. After a storm has passed, the dune is then restored with new beach sand carried in by wind or aeolian forces.

Due to the highly dynamic and highly valued naturally occurring protective benefits realized by maintaining the physical integrity of these dynamic beaches, implementing agencies must ensure that policies established to address these areas recognize these benefits and maintain these dynamic beaches in their natural state.

In examining these issues, the intent of Section 6: Dynamic Beach Hazard is to provide an analysis of the *dynamic beach hazard* as outlined in Section 3.1, Natural Hazards, of the Provincial Policy Statement (May 1996). For purposes of clarification, Section 6 will outline supporting background information on the nature of dynamic beach forms and processes, will promote an awareness and understanding of the response of dynamic beaches to natural or human-induced changes, and will provide a procedure for classifying and mapping dynamic beaches.

6.1 Dynamic Beach Processes

A beach is an accumulation of detrital material or sediment along a lake or broad river shoreline that has been transported and deposited by waves and by currents generated by waves and wind. The sediment composition of a beach may vary from sand to gravel, cobbles or boulders and may contain varying amounts of shell fragments.

6.1.1 Definition of Beach and Dynamic Beach

In a very restricted sense, the term beach can be used to describe the sediment that is exposed above the mean waterline during low wave conditions. Observations quickly show, however, that this sediment does not remain stationary for very long and that some of the sediment may be transported offshore during storms, only to be returned during periods of calmer weather. In addition, sand-sized sediment may be transported landward to be deposited in the form of sand dunes. During low lake level periods, the sand deposited and stored in the dunes may remain there for years and then returned to the water by storm wave action during periods of high lake levels. As such, for the purposes of this Technical Guide, the term beach is broadly defined to include the whole shoreline over which sediment is transported by wave action, extending offshore to the limit of wave action on the underwater bed and onshore to a point just landward of the maximum limit of wave action during intense storms. For instance, on sandy coasts where a dune system is developed the beach will be defined as including the embryo dune and foredune which lie adjacent to the top of the beach proper, and which receive sand directly from the beach. In general, sediment that is transported beyond these onshore and offshore boundaries cannot be returned and is permanently lost to the beach system.

To provide an illustrative description of a sandy beach, a generalized profile including the dominant features and commonly used terminology is provided in Figure 6.1. Typical of sandy shorelines, the beach is divided into the underwater nearshore; the foreshore, which is subject to wave action during low wave conditions; the backshore, which is only subject to wave action during storms; and the dune area which is subject to wave action near the beach and to sand transport by wind over the whole area. The features shown are not found on all beaches and may vary with seasonal and long-term changes in lake level and storm activity.

The term *dynamic beach* is used to emphasize and describe beach profiles which undergo changes on a broad range of time-scales, from hours or days to years and decades, in response to changing wave, wind, and water level conditions and to changes in the rate of sediment supply to a particular section of shoreline. An important consequence of this variability is that the elevation of any point on the beach profile is not a constant, instead this elevation varies through time. As such, it is not possible to define the landward limit of the *dynamic beach* based a single elevation. Instead, to define the landward extent of the dynamic beach requires that the range of the profile variation along each section of beach be evaluated.

The Provincial Policy Statement (May 1996) defines *dynamic beach* as:

> "areas of inherently unstable accumulations of shoreline sediments along the *Great Lakes - St. Lawrence River System* and *large inland lakes*. The dynamic beach hazard limit includes the *flooding hazard* plus a dynamic beach allowance."

As defined, the *dynamic beach hazard* recognizes that a combination of criteria are required to properly define and delineate the landward extent of dynamic beaches on sections of shoreline characterized by beaches (in contrast to cohesive bluffs or bedrock shorelines).

6.1.2 Factors Controlling Beach Dynamics

The factors controlling the dynamic nature of a beach environment are numerous and their interaction produces a highly complex set of processes and responses. In general terms, beach dynamics reflect the operation of processes such as wave-generated and wind-generated currents in the lake, transport of beach-building materials (i.e., sand, gravel) by wind on the sub-aerial part of the beach and dune, and the direct action of ice. The frequency and magnitude of these processes in turn are dependent on factors such as weather and climate, fluctuations in lake levels on a number of timescales (i.e., days, months, years), extent of winter ice cover, and the orientation and fetch of the beach. Finally, attributes of the beach itself, such as the size of the beach sediment, the sediment supply and beach sediment budget also act to determine the dynamic range of an individual beach.

6.2 Provincial Policy: Dynamic Beach Hazard

By definition, the *dynamic beach hazard* involves the calculation of the cumulative impact of the *flood hazard* limit, the average annual recession rate and a *dynamic beach* allowance (Provincial Policy Statement, May 1996).

In addressing these factors, the ***dynamic beach hazard*** is defined as:

- **the landward limit** of the ***flood hazard*** **<u>plus</u> a 15 metre** ***dynamic beach*** **allowance** (Figure 6.2);

OR

- **the landward limit** of the ***flood hazard*** **plus a** ***dynamic beach*** **allowance based on a study using accepted scientific and engineering principles**.

Figure 6.1: Generalized Profile of a Sandy Beach

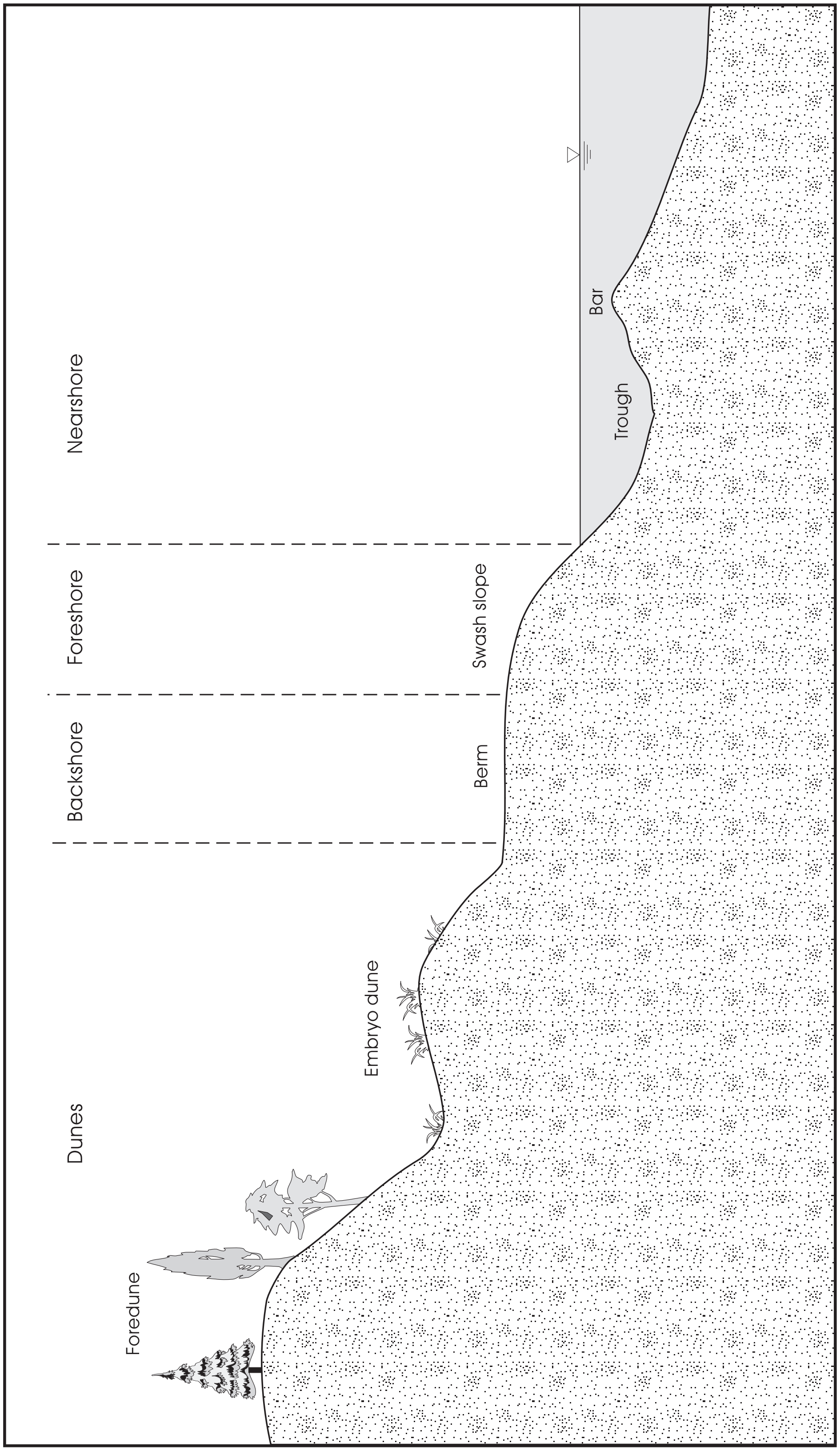


Figure 6.2: Dynamic Beach Hazard Limit

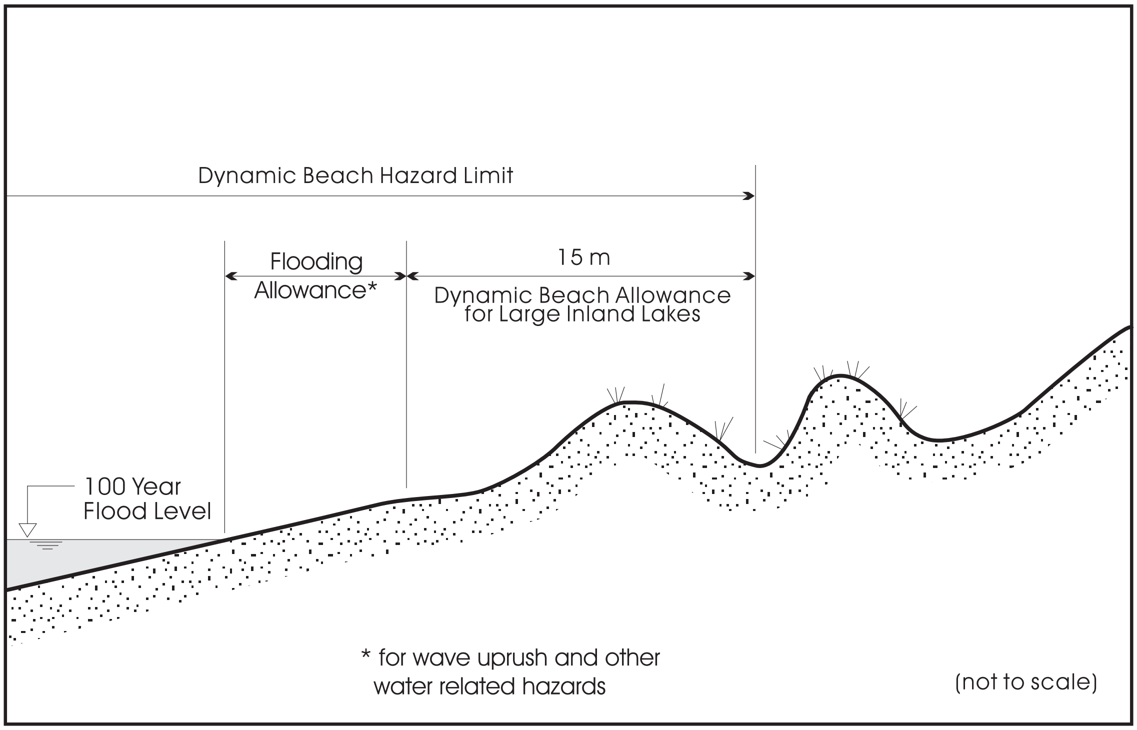
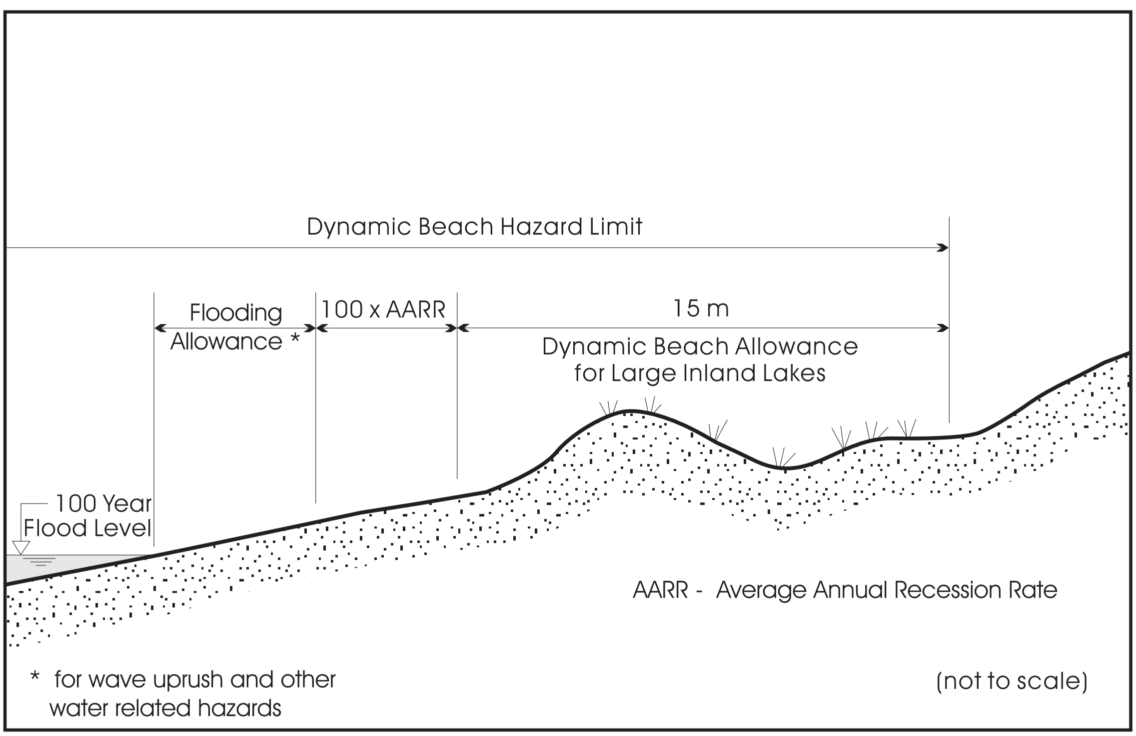


Figure 6.3: Dynamic Beach Hazard Limit for a Recessional Beach



The *dynamic beach hazard* **is applied** to all shorelines of *large inland lakes* **where there is an accumulation of surficial sediment landward of the stillwater line** (defined at the time of mapping under non-storm conditions), **such that action by waves and other water and wind-related processes can lead to erosion of the sediments and a resultant landward translation of the shore profile.**

The *dynamic beach hazard* **is not applied where**:

- beach or dune deposits do not exist landward of the stillwater line,

- beach or dune deposits overlying bedrock or cohesive material are generally less than 0.3 metres in thickness, less than 10 metres in width and less than 100 metres in length, or

- beach and dune deposits located in embayments, along connecting channels and in other areas of restricted wave action, where wave-related processes are too slight to significantly alter the profile landward of waterline. This generally applies where the maximum fetch distance measured over an arc extending 60^{o} on either side of a line perpendicular to the shoreline is less than 5 km.

The criteria used to define and classify a section of shoreline as a dynamic beach are intended to be applied over a stretch of shoreline on the order of 100 metres or more in length. Where shorter sections of sediments occur on a rocky or cohesive shoreline they are likely to be transitory. Beach width and thickness should be evaluated under calm conditions and at the average annual low water level. When lake level conditions are higher, consideration should be given to the submerged portion of the beach. If possible, mapping should not take place during high lake level conditions. It is expected that the person carrying out the mapping will exercise judgement, based on knowledge of the local area and historical evidence, in those areas where the beach width is close to the suggested criteria for defining a dynamic beach.

While the criteria used for defining and mapping of dynamic beaches generally tend to be based on "landside" characteristics or limits of the exposed beach, to ensure the proper identification and protection of the dynamic range of the beach, all delineations of shoreline dynamic beaches should also include a "lakeward" limit into the sub-aqueous portion of the profile to a depth of about 2 to 5 metres.

On the majority of beaches in *large inland lakes* the range of dynamic profile change due to waves and other processes can be accommodated within the defined landward limit of the *dynamic beach hazard*. However, it should be recognized that the *dynamic beach hazard* is designed to provide a minimum landward limit which can be easily interpreted, mapped and staked in the field, in the absence of more detailed studies.

For those situations where a municipality, the proponent and the implementing agencies determine that for various reasons a scientific and engineering study would be a more appropriate method in determining the landward limit of the *dynamic beach hazard*, there is flexibility to address these situations by having the option to:

- **permit or require the undertaking of a study using accepted scientific and engineering principles to determine the *dynamic beach hazard* limit.**

These studies may be initiated by the implementing agencies as part of the process of mapping of the *hazardous lands* or at the request of a development proponent. Where the studies have been undertaken using accepted scientific and engineering principles and have been approved by the implementing agencies (i.e., municipalities), the scientific/engineered *dynamic beach hazard* limit is to be applied only in the area studied.

Guidelines to assist shoreline managers in determining when and where such studies are appropriate and what constitutes accepted scientific and engineering principles and procedures are provided in Sections 5.5 and Appendix A5.1 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines (MNR 1996). Depending on the particular dynamic beach environment being studied, a study using accepted scientific and engineering principles may result in either a reduction or an increase in the landward limit of the *dynamic beach hazard*.

A study-defined increase in the dynamic beach allowance should be considered where the potential range of profile adjustment and extent of wave action is likely to exceed the limit defined by the *dynamic beach hazard*. In these areas, the landward limit of potential beach profile adjustment and of the area subject to wave action and other related shoreline processes, is based on site investigation and analysis using accepted geomorphological and engineering principles. Beaches that may warrant such an investigation include, but are not limited to, barrier beaches, beaches backed by dune systems, filet beaches and nourished beaches. In addition, where there is historical evidence that shoreline recession is occurring, consideration should be given to increasing the dynamic beach allowance to accommodate the shoreline recession within the planning framework (i.e., 100 times the average annual recession rate (AARR))(Figure 6.3). Procedures for distinguishing between long-term shoreline erosion and short-term fluctuations around a mean are given in Section 5.5 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines (MNR 1996).

There are several circumstances under which natural factors may require redefining the landward limit of the *dynamic beach hazard*, as mapped in the field, to a point lakeward of that defined by the standard *dynamic beach hazard* limit (i.e., *flooding hazard* plus 15 m). 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 6.4). The stable slope allowance and the erosion allowance should be applied to the cliff/bluff.

- 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* limit is mapped as the lesser of the landward boundary between the beach and associated dune deposits and the material forming the low plain <u>or</u> 15 metres measured landward from the base of the slope of the leeward side of the first main foredune dune (Figure 6.5).

- where the dynamic beach exists on a narrow barrier system, the landward limit determined by the *dynamic beach hazard* limit 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 6.6).

- **Defined Portions of a Dynamic Beach**

By definition, *defined portions of a dynamic beach*

> "means those portions of the dynamic beach which are highly unstable and/or critical to the natural protection and maintenance of the first main dune feature and/or beach profile, where any *development* or *site alteration* would create or aggravate *flooding* or *erosion* hazards, cause updrift and/or downdrift impacts and/or cause adverse environmental impacts" (Provincial Policy Statement, May 1996).

In determining the critical or *defined portions of a dynamic beach*, various factors should be considered including, but not limited to:

- physical characteristics of the shoreline;
- each individual component of the *flooding hazard* (i.e., water levels, wave uprush, other water related hazards);
- duration and frequency of flooding;
- pre-development/post-development flood conditions/impacts;
- date and reliability of the flood information;
- availability, accuracy, applicability of existing engineering studies;
- dynamic nature and range of the shoreline sediments, profile and planform;
- sediment/material (i.e., type, size, depth, width, composition, etc.);
- exposure to wave action;
- nearshore/offshore bathymetry;
- orientation of prevailing winds relative to the shoreline alignment (i.e., exposure);
- aeolian forces (magnitude, duration, etc.); and
- influence of vegetation in stabilizing the dynamic beach.

Figure 6.4: Dynamic Beach Hazard Limit for a Beach Backed by a Cliff or Bluff

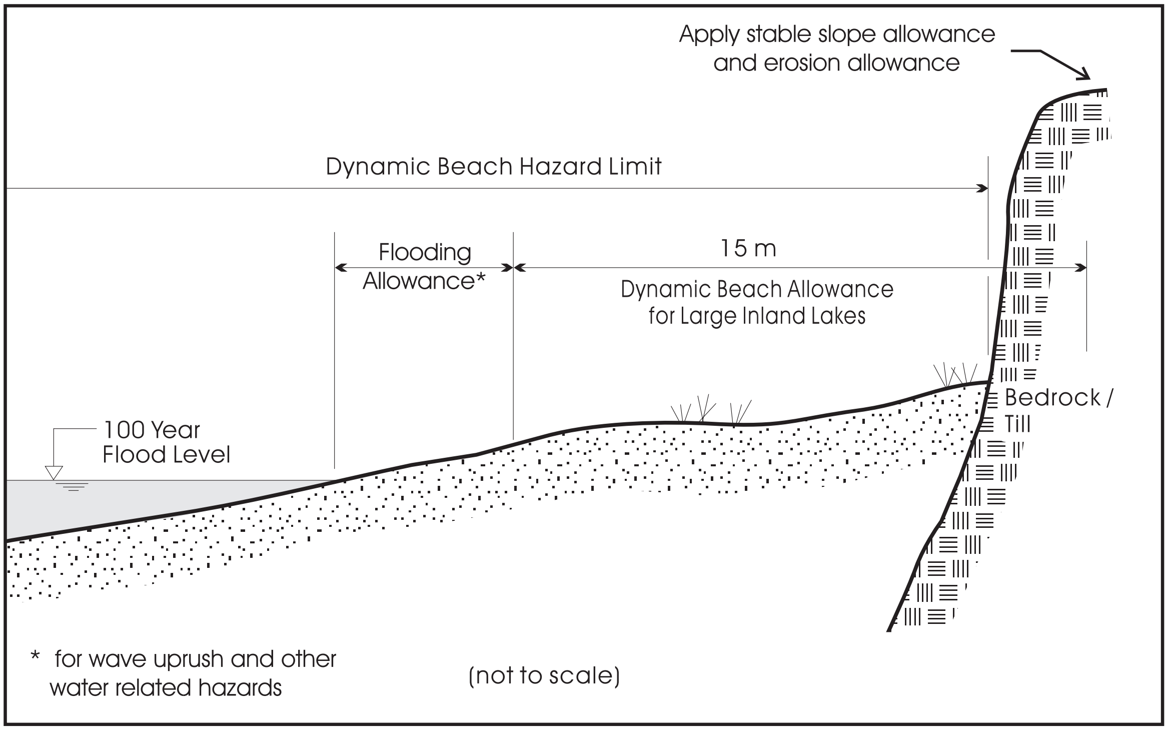


Figure 6.5: Dynamic Beach Hazard Limit for Beach Profile Lower than the 100 Year Flood Level

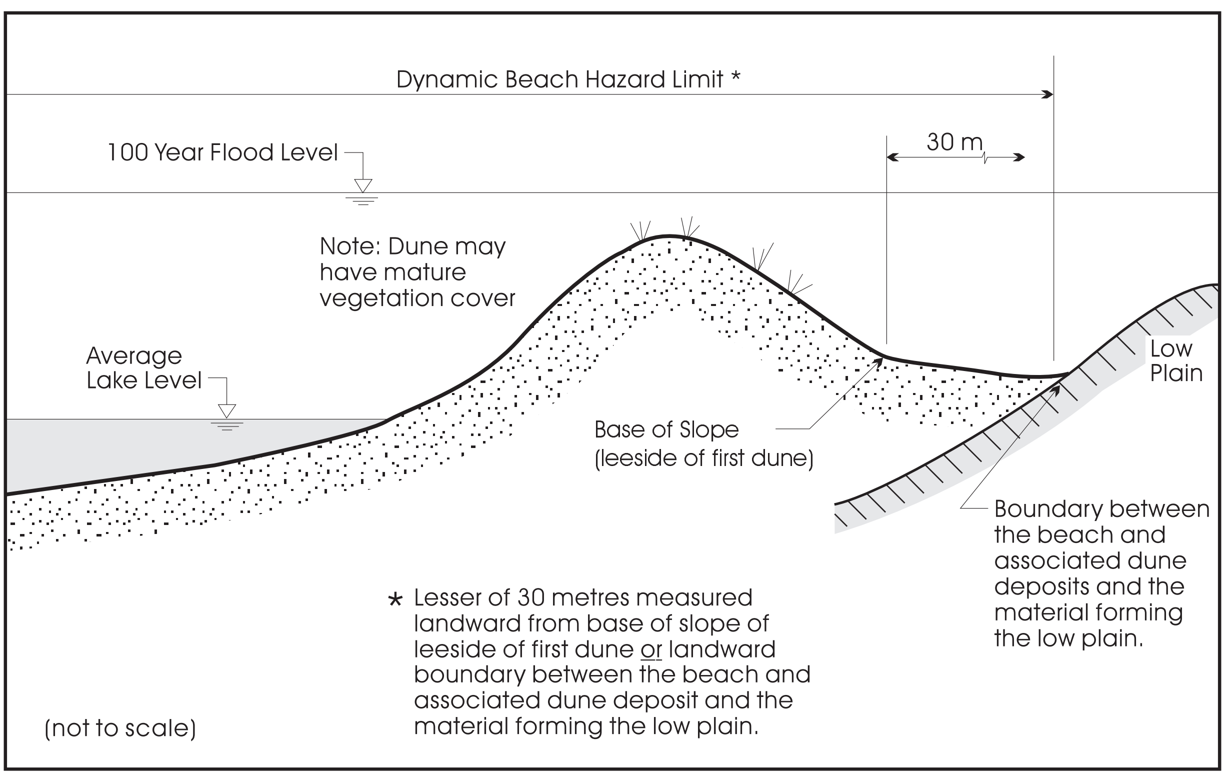
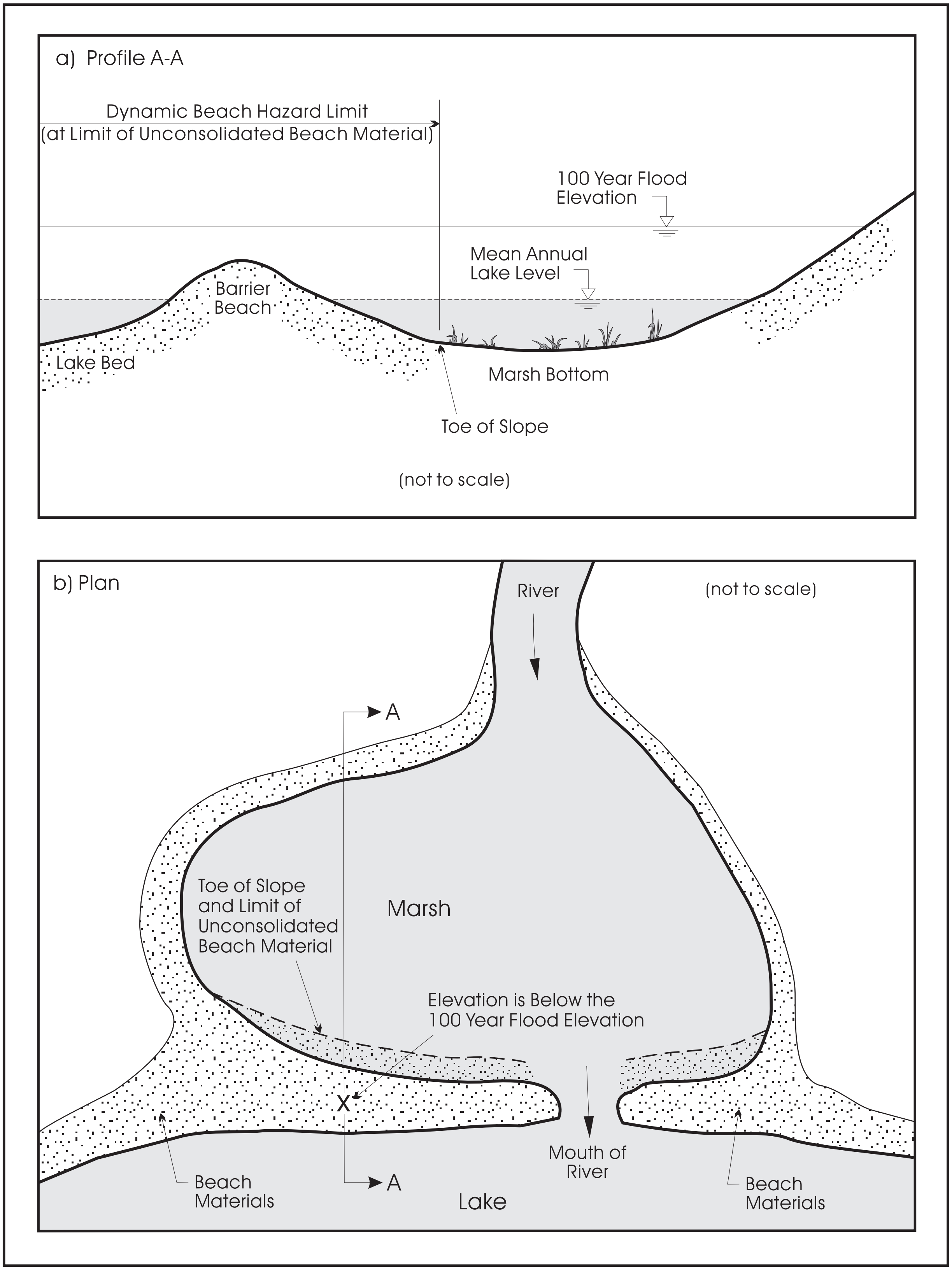


Figure 6.6: Dynamic Beach Hazard Limit for a Narrow Barrier System



Caution should be exercised in designating chronic problem areas as non-critical. While development in such areas could adequately be floodproofed or the "hazards" potentially addressed through the use of protection works, past experience throughout the Province has repeatedly demonstrated that such decisions can result in the creation of new hazards, the aggravation of existing hazards on updrift/downdrift properties, adverse environmental impacts, and ever increasing maintenance and replacement costs.

Past experience has also demonstrated that beach and dune formations left unaltered by humans, often naturally protect inland shoreline developments and lands from the destructive impacts of shoreline flooding and erosion. For example, 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. Where left unaltered, as water levels recede these same beach and dune features naturally rebuild to once again provide protection to inland shoreline developments.

It should be noted that the limit of *hazardous lands* is the furthest landward of the *flooding*, *erosion* and *dynamic beach hazard* limits. In some instances (e.g., narrow barrier system, low shoreline plain) the *flooding hazard* limit or *erosion hazard* limit may govern the limit of *hazardous lands*. The *flooding hazards* and *erosion hazards* for the river and stream systems must also be considered.

6.3 Beach Processes and the Dynamic Beach Sub-Classification

To assist shoreline managers in determining where detailed studies and field investigations may be required or appropriate for determining the landward limit of the *dynamic beach hazard*, one must first develop an understanding of the controls on, and the behaviour of, dynamic beaches.

The dynamics of beaches of the large inland lakes are determined by the interaction of controlling processes such as waves, wind and ice, and a number of physical beach attributes such as sediment size and supply, shoreline orientation, and the alongshore and the onshore-offshore form of the shoreline. While each beach can be regarded as unique, it is possible to produce a simple classification scheme based on a combination of the controlling factors which would then provide a mechanism for identifying the major controls on the dynamic nature of an individual beach. Application of this classification scheme would then serve as a guide to the selection of the appropriate procedure for mapping and field staking of the *dynamic beach hazard* limit.

Section 6.3.1, as follows, provides a general overview of the dynamic beach sub-classification scheme. For the purposes of clarification, the recommended dynamic beach sub-classification scheme is an expansion of the recommended shoreline classification scheme initially outlined in Section 3.0, Recommended Shoreline Classification Scheme to Determine Shoreline Reaches. For dynamic beaches, the surficial nearshore substrate material will be the same as the underlying controlling substrate. A more detailed explanation of this sub-classification procedure is contained in Part 5 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines (MNR 1996). Part 5 also identifies potential problems and provides guidance as to whether studies using accepted engineering, scientific and engineering principles to determine the landward limit of the *dynamic beach hazard* may be warranted.

6.3.1 Criteria for Sub-Classification of Dynamic Beaches

The criteria for developing the recommended dynamic beach sub-classification scheme have been selected to reflect their role in controlling the dynamic nature of beaches in *large inland lakes* and as a representation of their relationship to the hazard and to environmental sensitivity.

Fundamental to the recommended dynamic beach sub-classification scheme are the three primary criteria:

1) BEACH PROFILE TYPE
  1) cliff/bluff
  2) low plain
  3) barrier

2) **BEACH PLANFORM AND EXPOSURE**
   1) headland-bay
   2) partial headland
   3) exposed

3) **BEACH MATERIALS**
   1) gravel, cobble or boulder;
   3) sand

Application of these three criteria (i.e., beach profile type, beach planform and exposure, and beach materials) and their respective sub-classifications produces a total of 18 different beach types or classes, each being identified by a class name and associated number. Table 6.1 shows the outline of the sub-classification scheme.

Within each of the 18 classes recognition is also given to two other factors which act to influence the dynamic nature of the beach:

. **whether the beach profile is fully developed in sediment**, or instead is underlain by bedrock or cohesive materials which act to limit the dynamic range of the beach profile; and

. **whether the beach is the product of natural processes or has been artificially created**, in part or as a whole, by structures and/or beach nourishment.

Table 6.1: Dynamic Beach Sub-Classification

PROFILE TYPE	PLANFORM AND EXPOSURE	MATERIALS *	CLASS #
CLIFF/BLUFF	Headland-Bay	cobble sand	1-1-1 1-1-3
	Partial Headland	cobble sand	1-2-1 1-2-3
	Exposed	cobble sand	1-3-1 1-3-3
LOW PLAIN	Headland-Bay	cobble sand	2-1-1 2-1-3
	Partial Headland	cobble sand	2-2-1 2-2-3
	Exposed	cobble sand	2-3-1 2-3-3
BARRIER	Headland-Bay	cobble sand	3-1-1 3-1-3
	Partial Headland	cobble sand	3-2-1 3-1-3
	Exposed	cobble sand	3-3-1 3-3-3

* The term cobble is used here for simplicity although the class includes sediments ranging from gravel through cobble to boulder.

The recommended shoreline sub-classification scheme is based primarily on the physical attributes of the shoreline and associated beach deposits, which in turn exercise some control on the dynamic behaviour of the beach.

When using the recommended shoreline classification scheme, one should recognize that the dynamic range of each particular beach type is also determined by a number of process variables, including wave climate, storm surge potential, alongshore sediment transport patterns and beach sediment budget, as well as by the impact of human activities such as harbour construction, fill and shoreline protection measures (see discussion in Part 2: Physical Features and Processes). Any determination of the appropriate landward limit of the *dynamic beach hazard* at any location must therefore involve an evaluation of these factors and may require field inspection and additional geomorphological and engineering studies in some locations.

Given the complexity of the natural environment, the recommended and simplified dynamic beach sub-classification scheme, outlined for the purposes of this Technical Guide, cannot be assumed to describe all the shoreline situations that may occur within *large inland lakes*. Two possible exceptions where the recommended sub- classification scheme may be potentially unable to appropriately identify a single beach class type are:

- transitional sections of shoreline where one shoreline type changes to another (e.g., the transition from low, eroding shoreline bluff to sandy mainland beach); and

- sections of shoreline which are dominated by a unique factor or process that is not reflected in the shoreline classification scheme (e.g., the area immediately adjacent to a large river mouth).

6.3.2 Beach Profile

Of the three fundamental criteria used to describe beach class type under the recommended dynamic beach sub-classification scheme, the first is the beach profile type normal to the shoreline. For the purposes of this Technical Guide, a generalized profile beginning several hundred metres offshore and extending 200 to 300 metres inland is all that is required to determine the type of beach profile within a particular shoreline location.

In terms of beach profiles, three separate profile types can usually be recognized: cliff/bluff beaches; low plain beaches; and barrier beaches.

. Cliff/Bluff Beaches

The term **cliff** or **bluff** is used to describe a shoreline where the shore profile landward of the beach material rises steeply, where the slope angle is commonly greater than 18^{o} and where the elevation above the beach is greater than 2 metres. A distinction should be made between **bedrock cliffs**, which are usually resistant to erosion and associated with very low recession rates, and **bluffs** which are usually developed in cohesive sediments (with varying amounts of silt and clay present) or sand, having relatively little resistance to wave erosion and commonly associated with high recession rates (Figure 6.7a).

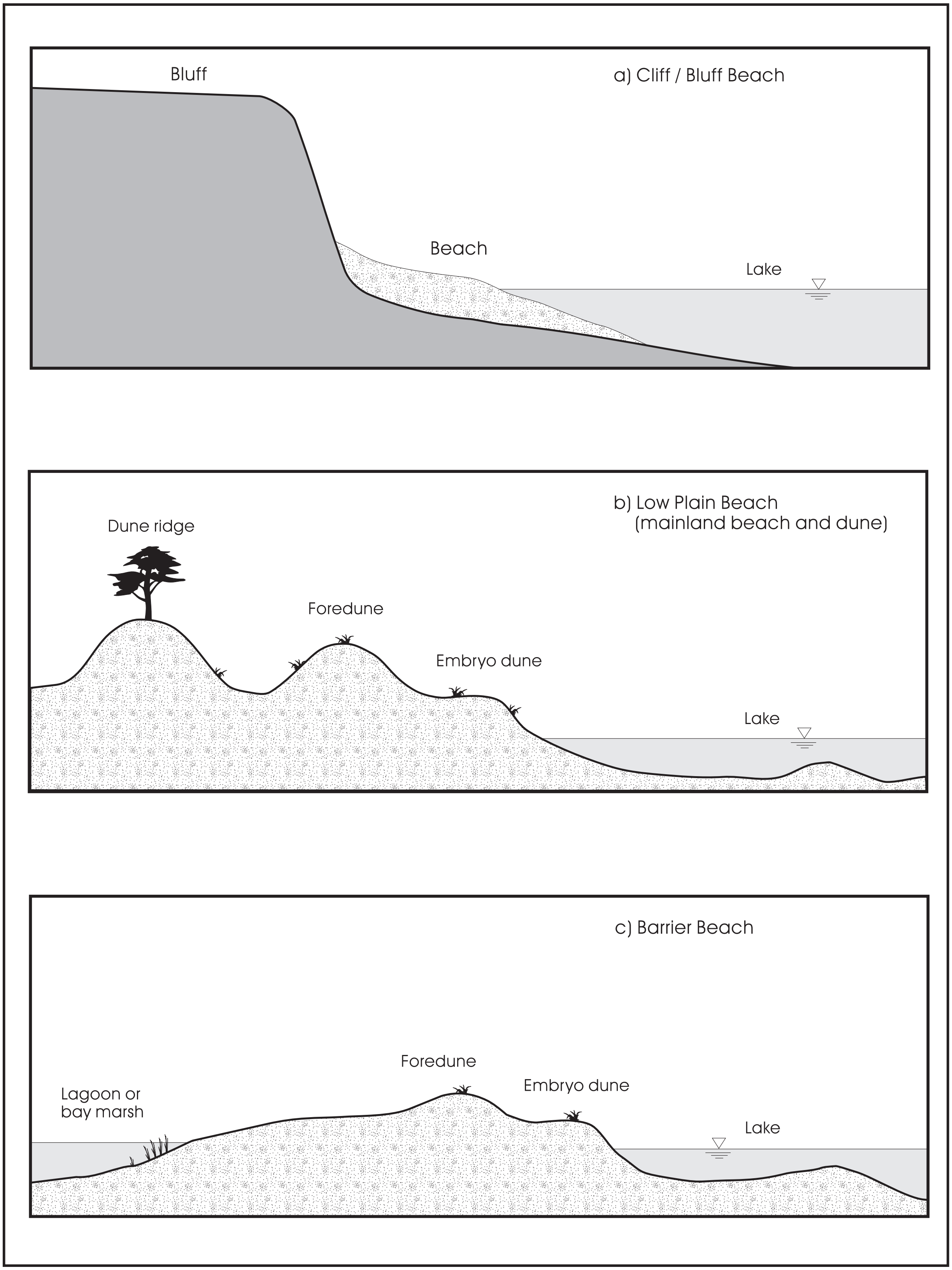
. Low Plain Beaches

In low plain beach shorelines the shore profile slopes gently upward from the beach and there is no abrupt change in slope angle as is normally seen with cliff or bluff shorelines (this description does not include slope changes associated with the presence of sand dunes which are superimposed on the general slope of the land surface). In addition, there is no topographic restriction on the landward limit of the dynamic range of profile adjustment of the beach (Figure 6.7b).

. Barrier Beaches

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 (Figure 6.7c).

Figure 6.7: Beach Classification Based on Profile Form



6.3.3 Beach Planform and Sediment Transport Patterns

Beach dynamics are also influenced by the overall three-dimensional planform and orientation of the shoreline on which they are developed, and consequently on the exposure of the beach and the significance of alongshore sediment transport in the sediment budget.

Although there are a wide range of possible **beach planforms**, for the purposes of this Technical Guide beach planforms will be described in terms of three main types: headland-bay beaches; partial headland and log-spiral beaches; and exposed beaches.

. Headland-Bay Beaches

In general, headland-bay beaches can be divided into two main types; pocket beaches which are limited in size and extent of surficial sediment; and full headland/bay beaches where there is a large sediment body (Figure 6.8a). The beach at the head of the bay forms the sink for two converging littoral cells. Recognizing that offshore sediment losses are restricted by the protection offered by the headlands, the bayhead beach tends to be stable or progradational.

. Partial Headland and Log Spiral Beaches

Partial headland and log-spiral beaches occur where headlands are not large enough to form a complete barrier to alongshore sediment transport and as a result, provide only partial shelter to a portion of the coastline (Figure 6.8b).

. Exposed Beaches

Exposed beaches occur where beaches develop along a straight or gently curving shoreline where there are no major headlands to shelter a portion of the shoreline from waves from one direction or to act as a barrier to alongshore sediment transport (Figure 6.8c). Beaches along this type of shoreline are typically exposed to waves from a wide range of directions (up to 180^{o}) and tend to have a greater dynamic range than the other two categories.

6.3.4 Beach Sediment Size

The size of the sediment forming the beach exercises an important control on the dynamic behaviour of beaches and to some extent on long-term stability. Of the 18 dynamic beach classifications, all can be divided into two broad groups on the basis of sediment size:

- coarse sediment beaches consisting of **gravel, cobble and boulders**, having a mean sediment size greater than 2 millimetres; and

- **sand beaches**, having a mean sediment size ranging from 0.062 to 2.0 millimetres.

This differentiation or classification of beach type according to sediment size applies primarily to the material in the zone from the bottom of the step across the foreshore and backshore to the limit of normal wave activity. For the purpose of clarification, a descriptive classification of sediments and corresponding size ranges for each sediment class, Table 6.2 should be consulted.

In practice, sediment sizes finer than about 0.05 millimetres are removed from beaches by wave action and deposited either in the deep lake basin or in sheltered bays and lagoons. As such, an accumulation of silt and clay near the edge of the water is an indication that wave activity is below the threshold required for a dynamic beach and the shoreline under investigation should not be classified as a *dynamic beach.*

Figure 6.8: Beach Classification Based on Planform

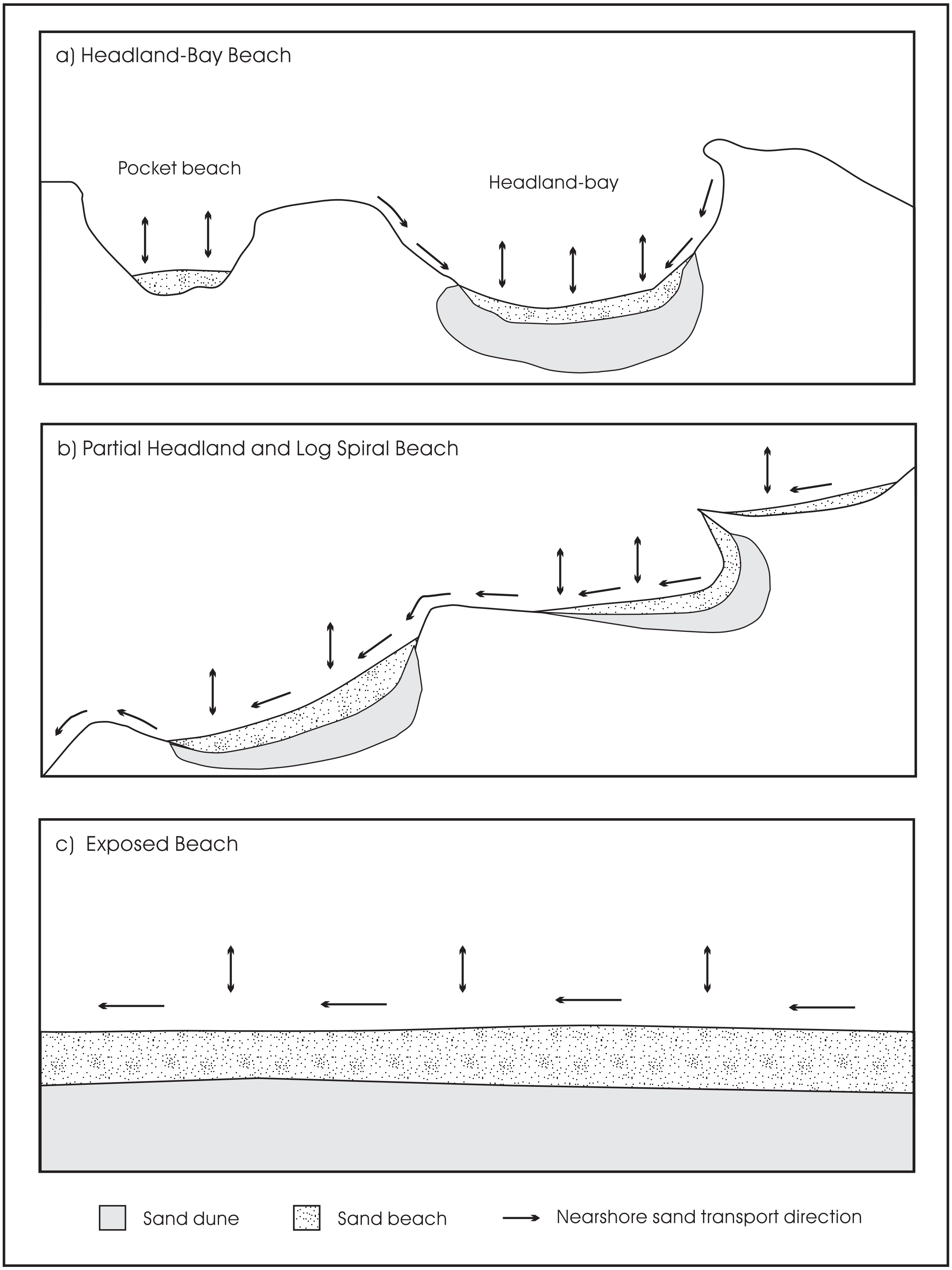


Table 6.2: Sediment Size Classification

Unified Soils Classification	ASTM Mesh	mm Size	Phi Value	Wentworth Classification
Cobble				Boulder
		256.0	-8.0	
				Cobble
		76.0	-6.25	
Coarse Gravel				
		64.0	-6.0	
				Pebble
		19.0	-4.25	
Fine Gravel				
	4	4.76	-2.25	
Sand: Coarse				
	5	4.0	-2.0	
				Gravel
	10	2.0	-1.0	
Sand: Medium				Sand: Very Coarse
	18	1.0	0.0	
				Sand: Coarse
	25	0.5	1.0	
				Sand: Medium
	40	0.42	1.25	
Sand: Fine				
	60	0.25	2.0	
				Sand: Fine
	120	0.125	3.0	
				Sand: Very Fine
	200	0.074	3.75	
Silt				
	230	0.062	4.0	
				Silt
		0.0039	8.0	
Clay				Clay
		0.0024	12.0	
				Colloid

Similarly, at the other end of the scale, boulders greater than 1 metre are not usually transported by wave action. Accumulations of boulders at the foot of bedrock cliffs are essentially stable and as such, these sections of shoreline should also not be classified as a *dynamic beach*.

The size of the sediments making up the beach effects the beach dynamics in several ways. For example, the slope of the beach foreshore and backshore generally increases in steepness as grain sizes become coarser (i.e., larger). As a result, the steepest beaches are usually associated with cobble-sized sediment. In addition, cobble or larger sized sediment beaches frequently have a steeper slope of the nearshore profile close to the beach which in turn permits large waves to break at, or close to, the shoreline. Conversely, where sand sized sediments are abundant, the nearshore profile is usually gentle, forcing large waves to break some distance offshore, thereby reducing wave energy at the shoreline.

During storm events, higher waves and water levels may result in the erosion of the berm and a flattening of the beach profile with much of the original sediment being returned to the nearshore (see Figure 6.9). With storm events generally tending to be more frequent and of a greater intensity in spring and fall (i.e, storm (winter) profile), sand beaches tend to be flatter and narrower in the those periods and higher and wider in the summer months (i.e., swell (summer) profile). When undertaking site investigations in sand beaches, it is important to keep this fact in mind.

Where sand beaches are formed they are generally backed by sand dunes formed by the landward transport of sand from the top of the beach by strong onshore winds and by the deposition of the sand in vegetation established beyond the limit of wave action.

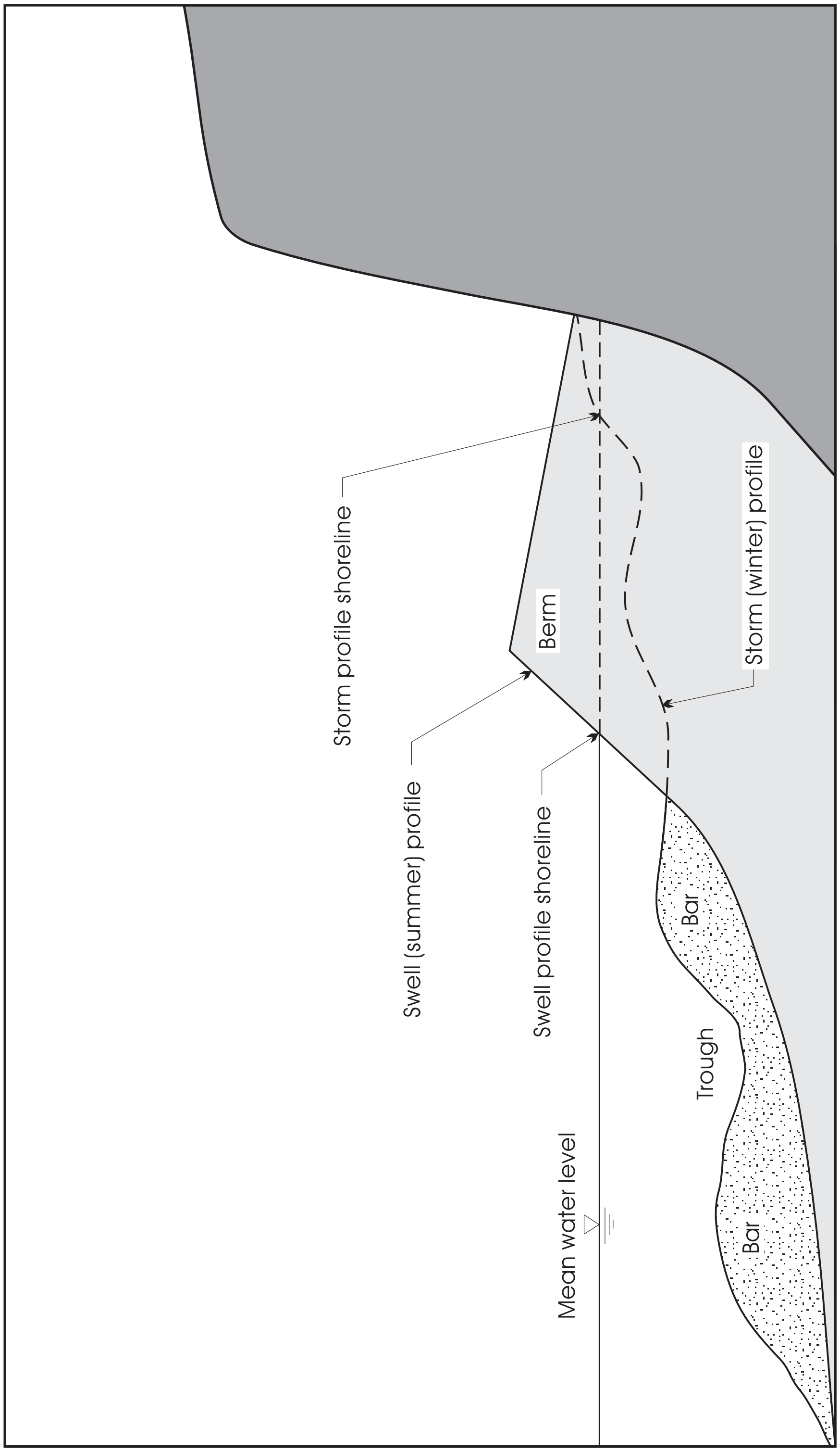
6.4 Classification and Alongshore Boundaries of Dynamic Beaches

The following presents a procedure for classifing a particular beach form using the recommended dynamic beach sub-classification scheme. Prior to following the procedures, one must first ensure that a preliminary identification and classification of the shoreline using the procedures described in Section 3 has confirmed that the subject shoreline is a dynamic beach form; that the person carrying out the classification and initial mapping procedure is familiar with the classification scheme for shorelines (outlined in Section 3 and Section 6.3); and that all the available relevant background information such as maps, consultants reports, aerial photographs, and shoreline videos, have been assembled.

The ultimate objective of the process for classifying dynamic beaches described in this section is to properly divide the shoreline into reaches with relatively uniform characteristics. After having segmented the shoreline into unique shoreline reaches, a determination of the classification of the dynamic beach reach can be achieved by following Table 6.1 and Section 6.3 which describes the information on the beach eventually permits the assignment of the beach to one of the 18 classes in the recommended dynamic beach sub-classification scheme.

Determining the alongshore extent of individual shoreline reaches sometimes becomes difficult, particularly in areas of transition between one shore reach type and another. In addition to providing a step-by-step procedure for classifying individual reaches of dynamic beach, this section also provides the procedures for determination of the alongshore boundaries of shoreline reaches. Repetition of this process of first identifying the dynamic beach classification for each general reach along a subject shoreline, followed by the determination of alongshore boundaries of each reach will ultimately enable the proper classification and delineation of unique reaches of dynamic beaches along a given stretch of shoreline.

Figure 6.9: Storm and Non-Storm Profiles on a Medium Grain Size Sand Beach



6.4.1 Classification Procedure

To ensure consistency and future cross-referencing of information developed through the completion of the outlined procedure to follow, it is assumed that the supporting background information for each shoreline reach has been collated and recorded in a systematic manner.

- **Step 1 -** Select the shoreline segment.
  Select one of the shoreline segments identified as a "dynamic beach". Begin with a point near the middle of the selected shoreline segment and away from any obvious boundaries for the selected segment such as a headland or river mouth.

- **Step 2 -** Determine the beach profile classification.
  Using topographic maps (e.g., 1:10,000 OBM) as a base and any additional information provided by hydrographic charts, aerial photographs etc., sketch a cross-section of the shoreline at that location beginning, where possible, 100 to 200 metres offshore and extending inland for 200 to 300 metres. Additional measurements landward may be required if there is a feature such as a marsh or bay behind the actual dynamic beach shoreline.

  On the basis of the cross-section and on an analysis of supporting background information, assign the selected shoreline segment to one of the three profile classifications, cliff/bluff, low plain, or barrier.

  A cliff or bluff profile will show up as closely spaced contour lines immediately landward of the shoreline on the topographic map. Based on aerial photographs, reports and personal experience, determine whether the material in which the slope is formed is bedrock (cliff) or cohesive sediments (bluff). Where large sand dunes are present, the dune features may also show up on the contour maps as high areas with steep slopes facing to the beach. In these instances, aerial photographs and field information should be consulted to distinguish the large sand dune features from cliff/bluff features. Where dunes are present, the shoreline is to be classified as low plain, except where the dunes develop only in a narrow band between the shoreline and a bedrock cliff or cohesive bluff.

  A low plain will show up as widely spaced contours on the topographic map. The area landward of the shoreline should be flat or slope gently upwards as the feature extends landward, and should be 2 metres or less in height close to the shoreline.

  Barriers should consist of a bay, estuary or marsh behind the shoreline, with at least some areas of open water. The area of land separating the open lake from the bay, estuary or wetland should be formed primarily in beach and dune sediments. In many instances there ill be a channel or channels connecting the bay, estuary or marsh to the open lake and there may be evidence of wave action reaching the bay/estuary/marsh in the form of washovers. This will be evident particularly on aerial photographs taken during or immediately after periods of high water.

- **Step 3 -** Determine the beach planform and exposure classification.
  Using a map with a scale of 1:50,000 or even 1:100,000 as a base, examine the shoreline planform for a distance of 10 to 20 kilometres on either side of the point of interest to determine the extent to which the beach is exposed to waves from a wide range of directions.

  Where there are headlands on both sides of the beach which restrict wave action to about 45^{o} on either side of a line perpendicular to the shoreline, the beach should be classified as headland-bay beach (Figure 6.8a). Partial headland beaches have headlands that are much shorter than the headland-bay class and as such, offer much less protection from wave action. Often the shoreline exhibits a tight curvature downdrift of each headland, giving a characteristic log-spiral form (Figure 6.8b). Exposed beaches are nearly straight shoreline features extending over a long distance and may be exposed to waves over angles greater than 75^{o} on either side of shore perpendicular (Figure 6.8c).

. **Step 4 -** Determine the beach material size classification.
This step is intended to distinguish between coarse sediment beaches and sand beaches on the basis of the average size of the sediment particles on the beach.

Coarse sediment beaches are made up primarily of sediments that are greater than 2 millimetres in diameter, and consist of gravel, cobble, boulders, or some combination of each. For simplification the term cobble is used at times although the class includes sediments ranging from gravel through cobble to boulders.

Sand beaches are made up of sediments smaller than 2 millimetres in diameter. The distinction between the coarse sediment and sand beaches is designed to be made qualitatively. In general, it is not necessary to carry out a detailed analysis of the beach sediments to make this distinction in particle size. In many instances the identification can be made from a simple visual inspection of aerial photographs, shoreline videos or a site visit. This information may also be available from reports and papers describing the particular shoreline area under investigation.

On aerial photographs and shoreline videos, sand beaches generally appear to be light in colour when compared to coarse sediment beaches. The existence of dunes behind the beach is a second indicator that the beach is composed of sand. Where sand is abundant in the nearshore, sand bars are nearly always present and show up as light patches in shallow water forming a distinct linear pattern parallel to the beach. The bars may be straight or crescentic shaped.

Coarse sediment beaches are nearly always associated with a nearby source of bedrock from which the material is eroded. Wherever bedrock cliffs or outcrops are present within the selected shoreline or within adjacent shoreline segments, and there are no indications that sand is present (e.g., the visual indicators discussed above), then it is likely that the sediments within the selected shoreline are gravel or cobble.

Field inspection of the selected shoreline segment should make it readily apparent whether most of the sediment is sand or coarser material. If the beach consists of a mixture of sands and coarse material, the assignment of beach classification (i.e., cobble or sand) should be based on an assessment of whether sand is present in the form of dunes or whether bedrock outcrops are common within and adjacent to the selected segment of shoreline.

. **Step 5 -** Determine the dynamic beach type sub-classification.
Based on the information determined from Steps 2, 3 and 4, the selected segment of shoreline can then be placed in one of the 18 dynamic beach sub-classifications outlined in Table 6.1.

At this stage it may be useful to confirm the correct classification of the beach by comparing the attributes of the shoreline to those previously described for the each dynamic beach sub-classification in Section 6.2 Where there are inconsistencies between the description provided in Section 6.2 and the shoreline segment under consideration, these should be resolved at this step, or immediately following the completion of Step 6.

. **Step 6 -** Determine the alongshore boundaries of the dynamic beach sub-classification.
Steps 6 and 7 form a two-stage procedure for dividing the shoreline into reaches. In Step 6, the alongshore boundaries of the dynamic beach sub-classifications identified in Step 5 are determined.

The boundaries are established simply by working along the shoreline first in one direction and then in the other direction starting from the approximate mid-point within the selected segment of shoreline.

The reach boundary is placed where there is a transition from one dynamic beach type to another dynamic beach type (e.g., from an exposed sandy beach backed by a bluff (1-3-3) to an exposed sandy barrier (3-3-3)), or a transition to a different shoreline type altogether (e.g. from an exposed sandy beach backed by a bluff to a bluff shoreline where the beach is less than 10 metres wide).

In many instances these transitions will be abrupt and readily apparent on maps and aerial photographs. In some locations, however, there may be a more gradual transition from one shoreline type to another. For example, along some sections of shoreline underlain by bedrock, narrow sand or gravel beaches may develop, often with small patches of bedrock outcropping. In other areas, narrow sandy beaches may exist in front of eroding cohesive bluffs during low water periods and then may be absent in the spring or during years of high lake levels. In all such situations, an assessment must be made to determine whether there is sufficient sediment present along the stretch of shoreline to act as a dynamic beach or whether the bedrock or bluffs essentially act to constrain any profile adjustment.

When endeavouring to determine a classification for an area of transition between shoreline types, the general guideline in identifying a "beach" is that sediment thickness should exceed 0.3 metres and that the beach form above the waterline should be greater than 10 metres in width. One should further note that these "guidelines" are minimum values and that they are intended to be applied as an average over a length of shoreline exceeding 100 metres. One should accept that some degree of judgement will have to be exercised in the precise placement of the dynamic beach classification boundary and that in some instances a field inspection may be warranted.

- **Step 7 -** Determination of alongshore reach boundaries
  A alongshore reach boundary can be determined in three different situations:

  - defining a change from one dynamic beach sub-classification to another
  - defining a change from one shoreline type to another
  - defining changes within a single dynamic beach sub-classification

  Changes identified between different dynamic beach sub-classifications and different shoreline types must automatically be marked by a reach boundary. Within a single dynamic beach sub-classifications there may be several unique reaches. In general, reaches should not be less than 0.5 kilometres in length and are usually not more than 20 kilometres in length.

  Within a single dynamic beach sub-classification individual reach boundaries may be drawn on the basis of a change in one of several criteria:

  - where there is a change in shoreline orientation;
  - where there is a break in beach continuity at a river mouth or inlet entrance;
  - where there is a change in the height or composition of the cliff/bluff or some other relevant feature landward of the beach; or
  - where there is some change in beach stability (e.g., from erosional to depositional).

  As a result, reach boundaries are drawn by examining the shoreline within the boundaries drawn for the individual dynamic beach sub-classification for any significant change in one of the factors noted above. Once the reach boundaries have been established, they can be placed on shoreline maps at the appropriate scale.

- **Step 8 -** Confirmation of Dynamic Beach Sub-Classification
  The final step in the classification procedure is to review the information collected and to confirm that the shoreline reaches meet all the requirements of a dynamic beach provided in Section 6.2.

  If these conditions are met then the dynamic beach sub-classification and reach boundaries, determined using the eight step procedures outline above, can be confirmed. In some areas, a field visit may be necessary to determine beach width and thickness.

6.4.2 Field Verification of Dynamic Beach Classification

The classification and boundary delineation process described previously is based primarily on an "in-office" assessment of background information, maps, aerial photographs, videos and field reports, and represents an appropriate level of investigation for those areas of shoreline not presently undergoing development. In areas where shoreline development is currently existing, intensifying, or proposed, field verification of the dynamic beach sub-classification and boundaries assigned to each reach is recommended.

For the majority of shorelines, the verification of dynamic beach sub-classifications and reach boundaries can simply be achieved through a single site inspection. In shorelines involving complex shore types or where a precise determination and delineation of the *dynamic beach hazard* is required, the verification procedure may involve more than one site visit to determine the final placement of the boundaries between reaches. This later process may also include the need to integrate information obtained from secondary sources with that obtained from the field inspections.

As a result, the verification process will often be an iterative one in which there are several stages of classification and revision until the boundaries of the shoreline units are finally confirmed. The actual process applied by any one individual or agency is likely to vary slightly from one region to another in response to differences in the length of shoreline reaches and shoreline complexities between regions.

The following step-by-step procedure is intended as a guide to assist shoreline managers in undertaking the verification process.

- **Step 1 -** Based on the information provided by the initial classification procedure, select a section of shoreline for field inspection centred on the area of interest. The selected section of shoreline will likely contain several dynamic beach reaches. It is expected that the selected section of shoreline will be defined by clearly identifiable boundaries. Wherever appropriate, the selected section of shoreline should include all, or a major portion, of a littoral cell.

- **Step 2 -** Identify all the dynamic beach units within the selected shoreline section and ensure that the supporting background information used in making this determination has been transferred to the field sheet for each unit.

- **Step 3 -** To begin the field verification process, select a dynamic beach reach at one end of the section under investigation. The selected dynamic beach reach should be at the updrift end of the section of shoreline wherever a well-defined littoral transport direction exists.

- **Step 4 -** Examine the characteristics of the shoreline within the selected dynamic beach reach in the field, focusing on the central part of the dynamic beach reach rather than on the boundaries of the reach. Verify the initial information on the field sheet that will be used in the classification procedure, by:

  - establishing that the minimum criteria for classification as a beach, in terms of the width and thickness of beach sediments, are met;
  - confirming that the information on beach profile and planform are correct;
  - determining through visual inspection the average size of the beach sediment;
  - classifying the beach as sand or coarse sediment (i.e., gravel/ cobble/boulder); and
  - determining whether the sediments are thick enough for the profile to be fully-developed (i.e., sediments generally thicker than 1 metre over bedrock or cohesive materials) or whether bedrock or cohesive materials are close enough to the surface to restrict profile changes due to wave action and water level fluctuations.

- **Step 5 -** Based on the information obtained in the field:
  - confirm the original sub-classification of the dynamic beach reach (i.e., determined in the office through analysis of supporting background information); or
  - use the information collected and recorded during the field inspection process to re-classify the reach.

- **Step 6 -** Work, in both directions, along the shore to determine the final placement of the boundaries of the reach. As was the case in the procedures described previously, the boundaries of the reach will be determined by:

  - a change in one of the factors that form the basis for the classification scheme (e.g., a change in sediment size class, or in the beach profile) so that a new dynamic beach unit occurs; or

  - by a transition to a section of shoreline that no longer meets the requirement for dynamic beach (e.g., bedrock outcrops and sediments become too thin to form a beach).

  In this latter case, one needs to make the determination of whether there is sufficient sediment present along the stretch of shoreline to act as a dynamic beach. The general guideline in these areas is that sediment thickness should exceed 0.3 metres and that the beach above the water line should be greater than 10 metres in width. In applying this general guideline, one should note that these are minimum values and that they are intended to be applied as an average over a stretch of shoreline of greater than 100 metres in length.

- **Step 7 -** Move to the adjacent dynamic beach unit and repeat Steps 1 to 6. As the process is repeated, new dynamic beach units or reaches may be created where the field investigation indicates and confirms changes to a different dynamic beach type that were not evident in the preliminary classification (e.g., a change from cobble to sand which was not evident in the initial data collected for that shoreline section). Conversely, some of the preliminary units may be merged where field investigation confirms that the initial boundary determined through the preliminary classification process was incorrect.

6.5 Determination Of Recession Rates On A Dynamic Beach Shoreline

On dynamic beaches backed by a cliff or bluff the calculation and definition of the *erosion hazard* limit is applied to the cliff or bluff feature and as such, shoreline recession is accounted for in the determination of this landward limit of erosion. Within the 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 difficulties 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*.

To assist shoreline managers in this task, Table 6.3 provides a brief description of the visible indicators of stability and long-term erosion and suggested reference points for determining and measuring long-term recession rates for the three broad groupings of dynamic beaches. For more general information on techniques for measuring shoreline recession, Part 5: Erosion Hazard, Section 5.4: Average Annual Recession Rates, should be consulted.

The decision as to whether measurements of the long-term shoreline recession rate should be made will depend on the availability and perceived reliability of evidence from previous studies, the results of preliminary field investigations, on the magnitude or severity of recession currently occurring at the location, and on the extent of existing or proposed shoreline development.

As a general guide, three situations can be envisaged:

- **recession rate is zero** - There is no visible or measured evidence of shoreline erosion and recession identified in available studies or from field investigations.

- **recession rate is low** - There is evidence that shoreline recession is occurring through available studies or from field investigations. The measured or visible rate of recession appears to be relatively slow (e.g., less than 0.15 metres/year). In most cases, the limits of resolution determined by the precision of the techniques for determining recession and the uncertainties introduced by the dynamic profile adjustments make it uneconomical for the municipalities to undertake studies to determine actual recession rates for small lengths of shoreline.

In these locations, it is recommended that for mapping purposes, the average annual recession rate should be set at 0.15 metres/year and detailed measurements of recession be undertaken only in conjunction with a proposal for development accompanied by a request to reduce this value (i.e., work is undertaken by the proponent).

. **recession rate is high** - There is evidence that the shoreline recession rates are high and probably exceeding 0.15 metres/year as determined from available studies or from field investigation.

In these locations, consideration should be given to undertaking preliminary studies to determine the long-term recession rates. Where the shoreline is undeveloped and no development is proposed the rate need only be determined for a few localities and these values used for mapping purposes. Where development is proposed, a determination on the level of field study and the degree of precision required in the calculation of the recession rate within a particular location or stretch of shoreline by the development proponent should be reflective of the type, density and level of investment associated with the proposed development.

Table 6.3: **Factors Indicative of Stability in the Absence of Long-Term Recession Rate Information**

BEACH TYPE	INDICATORS OF STABILITY	INDICATORS OF LONG-TERM EROSION	REFERENCE POINT
sand or cobble beaches backed by cliff/bluff	- vegetated backshore between beach and cliff/bluff - debris accumulation at cliff/bluff toe	- narrow backshore - absence of trees - evidence of toe erosion rockfall - slumping on cliff/bluff face	- cliff/bluff - crest or toe
cobble low mainland and cobble barrier	- cobble ridges - inland from modern beach - trees close to beach but no erosion of trees	- exposure of tree roots - toppling of trees - fresh (lichen-free) cobbles deposited in vegetation - peat exposure on barrier foreshore	- waterline - vegetation line
sandy low mainland and sandy barrier	- dune ridges inland from foredune - vegetation succession inland - hardwoods occur 50 m or more landward of beach	- dune cliffing and toppling of trees - soil layers exposed in eroding dunes - peat outcrops on foreshore of barriers	- lakeward edge of foredune crest

7.0 STAKING THE HAZARDOUS LANDS LIMIT

Following the proper classification of a given shoreline by shore types (see Section 3), and the determination of the appropriate *flooding hazard* (Section 4), *erosion hazard* (Section 5), and *dynamic beach hazard* (Section 6) for that shore type, the final step is the determination of the *hazardous lands* limit which indicates the landward extent of the "area of provincial interest".

This section will outline how to stake the *flooding*, *erosion* and *dynamic beach hazards* in the field. In those areas where 1:2000 scale mapping is available for the shoreline, then mapping the limit of the *hazardous lands* should be carried out. For more information on mapping the hazards and surveying techniques, Part 6 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines should be consulted.

7.1 Provincial Policy: Hazardous Lands

The "area of provincial interest", or *hazardous lands* as identified in the Provincial Policy Statement (May 1996), is based on the delineation of the **furthest landward limit** of the three shoreline hazards at each point along the shoreline (see Figure 7.1):

- ***flooding hazard***
- ***erosion hazard***
- ***dynamic beach hazard***

Mapping of the *hazardous lands* limit is simply the process of drawing a continuous line on a map along the furthest landward limit of the three hazard limits, where they exist. Applying the *hazardous lands* limit in the field will often require the **staking** of each hazard applicable to that specific shoreline reach. It also should be recognized that the **mapped** location of the hazard(s) may not coincide with their **staked** location on the day of the field investigation due to:

- changes in the configuration of the shorelines in response to local shoreline processes, or as a result of human-related activities (e.g., grading, placement of fill); and

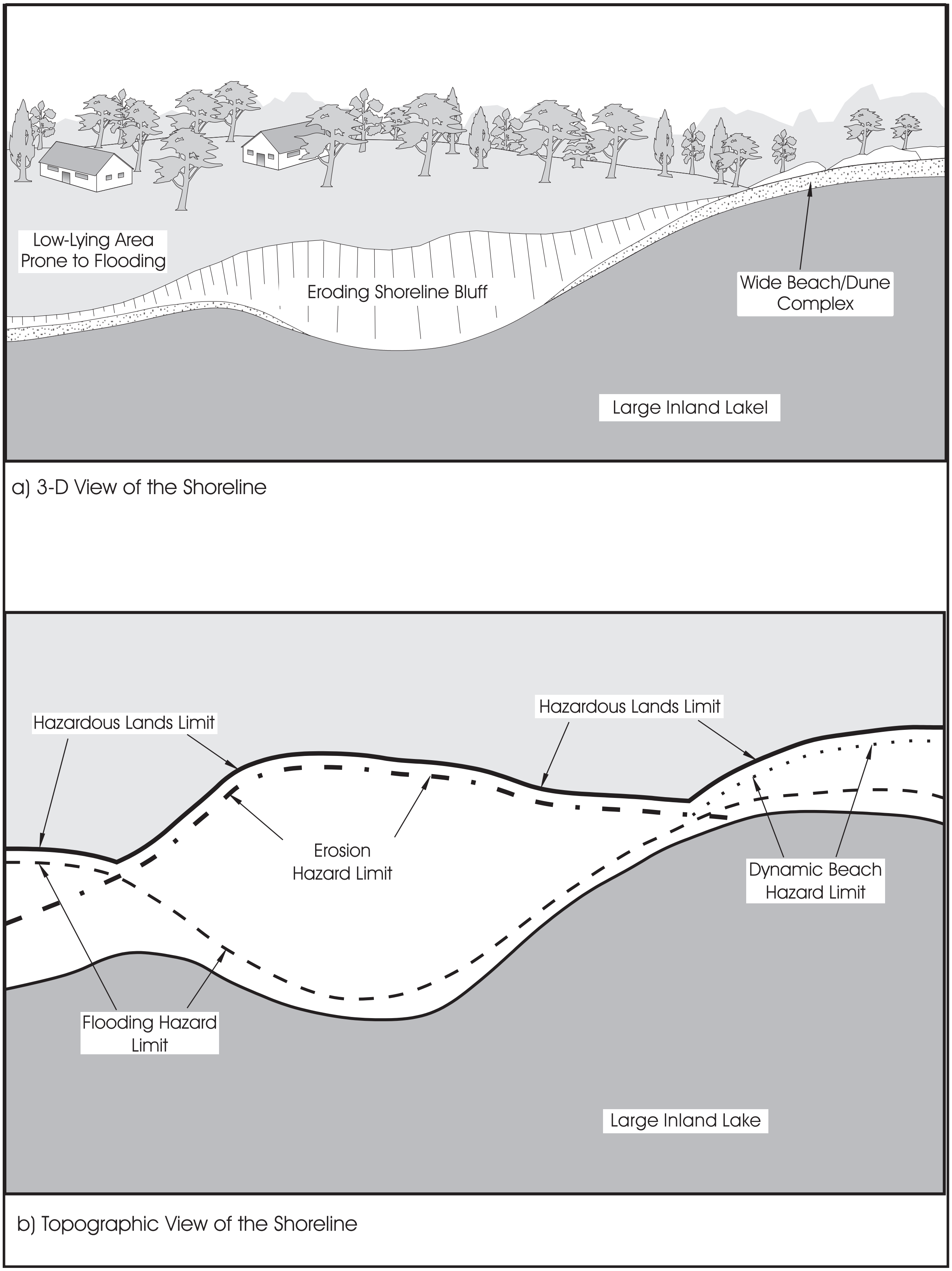
- inherent inaccuracies associated with the technique or medium (e.g., aerial photograph/historic maps) used to determine the components (e.g., 100 year flood level, average annual recession rate) of the hazards.

As such, the **map** location of the *flooding*, *erosion* and *dynamic beach hazards* and the *hazardous lands* limit is to be considered as a guide and should not be used exclusively in making final decisions on planning applications. Field **staking** of all the *hazards* applicable to a reach is highly recommended to ensure that the correct location of the *hazardous lands* limit is identified.

7.2 Procedure For Staking the Hazardous Lands Limit

The staking of the *hazardous lands* will be required as needed on a site by site basis. The *flooding hazard*, detailed in Section 4, should be staked first. The *erosion hazard*, detailed in Section 5, should be staked second unless the shoreline is classified as a dynamic beach. The *dynamic beach hazard*, detailed in Section 6, should be staked last and only for those shorelines that have been classified as being a dynamic beach (including any stable slope allowance and/or erosion allowance).

Figure 7.1: Limit of Hazardous Lands



The general procedure outlined below is for a shoreline with inadequate mapping (i.e., existing mapping is not current, does not reflect existing conditions, or is at an inappropriate scale) or no accessible reference points are available. Other procedures, when mapping and reference points are available, are described in detail in the Part 6 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines. In these areas one will require either a bench mark (BM), for vertical control (i.e., elevation) or a temporary bench mark (TBM) to determine an elevation from which the limit of the *hazardous lands* will be staked. The minimum instrumentation required would be a level and a tape measure. Other instruments such as a transit, theodolite or total station could also be used.

7.2.1 Staking the Flooding Hazard Limit

The *flooding hazard* consists of the 100 year flood level plus a flood allowance for wave uprush and other water related hazards, as outlined in Section 4. Once the *flood hazard* limit has been determined, it can be staked using the following method (see Figure 7.2):

- **Step 1** Establish the location of a BM or TBM to provide an elevation at the site. If the water level or elevation of a structure is used as the TBM, the same procedure is followed.
- **Step 2** Establish a point of known elevation at the site by bringing the BM or TBM elevation to the site using a levelling technique.
- **Step 3** Calculate the difference in elevation of the known point established at the site and the 100 year flood level.
- **Step 4** Determine the location of the difference in elevation using a level and stake this location. This is the location of the 100 year flood level.
- **Step 5** A horizontal flood allowance for wave uprush and other water related hazards (i.e., 5 metres for *large inland lakes* or as determined through a study using accepted engineering principles) must be added to the 100 year flood level. This horizontal flood allowance can then be measured from the location of the 100 year flood level with a tape and staked.

If necessary, repeat the process to determine the location of the landward limit of the *flooding hazard* for several points. The need to repeat the process will vary depending on the length of shoreline of concern and/or if the orientation of the shoreline changes. The landward extent of the *flooding hazard* is delineated by the staked points.

7.2.2 Staking the Erosion Hazard Limit

Staking the *erosion hazard* limit essentially involves delineating the landward limit of the *erosion hazard* in the field.

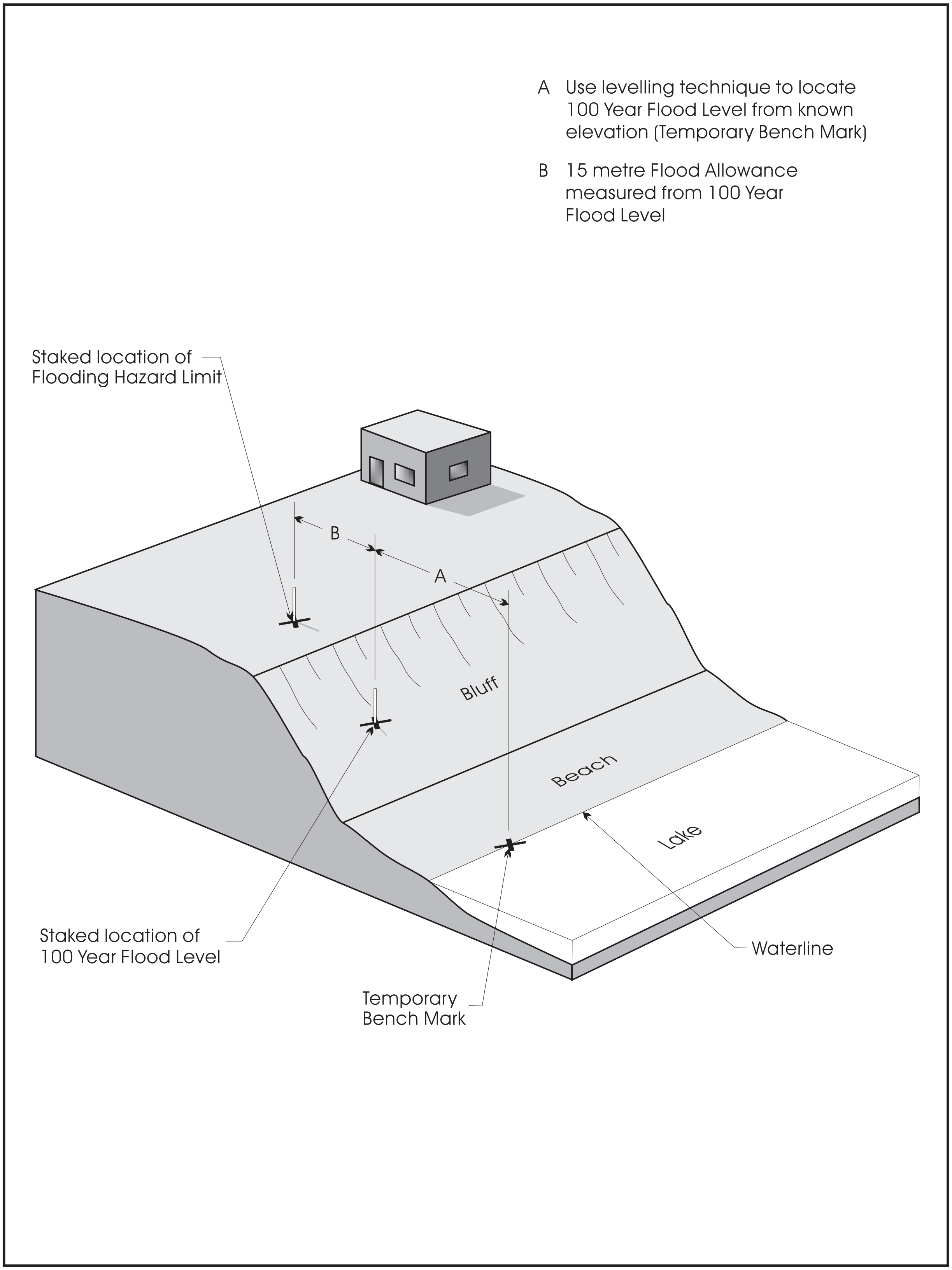
It is recommended to delineate the *erosion hazard* by staking:

- the **stable slope allowance plus 100 times the average annual recession rate** where there is recession rate information **or** where recession rate information is **not** available **a 15 metre erosion allowance**, and
- a **15 metre erosion allowance measured from the top of cliff/bluff/bank or the first lakeward break in slope**.

The most landward of these two points is the limit of the *erosion hazard*.

The steepness of the slope and the required accuracy of the data will dictate which type of surveying equipment and technique will be used to stake the *erosion hazard* limit. For example, in areas where the site may be more difficult to stake (i.e., steep, high bluff), more sophisticated survey techniques (e.g., total station or global positioning systems (GPS)) will be necessary for accurate results. If approximate results are adequate, a clinometer may be used. If the slope is gentle enough to walk up, the distance can be measured with a tape and hand level depending on the required accuracy. If greater accuracy is needed, instruments such as a transit or theodolite will be required.

Figure 7.2: Staking the Flooding Hazard Limit



a) Staking the Stable Slope Allowance Plus 100 times the Average Annual Recession Rate or a 15 metre Erosion Allowance

The following steps should be followed to stake the stable slope allowance plus 100 times the average annual recession rate or the 15 m erosion allowance (see Figure 7.3):

- **Step 1** Establish the location of the BM or TBM to provide an elevation near the site. The water level or elevation of a structure could be used as the TBM.
- **Step 2** Establish a point of known elevation at the site by bringing the BM or TBM elevation to the site using a levelling technique.
- **Step 3** Determine the location of the toe of the slope. If the water level is against the toe of the slope one may assume that the point where the water level intersects the slope is the toe of the slope.
- **Step 4** Determine the elevation of the toe of the slope from the known point elevation by using a levelling technique.
- **Step 5** Determine the location of the top of cliff/bluff/bank or the first lakeward break in slope.
- **Step 6** Knowing the elevation of the toe of the slope determine the elevation of the top of the slope by using a levelling technique. The steepness of the slope and the accuracy required will determine the instrumentation to be used.
- **Step 7** Once the difference in elevation of the slope (i.e. height of the cliff/bluff/bank) has been determined, calculate the horizontal distance for the stable slope allowance (i.e., 3 times the height of the cliff/bluff/bank or the stable slope allowance which was determined using accepted geotechnical principles).
- **Step 8** Landward from the toe the slope, stake the location of the stable slope allowance. This can be done by using a slope taping or horizontal taping technique or by using instruments such as a transit, theodolite, electronic distance measurement (EDM) or global positioning system (GPS).
- **Step 9** A horizontal erosion allowance must be determined depending on the available information. The erosion allowance is either 100 times the average annual recession rate where sufficient recession rate data is available or 15 metres where there is insufficient recession rate data or a study using accepted scientific and engineering principles may be permitted to determine the erosion allowance.
- **Step 10** Measure the horizontal erosion allowance from the stable slope allowance and stake this point. This is the *erosion hazard* limit.

If necessary, repeat the process to determine the location of the *erosion hazard* limit for several points. The need to repeat the process will vary depending on the length of shoreline of concern and/or if the orientation of the shoreline changes.

b) Staking the 15 metre Erosion Allowance Measured Landward from the Top of Cliff/Bluff/Bank or the First Lakeward Break in Slope

The following step should be followed to determine the 15 metre erosion allowance measured landward from the top of cliff/bluff/bank or first lakeward break in slope (see Figure 7.4):

- Go to the top of the cliff/bluff/bank (i.e., first lakeward break in the slope) and measure landward a 15 m erosion allowance. A study using accepted scientific and engineering principles may be permitted to determine the erosion allowance.

Figure 7.3: Staking the Stable Slope Allowance Plus 100 times the Average Annual Recession Rate or a 15 Metre Erosion Allowance

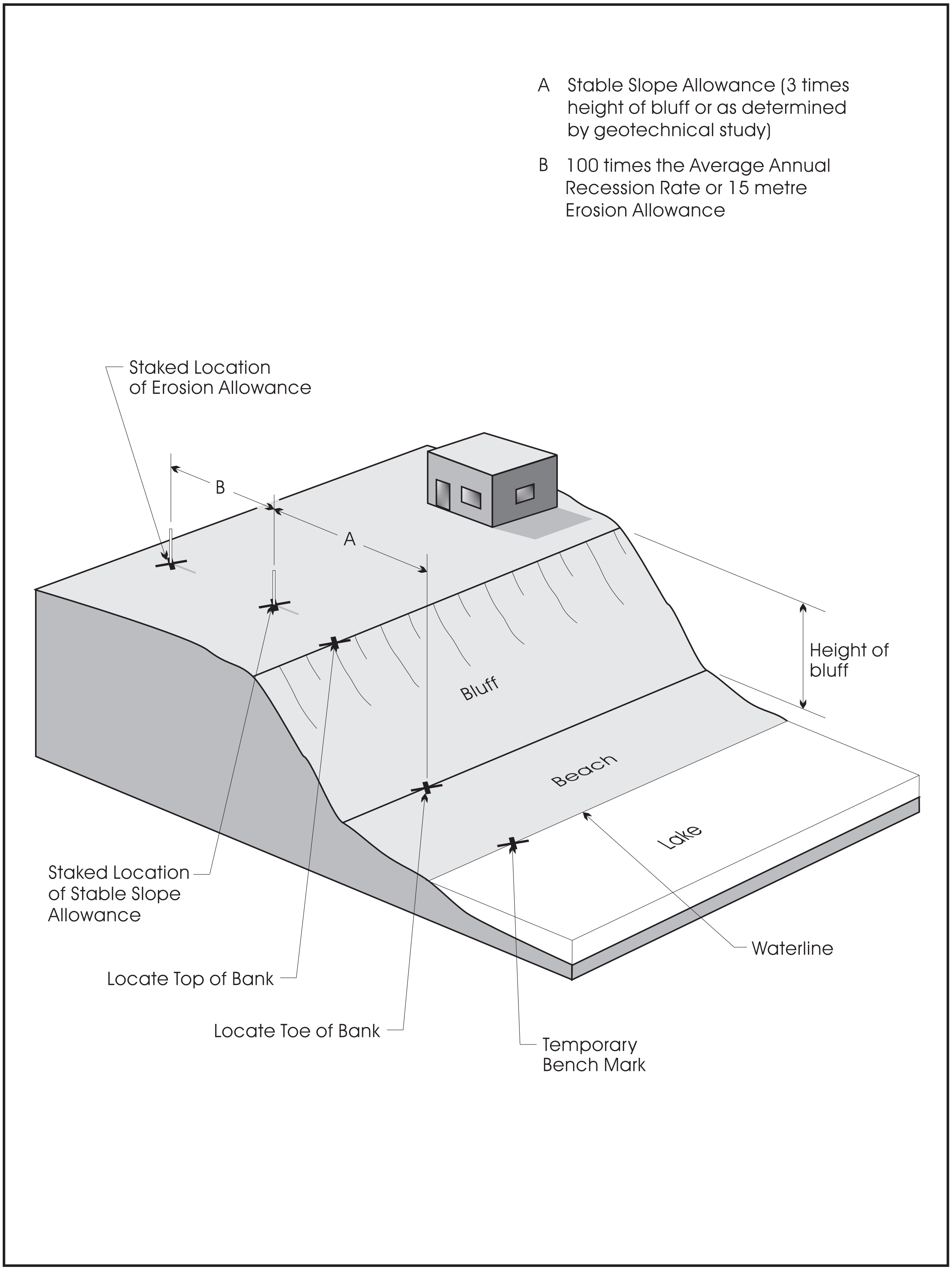
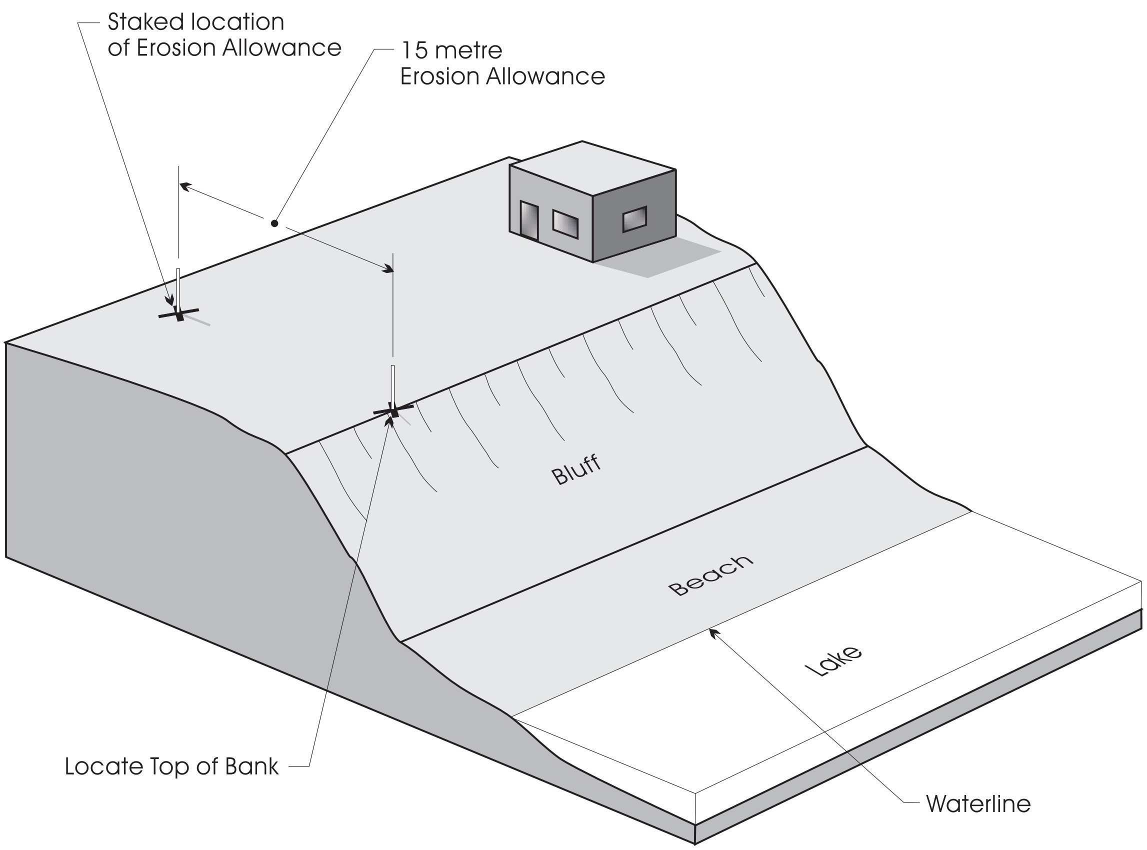


Figure 7.4: Staking the 15 Metre Erosion Allowance from the Top of Cliff/Bluff/Bank



If necessary, repeat the process to determine the location of the 15 metre top of bank allowance for several points. The need to repeat the process will vary depending on the length of shoreline of concern and/or if the orientation of the shoreline changes.

c) Staking the Erosion Hazard Limit Based on the Erosion Limits

Once the erosion limits, as defined through the procedures identified in sub-section (a) and (b), have been staked, the *erosion hazard* limit is the furthest landward of these staked erosion limits. If necessary repeat this process to determine the landward limit of the *erosion hazard* for several points. The landward extent of the *erosion hazard* is delineated by the furthest landward of these staked points.

7.2.3 Staking the Dynamic Beach Hazard Limit

Field staking of the *dynamic beach hazard* limit is usually undertaken in one of two situations:

- to compare the general location of the landward limit of the *dynamic beach hazard* with physical shoreline features to determine whether the landward limit within a reach or series of reaches is appropriate for the local conditions or whether further studies be undertaken to define the landward limit of the *dynamic beach hazard*; or

- to locate the precise landward limit of the *dynamic beach hazard* with respect to an individual feature such as a building or property lot line.

In the first situation, the *dynamic beach hazard* limit should be determined at several locations along the shoreline. The level of precision required in this type of exercise is generally low, with horizontal positioning being in the order of plus or minus 2 to 3 metres. This degree of accuracy is considered adequate for these types of situations. Measurements may be made with the use of a standard tape measure.

In the second situation, where a precise definition of the landward limit of the *dynamic beach hazard* is required at a single shoreline location, the use of a levelling technique may be necessary.

The following method should be followed for staking the *dynamic beach hazard* (see Figure 7.5):

- **Step 1** Stake the *flooding hazard* limit as described in Section 7.2.1

- **Step 2** From the *flooding hazard* limit, add a horizontal distance for the dynamic beach allowance. The dynamic beach allowance will be 15 m or an allowance determined through an acceptable scientific and engineering study.

  There are several additional factors which may complicate staking of the *dynamic beach hazard*. Where these factors apply, it is recommended that a study using accepted scientific and engineering principles be undertaken. The complicating factors include:

  - If the dynamic beach is eroding add 100 times the average annual recession rate to the 15 metre dynamic beach allowance. Therefore the *dynamic beach hazard* for an eroding dynamic beach will be the *flooding hazard* plus 100 times the average annual recession rate plus 15 metre dynamic beach allowance (see Figure 6.3).

  - If the dynamic beach is backed by a cliff/bluff such that the initial determination of the dynamic beach limit lies landward of the toe of the cliff/bluff, it is recommended that the *dynamic beach hazard* limit be staked as the toe of the cliff/bluff (see Figure 6.4). If the cliff/bluff is eroding the stable slope allowance plus 100 times the average annual recession rate should be staked for the cliff or bluff.

- If the dynamic beach profile is below the 100 year flood elevation, the *dynamic beach hazard* limit should be staked as the landward boundary between the beach and the associated dune deposits (i.e., unconsolidated beach material) and the material forming the low plain or 15 metres measured landward from the first break in slope on the lee side of the first dune (see Figure 6.5). In this instance the landward limit of the *flooding* and/or *erosion hazard* may govern the limit of the *hazardous lands*.

- If the dynamic beach exists on a narrow barrier such that the initial determination of the dynamic beach limit falls within the marsh or bay that exists landward of the barrier, it is recommended that the *dynamic beach hazard* limit be staked at 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 6.6).

- **Step 3** Stake this landward point which represents the limit of the *dynamic beach hazard*.

Repeat the process for several locations along the shoreline within the dynamic beach reach using the applicable method. The landward extent of the *dynamic beach hazard* for the reach being evaluated is delineated by the staked points.

7.2.4 Hazardous Lands Limit

The furthest landward of the staked *flooding*, *erosion* and *dynamic beach hazards* limits is the limit of the *hazardous lands* (see Figure 7.6).

Figure 7.5: Staking the Dynamic Beach Hazard Limit

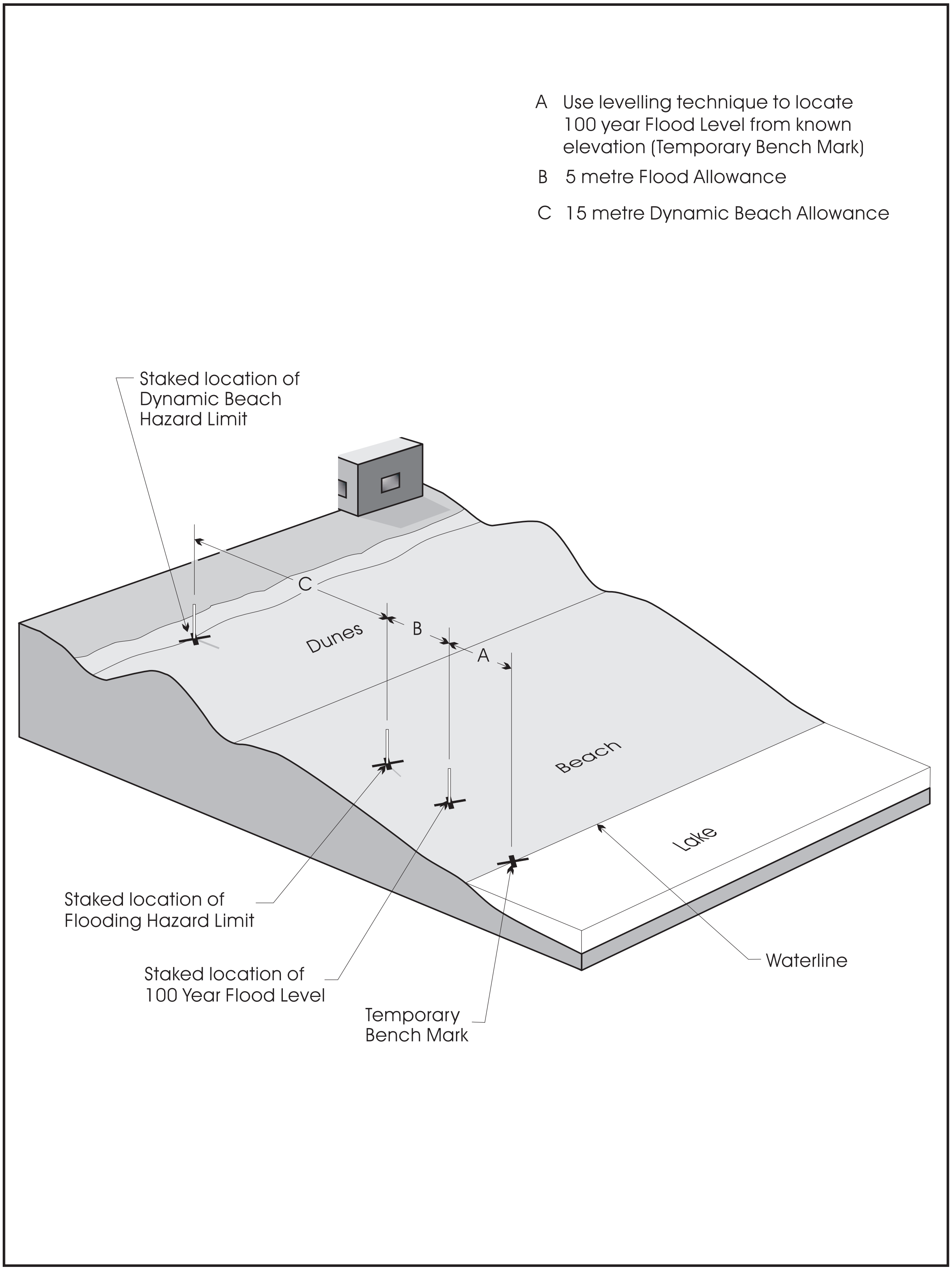
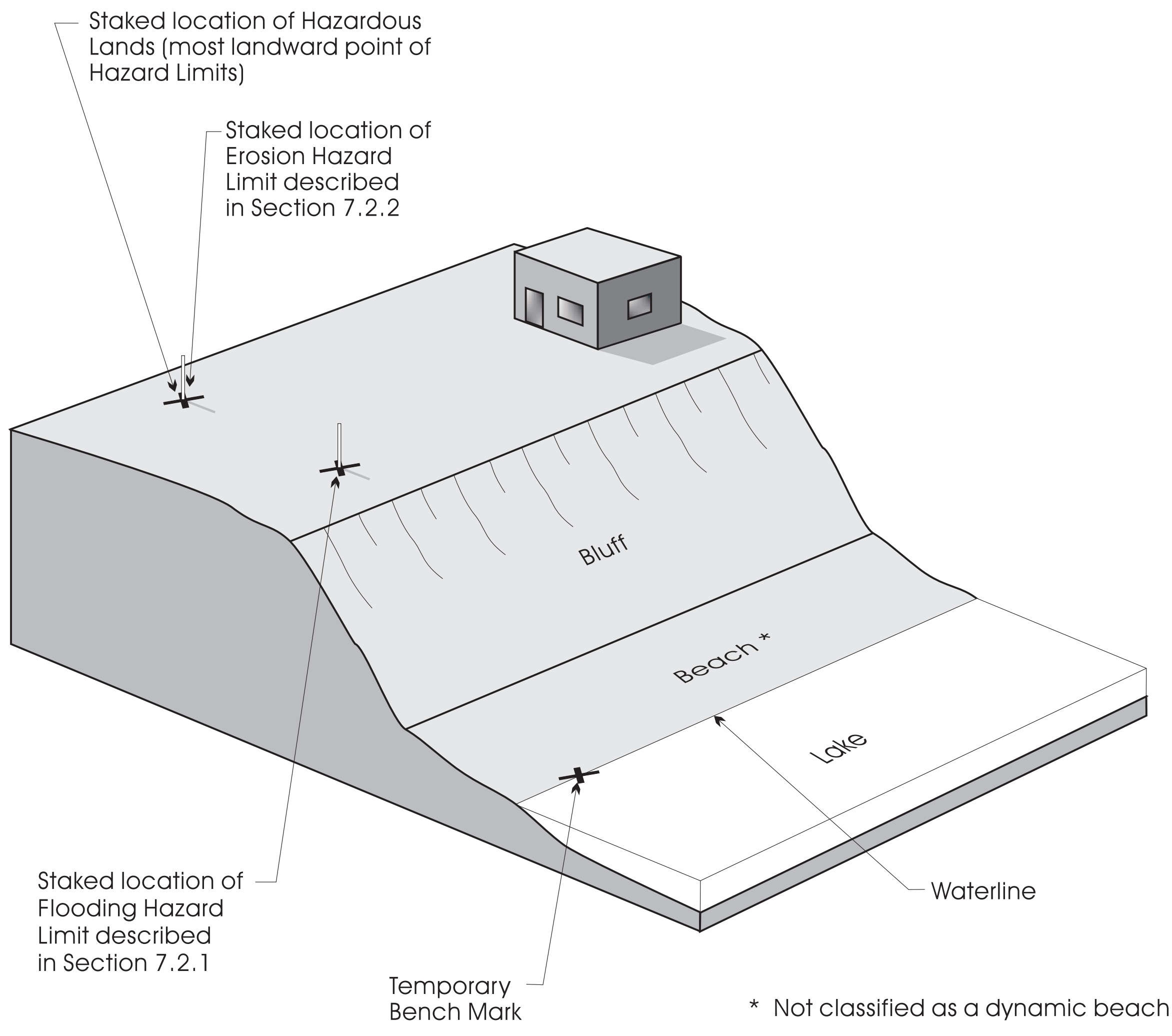


Figure 7.6: Staking the Limit of Hazardous Lands



8.0 ADDRESSING THE HAZARDS

Shoreline flooding, erosion and/or dynamic beaches are natural phenomena evident on many shoreline reaches of *large inland lakes*. These phenomena, or natural shoreline processes, only become shoreline hazards, when *development* and *site alterations* are located in close proximity to the shoreline. By definition, *development*

> "means the creation of a new lot, a change in land use, or the construction of buildings and structures, requiring approval under the Planning Act; but does not include activities that create or maintain *infrastructure* authorized under an environmental assessment process; or works subject to the Drainage Act" (Provincial Policy Statement, May 1996).

Site alteration

> "means activities, such as fill, grading and excavation, that would change the landform and natural vegetative characteristics of a site" (Provincial Policy Statement, May 1996).

Sections 1 through 7 of this Technical Guide have discussed the characteristics of the shoreline processes and the delineation and mapping of *hazardous lands* adjacent to the shorelines of the *large inland lakes* which are impacted by *flooding, erosion*, and/or *dynamic beach hazards*. Section 8 builds on this information and examines the shoreline management approaches that may enable the *flooding, erosion*, and/or *dynamic beach hazards* to be safely addressed in accordance with *established standards and procedures* and in an environmentally sound manner.

The potential impacts of the protection works on the physical coastal processes are identified. Guidance is provided on whether or not these impacts may create or aggravate hazards at other sites. The physical impacts identified in Section 8 are also used in Section 9 to help assess if the protection works are environmentally sound.

A series of three summary charts have been developed to aid in the identification of appropriate shoreline management approaches which have the potential to address the hazards on-site, for a particular shoreline type and nearshore substrate, and which do not create new, or aggravate existing hazards off-site.

8.1 Addressing the Hazards: Provincial Policy

8.1.1 Shoreline Policies

The Provincial Policy Statement (May 1996) provides direction with respect to *development* and *site alterations* within the *hazardous lands*. With the exception of certain situations noted later (i.e., Policies 3.1.2(a) and (b)), *development* and *site alteration* may be permitted within the least hazardous portions of the *hazardous lands* provided that all of the following policy requirements can be achieved:

- the hazards can be safely addressed, and the *development* and *site alteration* is carried out in accordance with *established standards and procedures* (Policy 3.1.3(a));
- new hazards are not created and existing hazards are not aggravated (Policy 3.1.3(b));
- no adverse environmental impacts will result (Policy 3.1.3(c));
- vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies (Policy 3.1.3(d)); and
- the *development* does not include *institutional uses* or *essential emergency services* or the disposal, manufacture, treatment or storage of *hazardous substances* (Policy 3.1.3(e)).

Development and *site alteration* are not permitted within those areas identified in Policy 3.1.2, namely:

- *defined portions of the dynamic beach* (Policy 3.1.2(a)); and
- *defined portions of the one hundred year flood level along connecting channels* (Policy 3.1.2(b)).

In Ontario, addressing shoreline *flooding, erosion* and/or *dynamic beach hazards* has typically involved one or more of three shoreline management approaches:

- prevention;
- protection works; and
- emergency response.

Prevention is essentially the orderly planning of land use and the regulation of *development* and *site alteration* along shorelines subject to *flood, erosion* and *dynamic beach hazards* (i.e., generally directing *development* and *site alteration* to areas outside of *hazardous lands* as stated in Policy 3.1.1(a)). Prevention reduces or minimizes hazard losses by modifying the loss potential and tends to have little or no impact on the shoreline environment. **Prevention is the preferred approach for the management of *development* and *site alterations* adjacent to the shorelines of *large inland lakes*.**

Where prevention approaches are not feasible, proper protection works, in combination with the appropriate stable slope and *hazards* allowances, may provide sufficient "protection" to warrant consideration of *development* and *site alteration* within the least hazardous portions of the *hazardous lands*. Protection works are essentially engineered, non-structural and structural protection works, such as relocation, floodproofing, bioengineering measures, dune enhancement, filling and dyking, revetments, seawalls, groynes, artificial headlands and detached breakwaters. Protection approaches reduce hazard losses by modifying the *flooding* and/or *erosion hazards* at the shoreline. Structural protection works are most commonly associated with impacts to adjacent properties as well as to the terrestrial and aquatic environment.

The inclusion of Policy 3.1.3 (Provincial Policy Statement, May 1996) is intended to provide flexibility to recognize local conditions. When applying this flexibility, care must be taken to ensure that the magnitude or degree of risk(s) is clearly understood, and that the potential or feasibility for *development* and *site alteration* to safely locate within certain portions of the *hazardous lands* is sound, reasonable and can be implemented in accordance with the *established standards and procedures* (Policy 3.1.3(a)). Care must also be taken to ensure that the interests and intent of other policies addressing the same shoreline areas are not compromised. Where all of these conditions cannot be fulfilled, the *development* and *site alteration* should be directed to areas outside the *hazardous lands*.

The requirements of Policies 3.1.3 (a) to (e) are intended to promote public safety and to minimize risks to life, property damage, adverse environmental impacts and social disruption. Ecological, geomorphological and socio-economic elements are concentrated at the shoreline and are uniquely defined by their interactions within the shore environment. A delicate, dynamic balance exists between these elements, a balance which can easily be altered or upset. It is imperative that any protection works consider both the immediate and the broader ecological, geomorphological and socio-economic contexts, as no part of the system operates independently of any other part. The proponent should also consider whether or not the protection works are justified from a benefit-cost perspective and are in keeping with any objectives for public access, recreation and aesthetics.

When applying Policy 3.1.3, a number of complicating planning issues may arise. For example, municipalities and planning boards may need to develop strategies to deal with existing lots of record, *residential infilling*, *residential intensification*, or with additions and alterations to existing development. In some shoreline municipalities, development applications involving structures or buildings which by the nature of their use are normally located in close proximity to or within the water (e.g., water intake structures, marinas, boathouses, utilities, etc.) may also require a more detailed evaluation. In each of these cases, municipalities and planning boards should determine the potential risks associated with the various municipal land use planning strategies that may be under consideration or applied. In all of these situations, regardless of the planning issue being evaluated, the overall intent of the Policy, to minimize the potential risk to life and property, is to be preserved.

8.1.2 Established Standards and Procedures

Where the potential for environmentally sound development to safely occur does exist, the *development* and *site alteration* should be carried out in accordance with the *established standards and procedures* (Policy 3.1.3(a)) that apply (Provincial Policy Statement, May 1996). By definition, *established standards and procedures* means the following:

- "**floodproofing standard**, which means the combination of measures incorporated into the basic design and/or construction of buildings, structures, or properties to reduce or eliminate *flooding*, *wave uprush* and *other water related hazards* along the shorelines of the *Great Lakes - St. Lawrence River System* and *large inland lakes*, and *flooding* along *river and stream systems*";

- "**protection works standard**, which means the combination of non-structural or structural works and allowances for slope stability and flooding/erosion to reduce the damages caused by *flooding, erosion* and/or *other water related hazards*, and to allow access for their maintenance and repair"; and

- "**access standard**, which means a method or procedure to ensure safe vehicular and pedestrian movement, and access for the maintenance and repair of protection works, during times of *flooding, erosion*, and/or *other water related hazards*" (Provincial Policy Statement, May 1996).

Further discussion regarding the floodproofing, protection works and access standards is provided in Section 8.2.4.

8.2 Addressing the Hazards On-Site

8.2.1 Initial Considerations

After the *flooding*, *erosion* and *dynamic beach hazards* have been delineated and prior to the selection of a particular protection works to safely address the *hazards* at a specific site, it is appropriate to first consider a number of important questions:

- What type of development activity is at risk?

- What is the intended purpose of the structure (i.e., is it to safely address the hazards or is it for recreational, aesthetic or other reasons)?

- Have prevention and relocation measures been given serious consideration?

- Is there a significant potential risk that the protection works will have any adverse impacts on neighbouring properties or the environment?

- What is the total cost of the protection works over the long-term (i.e., including construction, maintenance and replacement)?

- Is the structure viable considering what exists at the adjacent properties (i.e., is there a coordinated approach with the adjacent properties)?

Seeking answers to these questions will guide the shoreline manager and the proponent in determining the most suitable and environmentally sound approach to addressing the hazards. The following subsections examine some of the issues raised by these questions.

a) Type of Development Activity

The characteristics of a proposed development activity, or the resulting land use, should influence the type of protection works to be applied. For example, habitable residential development will obviously require a greater degree of protection from *flooding* and *erosion hazards* than minor non-habitable buildings (e.g., gazebos, garden sheds). Structural protection works proposed for certain *site alterations*, such as decks and groomed lawns, in many cases are not appropriate.

Development can generally be grouped into three major categories:

- **multi-lot, large lot and large scale development**

  · creation of multiple lots, or large lot, medium to high density residential development, or other large-scale developments (see Figure 8.1).

- **residential or habitable infilling, redevelopment, replacement, major additions/alterations, minor additions/alterations**

  · infilling: development on previously undeveloped lot, or creation of a residential lot, generally between two existing developed lots of a similar size and which are situated on the same side of a road and are not more than 100 m apart;

  · redevelopment/ intensification: existing residential unit removed from previously developed, serviced land and a new larger residential unit erected or the creation of new residential units or accommodation in existing buildings on previously developed, serviced land;

  · replacement: existing structure removed and new residential or habitable unit for same use and of same size or smaller erected;

  · major additions/ alterations: construction is equal to or exceeds 30% (50% for floodproofing) of the foundation area or market value of the existing structure or work;

  · minor additions/ alterations construction is less than 30% (50% for floodproofing) of the foundation area or market value of the existing structure or work.

- **Non-habitable buildings and structures** (see Figure 8.2)

  · major structures: non-habitable buildings or structures that do not qualify as minor structures;

  · minor structures: non-habitable, moveable structures with no utilities and maximum size of 14 m^2.

Further discussion dealing with existing development within the *hazardous lands* is presented in Appendix A7.2 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines.

Figure 8.1: Large Scale Development

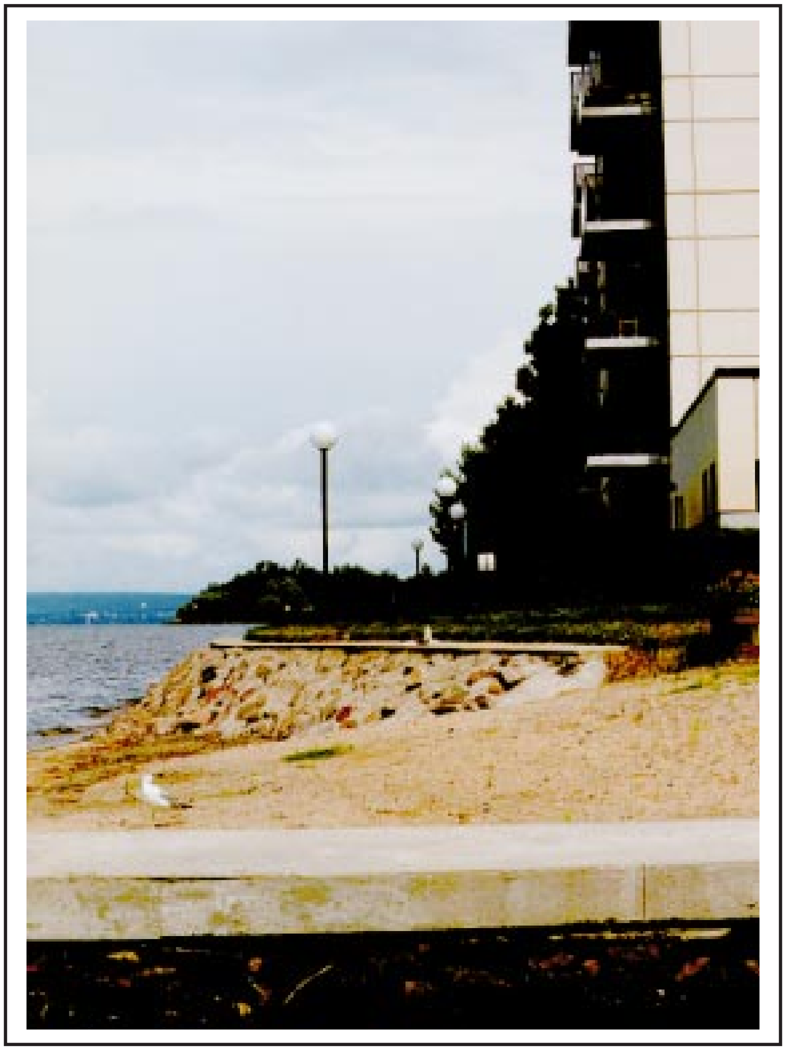


Figure 8.2: Non-habitable Building

b) Understanding the Purpose of Shoreline Protection Works to Address the Hazards

Where prevention approaches are not feasible, the goal of protection works is to address the hazards on-site (e.g., minimize flooding, stabilize erosion) without creating or aggravating hazards off-site and without creating adverse environmental impacts. If possible, aquatic and terrestrial habitat should be enhanced and the shoreline aesthetics maintained or improved.

In areas of real *flooding* and *erosion hazards*, when development requires protection, structural measures may be considered necessary and acceptable provided they meet the policy requirements as discussed in Section 8.1.1. However, there have been situations where structural shoreline works were permitted, for the stated purpose of flood and/or erosion control, on shorelines where no real or significant flood or erosion problems existed. In some of these cases the shoreline was stable and no modifications were necessary. In other cases, minor problems existed which could have been easily controlled by non-structural measures. Yet in other cases, the real purpose of proposed structural works was to create additional lawn or recreational beach areas or ancillary facilities such as boathouses, docks and marine railways. Thus, the need for structural protection works to address the hazards should be demonstrated by examining the following questions:

- Is there a real flooding, erosion or dynamic beach hazard that needs to be addressed (i.e., have the *flooding*, *erosion* and/or *dynamic beach hazard* limits been established)?

- How severe is the hazard and what is the cause (i.e., is it a natural process or has it been exacerbated by actions such as inappropriate removal of vegetation (see Figure 8.3a) or improper regrading or filling (see Figure 8.3b))?

Figure 8.3a Effects of Vegetation Removal

Figure 8.3b Erosion of Unprotected Fill Material

- Is a structural protection measure to address the hazard warranted at the site (i.e., what type of development is at risk and is the risk worth preserving the shoreline in its natural condition)?

Sections 4, 5 and 6 discuss the *flooding*, *erosion* and *dynamic beach hazards* respectively.

The primary purpose of shoreline protection works to address the hazards can be: flood protection, which includes wave uprush (i.e., storm wave damage) and other water related hazards; erosion protection; or a combination of flood and erosion protection. There may be secondary purposes, such as retaining upland soil (e.g., bulkhead wall) or providing access for people or boats (e.g., walkways and boat ramps). It is important that the primary purposes of the protection works be clearly defined and understood.

Design criteria for shoreline protection works to address the hazards should be governed by the primary *flooding* and/or *erosion hazard* protection purposes and should not be unduly compromised for secondary purposes, such as recreational access to the water. For example, an armour stone revetment protection works that must be a certain height to provide effective wave overtopping protection should not be arbitrarily lowered just because easier access is desired. However, that is not to say that protection works can only satisfy one purpose. There are many ways in which protection works can effectively satisfy multiple purposes. In fact, as noted earlier, aquatic and terrestrial habitat should be enhanced and the aesthetics maintained or improved wherever possible. In the example provided above, effective protection and access could possibly be provided by stepping the armour stone, by using a flatter, more permeable structure, and/or by incorporating vegetation into the works.

Proposed shoreline works intended primarily for purposes other than addressing *flooding* and *erosion hazards* and which by the nature of their use are normally located in close proximity to or within the water (e.g., water intakes, walkways, boathouses, boat ramps, boat docks and landscaping or aesthetic improvements) may be governed by design criteria which are not necessarily as stringent as those for safely addressing flood and\or erosion hazards. However, in all of these situations adverse environmental impacts and new hazards are not to be created and existing hazards are not to be aggravated. Also, regardless of the planning issue being evaluated, the overall intent of the Policy, to minimize the potential risk to life and property, is to be preserved.

c) Prevention and Relocation Versus Shoreline Protection

The shoreline manager should always ask: Would a prevention, relocation or a non-structural approach be more suitable than a structural protection measure?

The preferred and often the most appropriate means of addressing *flood*, *erosion* and *dynamic beach hazards* at a given site, for all types of shorelines, is through prevention; namely, locating development landward of the *hazardous lands*. Structural protection works should not be necessary for development that is located landward of the *hazardous lands* since the development will be reasonably safe from the flood, erosion and dynamic beach hazards for the planning horizon. **In areas of existing development, relocation should be given serious consideration.** Section 8.2.3(b) provides further discussion of the relocation option.

The advantages of prevention and relocation over structural protection works are:

- the hazards are addressed within a defined acceptable level of risk (i.e., *flooding*, *erosion*, and *dynamic beach hazard limits*);
- no adverse environmental impacts will result;
- new hazards are not created and existing hazards are not aggravated;
- initial capital construction costs and long-term maintenance and replacement costs are greatly reduced;
- natural aesthetics and amenities of the shoreline are preserved; and
- approvals and permitting requirements are greatly reduced.

Prior to permitting development to occur within the *hazardous lands*, through the implementation of structural protection works, proponents should be required to demonstrate that other alternative approaches (i.e., prevention or nonstructural measures, such as relocation, floodproofing, bioengineering measures and dune enhancement) have been evaluated and have been found to be not feasible.

d) Impacts

Determining whether or not a particular shoreline management approach safely addresses the hazards at a given site is only the first step in establishing the best overall acceptable approach. In addition to addressing the hazards at the site, the selected management approach must not create or aggravate existing hazards off-site (Policy 3.1.3(b)) nor can it result in any adverse environmental impacts (Policy 3.1.3(c), Provincial Policy Statement, May 1996).

Structural protection works are most commonly associated with effects on the physical shoreline environment (e.g., trapping and/or deflecting alongshore sediment transport, altering the nearshore topography). These effects are discussed in more detail in Section 8.3. Changes in the physical processes due to structural protection works may also result in a range of potential impacts on the terrestrial and aquatic environment. These environmental impacts are discussed in detail in Section 9.0: Environmentally Sound Hazard Management, of this Technical Guide.

Proposed shoreline protection works must be accompanied by an impact assessment which demonstrates that new *flooding*, *erosion*, and *dynamic beach hazards* are not created and existing hazards are not aggravated at updrift and downdrift properties.

The assessment of the proposed protection works must also identify that no adverse environmental impacts will result. If it is determined that major environmental impacts will occur as a result of the proposed structure, then the works should not be permitted. If it is determined that the structural protection works will cause minor environmental impacts, mitigation and/or compensation measures should be applied.

e) Total Costs

Proponents should be encouraged to critically evaluate the total costs and benefits of proposed protection works. Many shoreline property owners have often resorted to structural protection works to address hazards on-site with little or no consideration of the real costs of maintaining, repairing and replacing the protection works over the full life of the development (i.e., the planning horizon). In addition, the impacts, or indirect costs, of structural works to the environment and to updrift/downdrift shorelines are often not factored into the benefit-cost analysis. However, along with these indirect costs can also come indirect benefits beyond property protection, such as enhanced recreational opportunities or protection of significant resources (e.g., an important wetland or a cultural feature of historical value). A broad evaluation, including direct and indirect costs and benefits, both quantitative and qualitative, should be applied to provide a more comprehensive and more realistic determination of the appropriateness of the various forms of protection approaches.

f) Coordinated Efforts with Adjacent Properties

To be most effective, shoreline protection works must be coordinated with the adjacent properties. The lack of, or the level and type of, flood and/or erosion protection at adjacent properties must be considered. It is of little value to provide wave uprush protection along the lakeside of a site if the properties adjacent to the site have little or no flood protection. Water that floods the properties adjacent to the site could easily flow to the site from the sides (see Figure 8.4). Also, erosion protection along a single, narrow lot may be of little value, even if flank protection is provided, if the adjacent properties are not protected (see Figure 8.5). One must consider that for individually protected lots, or at the property limits of subdivisions, there has to be sufficient stable slope and erosion allowances from the sides of the development, as well as directly perpendicular from the development to the lake. Concern regarding sufficient allowances from the sides increases as lot width decreases, bluff height increases and recession rates increase.

Figure 8.4: Insufficient Adjacent Flood Protection

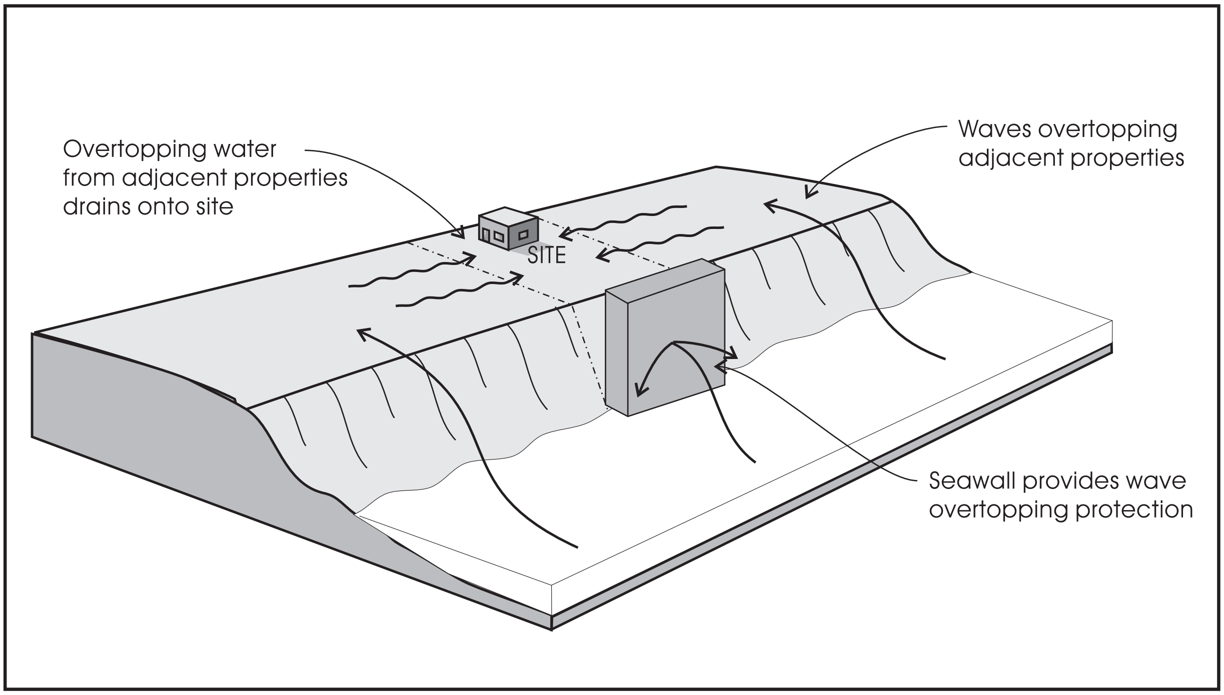
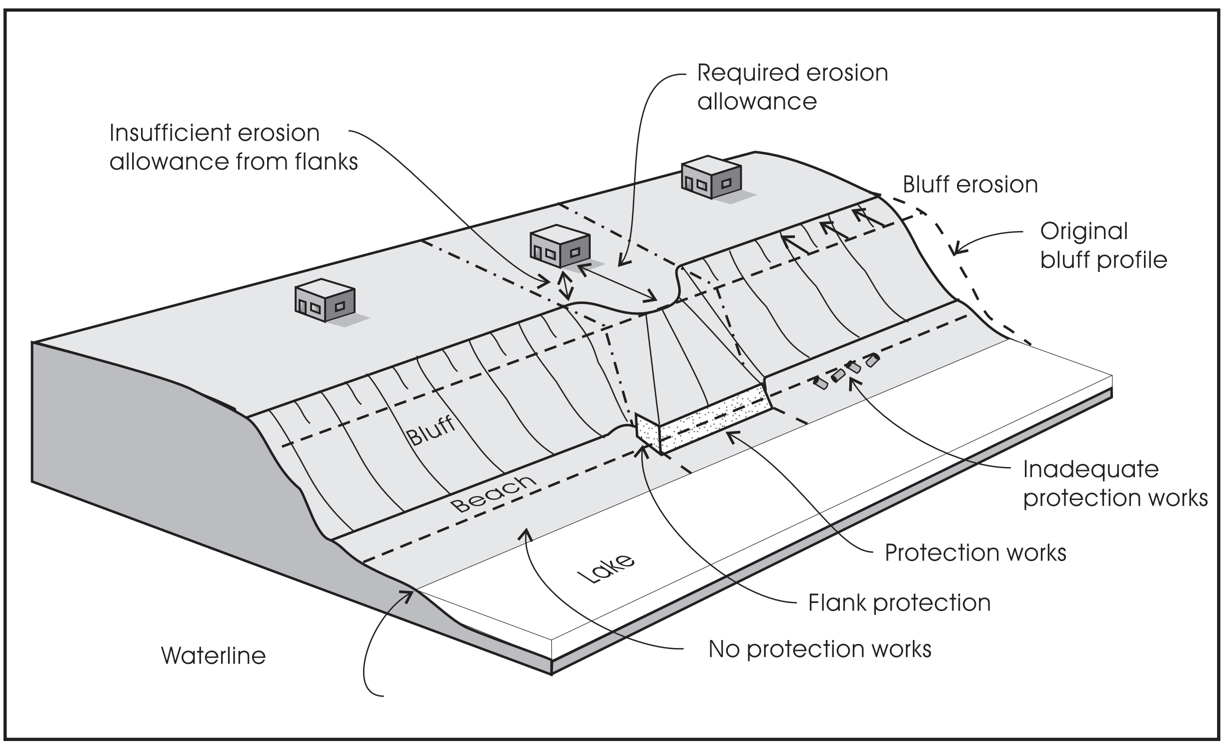


Figure 8.5: Insufficient Flank Erosion Allowance



8.2.2 Characteristics of Hazards

a) Flooding Hazard

Flood damages along the shorelines of *large inland lakes* vary with the type and severity of shoreline flooding which in turns depends on the velocity, depth and resultant inland extent of shoreline floodwaters. The three types of shoreline flooding, as described in Part 4: Flooding Hazards, of this Technical Guide, are as follows:

- higher, lakewide, static water levels;
- wind setup; and
- wave uprush and overtopping and other water related hazards (e.g., ice and boat generated waves).

Low plain and beach shorelines are typically susceptible to flooding particularly in areas subject to significant storm surges or more moderate surges accompanied by higher lakewide static water levels. Bluff and cliff shorelines are generally not prone to flooding due to their height. To address the *flooding hazard,* the protection works must prevent entry of flood waters and/or minimize damage due to wave impact. Wave impact damage is a result of wave uprush striking shoreline development.

Floodwaters impose hydrostatic forces and hydrodynamic forces. Hydrostatic forces result from the static, or stationary, mass of water at any point of flood water contact with a structure. They are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic forces can act vertically on structural members, such as floors and decks (i.e., tends to uplift or “float” structures), and can act laterally on upright structural members, such as walls, piers, and foundations (i.e., tends to “push” the structure over, see Figure 8.6a). Hydrostatic forces increase as the water depth increases.

Hydrodynamic forces result from the flow of flood water around a structure, including a drag effect along the sides of the structure and eddies or negative pressures on the structure's downdrift side (Figure 8.6b). These are more common in flash floods, shoreline floods, and when flood water is wind-driven.

Flooding characteristics that must be considered when evaluating floodproofing measures include:

- Depth of expected flooding and, in shoreline areas, height of wave crests, which will determine the required elevation of a building and the hydrostatic and hydrodynamic forces to be expected.

- Velocity of flood waters and waves, which influences both horizontal hydrodynamic forces on building elements exposed to the water and debris impact loads from water-borne objects. Waves striking structures in the shore zone can cause considerably more damage than simple inundation. Past storms have resulted in waves knocking houses off their foundations, demolishing walls and destroying shore protection works. The amount of wave damage depends on the position and exposure of buildings/structures to the effects of storm wave action and the frequency and energy with which the storm waves act on the shore.

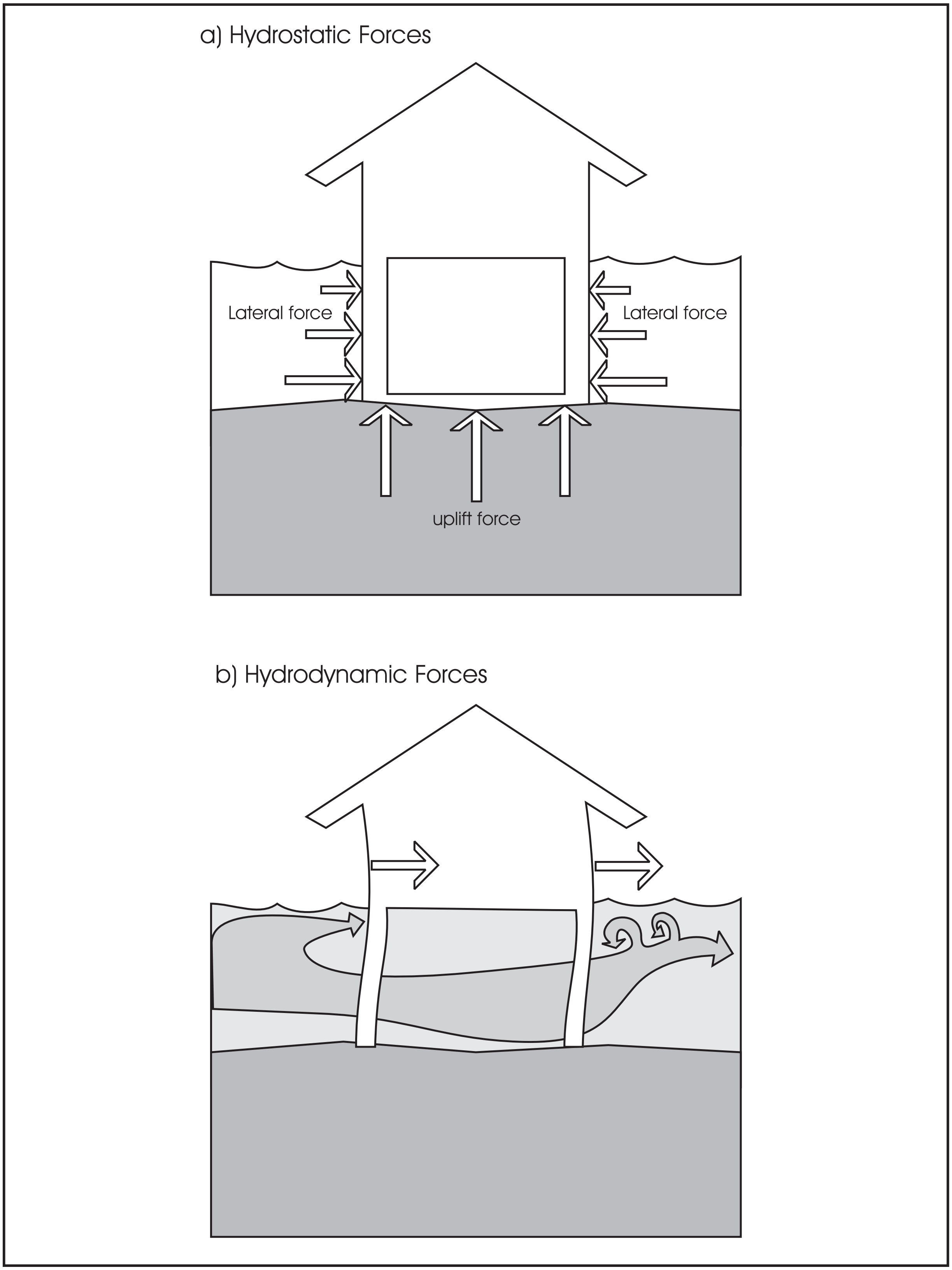
- Frequency of flooding, which is the amount of time between occurrences of damaging floods. This will have an important influence on site selection.

- Duration of flooding, which affects the length of time a building may be inaccessible, as well as the saturation of soils and building materials.

- Rate of rise, which indicates how rapidly water depth increases during flooding. This determines warning time before a flood, which will influence the need for access routes (ingress/egress) to be elevated above floodwaters and whether valuable possessions should/can be kept underneath the structure and moved only when flooding is imminent.

- Ice and debris, which can cause serious damage to structures. Wind-driven ice or ice jams have, in some cases, completely demolished bridges, homes and businesses, snapped off large trees and pushed buildings completely off their foundations. Floating debris can be equally dangerous in this regard. Little can be done to avoid these phenomena short of avoiding sites where they are more likely to occur.

Figure 8.6: Flooding Forces



For further information regarding the characteristics of flooding, Part 4: Flooding Hazard of this Technical Guide, should be consulted.

Within the *flooding hazard* limit, flood hazards can be addressed in ways similar to addressing *flooding hazards* in riverine flood plains. However, two additional considerations must be addressed when dealing with shoreline *flooding hazards*, namely, wave impact and prolonged high water levels. Higher lakewide levels are of particular concern given that they can persist for months and sometimes years.

Options to protect against shoreline flooding include preventing the entry of floodwaters (e.g., "floodproofing") and reducing the wave uprush by reducing the incoming wave energy. For the purposes of this Technical Guide, a distinction has been made between non-structural and structural floodproofing protection measures. Non-structural protection measures are essentially those structures that are located onshore and do not involve construction or placement of significant additional structures and/or materials at the shoreline. However they can include design features related to the habitable structure (e.g., raising structure up on piles and elevating services). Hence, some floodproofing measures, even those requiring “structural” modifications to a house, are not classified as "structural" protection works. Structural floodproofing protection measures refer to measures that involve significant construction and/or the placement of significant quantities of imported materials (e.g., filling, dyking and floodwalls).

Standard structural protection works, such as revetments and seawalls, can be used to mitigate flood and storm hazards, typically wave uprush and overtopping, in the onshore area (e.g., the structure is located above the 100 year flood level) on relatively stable shorelines (i.e., low recession rate, less than or equal 0.3 m/yr). Suitable design guidance for these "standard" works (i.e., located on stable shoreline and above 100 year flood level) can be obtained from existing publications (e.g., MNR 1987; USACE 1981, 1984). One is reminded that the approaches outlined in USACE (1981) and MNR (1987) are generally not suitable for open coasts exposed to direct wave attack and erosion. If the flood hazard is reduced, specifically the potential wave impact hazard, non-structural floodproofing measures for development in the onshore area may be more feasible.

Filling and dyking exposed to wave action will require erosion protection. If the fill or dyke is located above the 100 year flood level (only exposed to wave uprush and other water related hazards), standard erosion protection measures, as discussed above, could be used.

Floodproofing protection works are described in Section 8.2.3.

b) Erosion Hazard

As discussed in Section 5 of this Technical Guide, erosion is a natural process resulting in the wearing away and removal of the land by water action. For the most part, the shoreline erodes from the forces of wave action. Waves work endlessly to break down and reshape the shoreline, a process which property owners often overlook or are not aware of in their eagerness to be close to the water. Therefore, shoreline property losses are generally the result of naturally occurring erosion processes associated with wave action, unstable slopes and the continuous landward recession or retreat of the shoreline. Section 5: Erosion Hazard, of this Technical Guide, provides a detailed discussion of the erosion processes and slope stability.

The severity or risks associated with the *erosion hazards* and the selection of approaches to address these hazards are dependent on the controlling nearshore substrate (i.e., bedrock, cohesive or dynamic beach) and the general shoreline type (i.e., bedrock cliff or low plain, cohesive/noncohesive bluff or low plain or dynamic beaches). More detailed information on the controlling nearshore substrates and general shoreline types is outlined in Section 3 of this Technical Guide.

At different locations, shoreline recession rates can vary from low (0.0 to 0.3 m/yr) to severe (>2.0 m/yr). Where it found that recession rates exceed 0.3 m/yr, the shoreline manager may wish to consult the Technical Guide for Great Lakes - St. Lawrence River Shorelines for further information.

.   Bedrock Shorelines

As outlined in Section 3: Recommended Shoreline Classification Scheme to Determine Shoreline Reaches, of this Technical Guide, bedrock shorelines consist of a controlling substrate of bedrock at, or very near the lakebed. Most bedrock shorelines (but not all bedrock shorelines), are characterized by low to stable recession rates and generally do not pose a significant erosion hazard. The resistance to erosion, however, can vary with the bedrock material. Softer bedrock materials, such as some shales and limestones, do erode but at a relatively low rate. Factors that may cause shale to erode include, but are not limited to, wetting/drying and freezing/thawing processes. For the softer bedrock materials, such as shale, it may be useful, when reviewing protection options, to consider them as an erosion resistant cohesive material.

Along bedrock-controlled substrate shorelines, where the backshore and onshore area is comprised of a cohesive or noncohesive material, the erosion hazard can increase. The relatively stable base provided by a bedrock nearshore typically permits consideration of the full range of alternative structural erosion protection works to address *erosion hazards* at a shoreline site. If the backshore/onshore material is erosion resistant bedrock, then erosion protection is unlikely to be necessary.

.   Cohesive Shorelines

The controlling process for the recession of a cohesive shoreline is the downcutting, or downwards erosion of the nearshore profile by wave induced forces. This downcutting of the cohesive material is considered to be irreversible and constant. "Fine-grained cohesive" shorelines (see Section 3 of this Technical Guide), often characterized by moderate to severe recession rates, have exposed cohesive nearshores and tend to have concave-shaped profiles (i.e., the depth increases rapidly as you move offshore). The downcutting rate of the nearshore profile is the greatest at the shoreline and gets less towards the offshore. The presence and movement of sediments over the cohesive profile can influence the erosion of the profile depending on the quantity and volatility of the sediment cover. Cohesive shorelines with a significant amount of cobbles and boulders are more erosion resistant. Further explanation of cohesive shorelines is presented in Appendix A1.2: Lake/Land Interaction, of the Technical Guide for Great Lakes - St. Lawrence River Shorelines).

To truly control the recession of a cohesive shoreline over the long term, it is necessary to slow or stop the downcutting of the nearshore profile. Such a requirement can only be accomplished by "macro" type protection works that extend into the nearshore, such as:

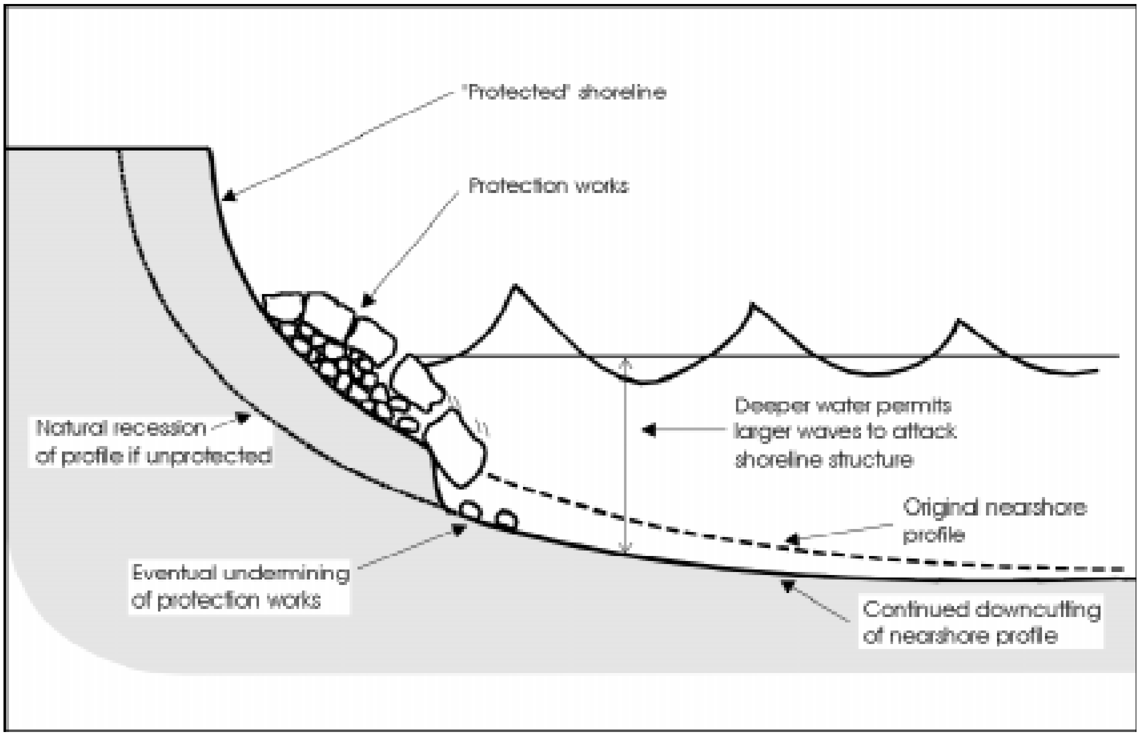
- protective beaches (i.e., beach nourishment generally accompanied by detached breakwaters or large artificial headlands) to protect the cohesive profile; and
- detached breakwaters which reduce wave action across the nearshore profile.

These macro-scale projects are costly and require the coordinated response of many property owners over hundreds of metres of shoreline and an extensive design effort. Due to fact that they extend into the nearshore, they would typically require permission to occupy Crown Land. Also, these macro-scale projects, because of their large scale and their location in the nearshore, are most likely to cause adverse impacts to the environment.

Backshore, shore parallel structures, such as revetments and seawalls only protect the backshore area. These structures typically do nothing to reduce the erosion of the nearshore lakebed which is the root of the long term recession of cohesive shorelines. Along cohesive shorelines, revetments and seawalls only postpone the inevitable by "buying time" for the property owner who is then faced with the decision to increase the size of the structure at a later date or to abandon the structure (see Figure 8.7).

On cobble/boulder till cohesive shorelines, where recession rates are relatively lower, protection structures limited to the backshore area may be viable. To appropriately address the hazard, backshore structural protection works must be designed to accommodate the effects of erosion of the nearshore lake bottom. The design must incorporate provisions for this downcutting as it relates to the potential undermining of the structure and the increased depth limited wave heights as the water gets deeper. The increased wave heights result in increased wave forces, uprush and overtopping.

Figure 8.7 Schematic of Continued Downcutting of Nearshore Profile



c) Dynamic Beach Hazard

Two types of natural hazards can be identified on dynamic beaches: a) wave action and other water related hazards such as wave spray and ice action that impinge directly on buildings, roads, and other facilities, or wave action that indirectly affects structures by removing beach material which supports foundations, footings and piles; and b) flooding due to a rise in the water table within sand dunes and low-lying areas landward of the beach during periods of seasonal and long-term high lake levels as well as to short-term events associated with storms. In the latter case the property is not subject to direct wave action and the hazard may be overcome using the approaches outlined in Section 8.2.3(b) on floodproofing, provided they do not interfere with the normal adjustment of the dynamic beach profile. In this section, attention will be focused on addressing the *hazards* associated with wave action.

Along non-erosional 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 reason for this is simply that dynamic beaches adjust to changing wave and water level conditions and that the natural beach itself provides the best protection against wave action. If permanent structures are located landward of the limit of profile adjustment on a stable dynamic beach then, by definition, they will be protected from wave-related *hazards*.

If a building is located within the *dynamic beach hazard* limit, it will be within the zone exposed to wave action at some time as well as being subject to the removal of its supporting beach material. Thus the building itself, or any structure designed to protect it, will not only be subject to the hazard, but it will also interfere with the ability of the beach to adjust to natural processes. This in turn will impair the ability of the beach to offer protection to the area behind it, as well as having the potential to affect adjacent sections of the beach. This is the rationale behind the provision in the Provincial Policy Statement (May 1996) that *development* and *site alteration* will not be permitted within *defined portions of the dynamic beach*.

Outside the *defined portions of the dynamic beach*, *development* and *site alteration* may be permitted provided it meets all the requirements of Policy 3.1.3. The preferred order to implementing the range of potential response to addressing the *hazard* is outlined in the following paragraphs.

Where development already exists within the *dynamic beach hazard* limit on a non-erosional beach (i.e., overall long-term recession rate is zero or negative), or where it is proposed to locate *development* and *site alteration* outside the *defined portions of the dynamic beach*, there is a preferred order to implementing the potential range of responses to addressing the hazard:

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 and groynes completely 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 impacts on the 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 remain 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 minimise impact on the beach in front of the property and on adjacent beaches. <u>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.</u> Alternative approaches that involve either building out of the beach, through trapping of sand in groynes, or behind detached breakwaters, may have an even greater impact on downdrift areas and therefore may be 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 minimise 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.

8.2.3 Protection Works

The preferred approach to address the hazards is prevention by locating *development* and *site alterations* outside the *hazardous lands*. However, as previously identified in Section 8.1.1, *development* and *site alteration* is permitted within the least hazardous portions of the *hazardous lands* adjacent to the shoreline of *large inland lakes* provided <u>all</u> the conditions of Policies 3.1.3(a) to (e) inclusive, are fulfilled.

Protection approaches involve engineered methods for protecting development susceptible to *flooding*, *erosion* and/or *dynamic beach hazards*. Where protection works are installed, they are always to be combined with an appropriate allowance for stable slope and an appropriate hazard allowance. Protection approaches reduce hazard losses by modifying the flood and/or erosion hazard.

For the purpose of this Technical Guide, protection approaches or methods have been classified as non-structural or structural works. **Non-structural** protection works are activities that do not involve the construction or placement of significant additional structures or material. **Structural** protection works have been defined as engineered works that involve the construction and/or placement of significant additional structures and/or materials at the shoreline.

Bioengineering is the utilization of vegetation, either by itself (i.e., live construction) or in combination with structural elements (i.e., biotechnical methods). **Live** construction entails the use of conventional plantings alone (e.g., grasses and shrubs). **Biotechnical** is a term used to describe bioengineering methods which consist of both structural and vegetative elements working together in an integrated manner (e.g., brush layering, vegetated crib walls). With biotechnical methods, the vegetation has an important functional role that will vary depending on the structural elements involved. Therefore, depending on the construction details, a given bioengineering measure can be classified as either non-structural (e.g., vegetation on its own, contour-wattling, brush-layering) or structural (e.g., vegetated crib walls, vegetated rip rap). Where the role of vegetation is primarily decorative, the protection works can no longer be considered a bioengineering approach; they would be considered an inert, structural measure (e.g., conventional concrete seawall, steel sheetpile bulkhead).

a) Exposure and Other Site Conditions

Wave and ice action are the primary natural forces which govern the type of protection works suitable for a given site. Vegetation on its own can only be used in sheltered areas. Sites exposed to significant wave action will require structural works to address the high wave energy. In some high wave energy situations, structural measures could be introduced into the nearshore (e.g., detached breakwaters) to modify the backshore into a low wave energy environment suitable for vegetation. Other factors also play a role in determining the appropriate protection works, including: substrate, nearshore slope, water quality and available sunlight.

Table 8.1 provides some generalized criteria for using vegetation on its own or “light-duty” biotechnical protection works.

The use of vegetation and light-duty biotechnical measures involves considerable practical experience and judgement. There is little in the way or quantitative design guidance available.

Where the fetch length exceeds about 5 km, only biotechnical measures with a heavy structural component should be considered. For the larger *large inland lakes* (i.e., those with surface areas greater than 500 km^2 and/or with a maximum fetch length ranging from 20 to 60 km, typically 40 km), and/or for *large inland lakes* with recession rates much greater than 0.3 m/yr, the suggested requirements for addressing the hazards found in the Technical Guide for Great Lakes - St. Lawrence River Shorelines may be more applicable.

b) Non-Structural Protection Works

. Relocation

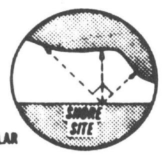
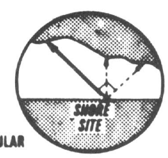
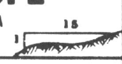
Relocation is an effective means of mitigating flood, erosion and dynamic beach hazards by moving the building or service (e.g., roadway, utility) to a different site further inland or to a more landward location within the existing site (see Figure 8.8). Relocation often proves to be less costly than protection, especially in areas of high to severe erosion. Virtually any structure can be relocated but whether or not the cost of relocating is justified depends on several factors. The major limitations are the size and construction style of the building (and therefore the actual feasibility of moving) and the availability of a site for relocation. The actual moving costs for a typical single family dwelling can be relatively small in comparison to providing effective protection works. Generally, the width and height of the house are the limiting factors. The width must be less than the clearance along the roadways (i.e., between trees, hydro poles) and the height lower than the overhead clearance (i.e., under overhead wires, bridges). Houses with slab foundations, concrete block walls, extensive brick or stone work, or large unusual shapes are often impracticable to move. The greatest costs associated with relocation may be in acquiring an additional parcel of land if setbacks requirements do not permit relocation on the same property. When a building or service is relocated it should be placed landward of the *hazardous lands*.

Table 8.1 Criteria for Vegetation and Biotechnical Protection Works

Shoreline Treatment	Generalized Criteria	Reference
Submerged vegetation	- substrate is sand or finer - depth less than twice the Secchi depth - nearshore slope <15% - effective fetch less than 2 km	Minns et al. 1995
Emergent vegetation	- see Table 8.2	USACE 1980
	- open water fetch <1.6 km (use of stone breakwaters or sills can expand site suitabilities to more exposed sites) - slope of existing shore no steeper than 10:1 - motor boating activities offshore of the site are negligible - site can receive at least 6 hours of direct sunlight daily during the growing season	Garbisch and Garbisch 1994
	- depth generally between 0.2 m and 1.5 m and are more rich and diverse between 0.6 and 0.9 m - wave heights less than 0.6 m	Silander and Hall 1997
Timber piles and brush ("light-duty" biotechnical)	- wave height <0.6 m	USACE 1981

Figure 8.8 Relocation of Residence from Hazardous Lands

Table 8.2 Site Evaluation Form for Marsh Plants

1. SHORE VARIABLES	2. DESCRIPTIVE CATEGORIES (SCORE AS INDICATED)						3. SCORE
a. FETCH - AVERAGE AVERAGE DISTANCE IN KILOMETERS (MILES) OF OPEN WATER MEASURED PERPENDICULAR TO THE SHORE AND 45° EITHER SIDE OF PERPENDICULAR 	Score : 0 LESS THAN 3.0 (1.8)	Score : 2 3.1 (1.9) to 6.0 (3.7)	Score : 4 6.1 (3.8) to 9.0 (5.6)	Score : 6 9.1 (5.7) to 12.0 (7.5)	Score : 8 12.1 (7.6) to 15.0 (9.4)	Score : 10 GREATER THAN 15.0 (9.4)	
b. FETCH - LONGEST LONGEST DISTANCE IN KILOMETERS (MILES) OF OPEN WATER MEASURED PERPENDICULAR TO THE SHORE OR 45° EITHER SIDE OF PERPENDICULAR 	Score : 0 LESS THAN 4.0 (2.5)	Score : 2 4.1 (2.6) to 8.0 (5.0)	Score : 4 8.1 (5.1) to 12.0 (7.5)	Score : 6 12.1 (7.6) to 16.0 (10.0)	Score : 8 16.1 (10.1) to 20.0 (12.6)	Score : 10 GREATER THAN 20.0 (12.6)	
c. SHORELINE GEOMETRY GENERAL SHAPE OF THE SHORELINE AT THE POINT OF INTEREST PLUS 200 METERS (660 FT) ON EITHER SIDE	Score : 0 COVE		Score : 2 IRREGULAR SHORELINE		Score : 4 HEADLAND OR STRAIGHT SHORELINE		
							
d. SHORE SLOPE SLOPE OF THE PLANTING AREA (VERTICAL TO HORIZONTAL) 	Score : 0 GRADUAL 1 to 15 OR LESS			Score : 4 STEEP MORE THAN 1 to 15			
e. SEDIMENT GRAIN SIZE OF SEDIMENTS	Score : 0 SILT & CLAY	Score : 2 FINE SAND	Score : 4 MEDIUM SAND	Score : 6 COARSE SAND	Score : 8 GRAVEL		
f. BOAT TRAFFIC PROXIMITY OF SITE TO NAVIGATION CHANNELS FOR LARGE VESSELS OR SMALL RECREATIONAL CRAFT	Score : 0 NO NAVIGATION CHANNEL WITHIN 1 KILOMETER (0.6 MILES)		Score : 8 NAVIGATION CHANNEL WITHIN 1 KILOMETER (0.6 MILES)		Score : 16 NAVIGATION CHANNEL WITHIN 100 METERS (330 FT)		
g. WIND THE ORIENTATION OF THE SITE IN RELATION TO LOCAL WINDS	Score : 0 SHELTERED FROM WIND		Score : 4 DOES NOT FACE IN THE DIRECTION OF PREVAILING WINDS OR FREQUENT STORM WINDS		Score : 8 FACES IN THE DIRECTION OF PREVAILING WINDS OR FREQUENT STORM WINDS		

4. CUMULATIVE WAVE CLIMATE SCORE ____

SCORE = 1 TO 10: USE SPRIGS AT 3-FOOT SPACINGS IN 10-FOOT (MINIMUM) ZONES.
= 11 TO 20: USE SPRIGS OR 15-WEEK SEEDLINGS AT 1½-FOOT SPACINGS IN 10-FOOT (MINIMUM) ZONES.
= 21 TO 30: USE 5-7 MONTH SEEDLINGS OR PLUGS AT 1½-FOOT SPACINGS IN 20-FOOT (MINIMUM) ZONES.
= ABOVE 30: DO NOT PLANT

.   Floodproofing

In the context of the *large inland lakes*, floodproofing is defined as the combination of measures incorporated into the basic design and/or construction of buildings, structures, or properties to reduce or eliminate *flooding, wave uprush* and *other water-related hazards*." Some examples of floodproofing include the elevation of buildings on posts, piers, wall or pilings (see Figures 8.9 and 8.10), watertight closures for doors and windows and location of electrical equipment and utilities above the expected flood levels (see Figure 8.11). Two structural types of floodproofing that are discussed later in this section are placement of dykes or floodwalls around individual buildings and the elevation of buildings on fill.

Floodproofing is somewhat of a misnomer in that floodproofing measures and flood protection works can only lessen flood damage to properties. No floodproofing measure will prevent all damages due to flooding. Measures undertaken to prevent the entry of flood waters into a structure are termed dry floodproofing. Dry floodproofing can be carried out by elevating the development above the level of the floodproofing standard. Wet floodproofing is considered to include measures that minimize damage to the structure if flood waters do enter. Wet floodproofing is generally limited to non-residential/non-habitable structures. All floodproofing measures can be further described as active or passive. Active floodproofing requires advance warning and some action to be taken (e.g., closing of water tight doors). Passive measures (e.g., continuous dykes or floodwalls) are those that are in place, do not require flood warning and do not require any action to be taken.

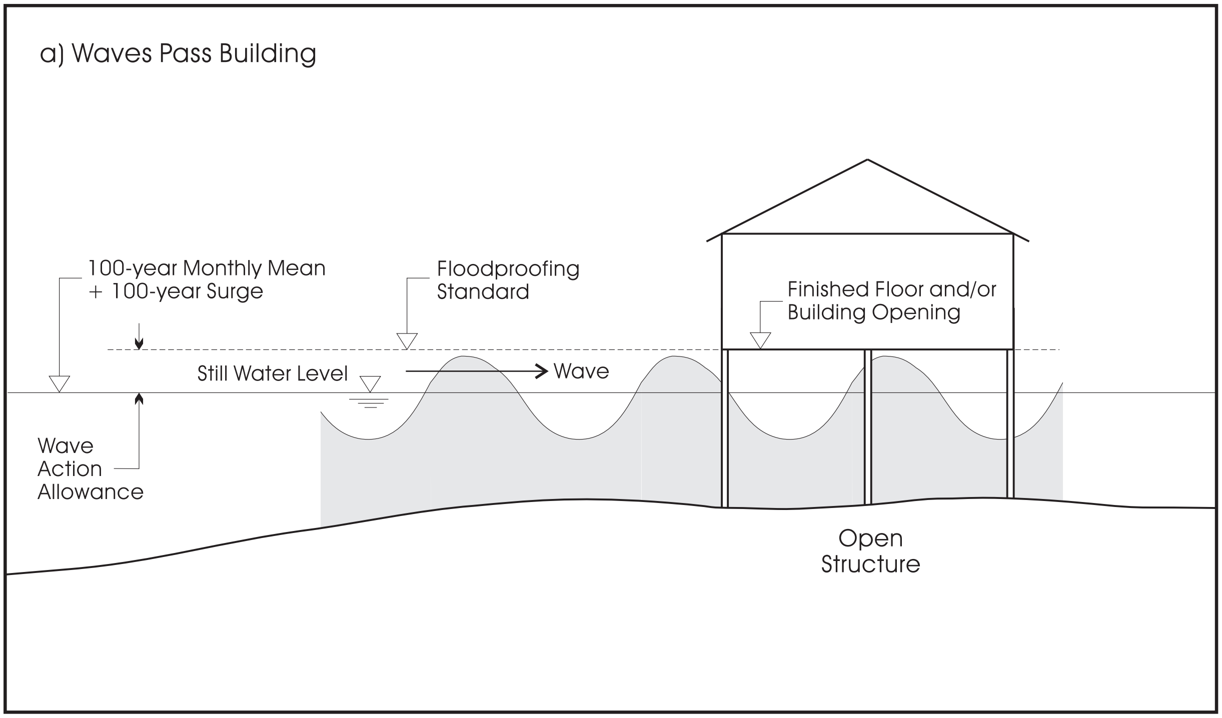
In general, dry, passive flood protection is the most desirable approach for all types of *development* adjacent to the shorelines of *large inland lakes*.

Although it may be technically possible to incorporate floodproofing measures into structures exposed to any depth of *flooding hazard*, there are practical limitations due to the rapid increase in floodproofing costs as the flood depth and wave attack exposure increases. This may in fact prove to be the limiting factor in the construction of buildings where the potential of flood damage cannot be economically reduced or eliminated. In addition, some floodproofing measures (e.g., pumps, floodgates) involve contingency items which must be kept in a perfect state of readiness and be easily accessible at all times. As such, these items should undergo periodic inspections, testing and continual maintenance. The roles, responsibilities and schedule of maintenance checks should be established in a formal agreement with the municipality. Regardless of the degree or magnitude of *flooding hazards* identified on-site, floodproofing measures should not be considered as a panacea for all flooding problems. Other approaches may be more appropriate under certain conditions.

Floodproofing measures are applicable with certain limitations and only after certain prerequisite information is given to verify its feasibility. Since there are various types of floodproofing measures, selection of the most appropriate approach depends on the following conditions:

- nature of the development and adjoining property under consideration (i.e., existing structure or proposed new structure, type of land use, impact on neighbouring properties);
- physical characteristics of the shoreline and the potential for updrift and/or downdrift impacts;
- local flood and other water related hazard(s) conditions and the level of the floodproofing standard, in order to evaluate the type or degree of floodproofing required and the requirements for access (i.e., ingress/egress); and
- cost-effectiveness of the floodproofing measure(s).

Figure 8.9: Elevation of Flood Prone Residence (Dry Passive Floodproofing)



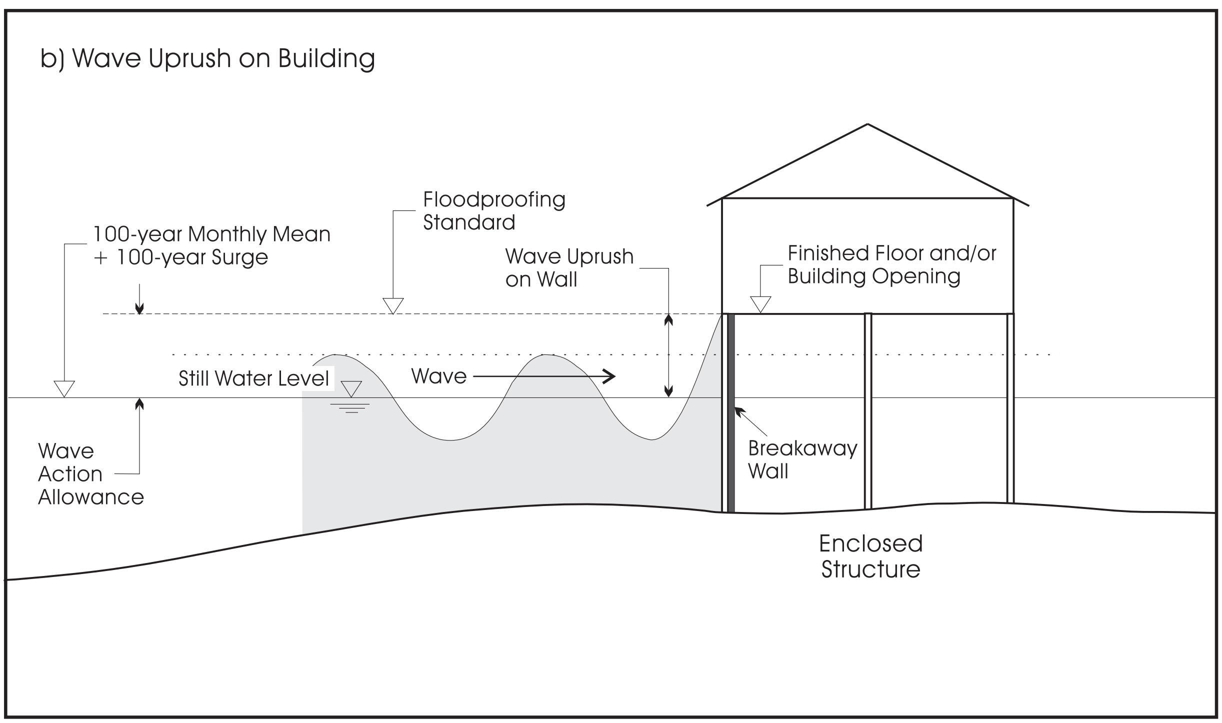
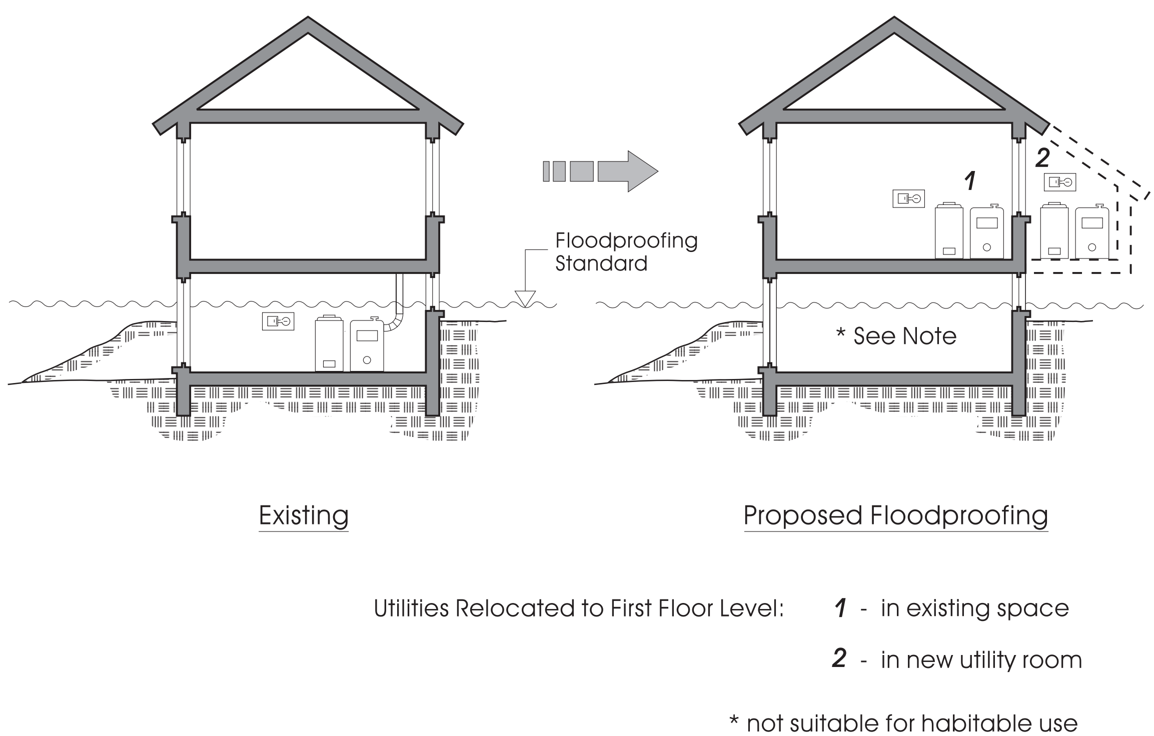


Figure 8.10: Structure Elevated as Floodproofing Measure

Figure 8.11: Utilities Relocated Above Floodproofing Standard (Wet Floodproofing Measure)



Within the Province of Ontario, there are two basic approaches to floodproofing which may be described as follows:

- **dry floodproofing**
  - . the use of fill, columns, or design modifications to elevate openings in buildings or structures above the floodproofing standard;

    or
  - . the use of water tight doors, seals, berms/floodwalls to prevent water from entering openings below the floodproofing standard.

- **wet floodproofing**
  - . the use of materials, methods and design measures to maintain structural integrity and minimize damage due to flood water and other water related hazards
  - . building or structures are designed to intentionally allow flood waters to enter.

In addition, there are two basic techniques to floodproofing which may be described as follows:

- **active floodproofing**
  - . floodproofing techniques which require some action prior to any impending flood in order to make the flood protection operational (e.g., closing of water tight doors, installation of waterproof protective coverings over windows, etc.);

- **passive floodproofing**
  - . floodproofing techniques which are permanently in place and do not require advance warning and action in order to make the floodproofing and/or flood protection measure effective.

Development activity, or land use considerations could also influence the type of floodproofing measures to be applied. For multi-lot or large lot development, infilling, redevelopment, replacement, major additions/alterations and minor additions/alterations, different land use factors will influence the range or type of floodproofing measures which may be deemed appropriate. For example, the height of surrounding buildings will be a primary consideration in examining possible floodproofing measures for infilling, replacement buildings, and major additions/alterations. As a result, floodproofing through the use of fill may be deemed undesirable in certain situations. However, for a large, multi-lot subdivision, conformity with surrounding areas may not necessarily be as critical.

In keeping with the goal of minimizing risks/threats to life, certain floodproofing approaches may be less desirable for some land uses than others. For example, special consideration should be given to land uses such as residential where overnight accommodation exists. Wherever possible, floodproofing measures should be to the floodproofing standard, however, lower levels of protection may be considered providing there is adequate rationale/justification (i.e., floodproofing requirements are lessened/altered with the installation of protection works).

Based on all of the foregoing, the following will serve to guide shoreline floodproofing measures in Ontario:

- in general, dry, passive flood protection is the most desirable approach for all types of development;

- new multi-lot or large lot residential development and the habitable portions of any other new buildings should incorporate dry passive floodproofing measures. Wet floodproofing measures should not be considered acceptable;

- it is recognized that the proximity to water is a key consideration in the use and enjoyment of recreational facilities such as marinas, campgrounds, boathouses, and park buildings. Dry passive floodproofing may not be achievable or practical in all instances but should, however, be implemented to the fullest extent possible;

- wet floodproofing could be considered for development earmarked for non-residential/non-habitable use and for buildings accessory to residential/habitable uses (e.g., garages). Dry active floodproofing could also be considered where a minimum of six (6) hours flood warning is available;

- minor additions/alterations to an existing building is the only development permitting floodproofing to less than the applicable floodproofing standard;

- minor additions/alterations should incorporate floodproofing measures to the extent and level possible, based on site-specific conditions. As a minimum, the addition/alteration should not be more flood vulnerable than the existing structure;

- infilling, replacement or major additions for residential/habitable use, should require dry passive floodproofing to the applicable floodproofing standard. However, where such a requirement impacts on or is significantly out of context with neighbouring properties, other flood reduction approaches, such as dry active or wet floodproofing measures may have to be considered. Any acceptable floodproofing approach could be considered for replacement or major additions/alterations for non-residential/non-habitable use;

- as a minimum, access (ingress/egress) should be considered "safe" for all buildings, such that flood depths and associated wave action do not hinder safe pedestrian and vehicular movement during times of flooding. Access (ingress and egress) should remain "dry" at all times for institutional buildings servicing the sick, the elderly, the physically challenged or the young. It is however recognized that in some situations this may be difficult if not impossible to achieve. Therefore, some exceptions may be permitted in special situations following careful and detailed evaluation of the alternatives. As well, ingress and egress should remain "dry" at all times for buildings housing essential services such as police, fire and ambulance.

With increases in flood levels and the impacts associated with other water related hazards (e.g., wave action, wave spray, ice, etc.), design considerations for floodproofing buildings and structures generally become more complex and costly. In addition, increasing flood levels and associated *hazards* pose greater risks of loss of life and property damage. As different buildings and structures can withstand flooding, associated other water related hazards and related loadings better than others, it is recommended that a professional engineer or architect skilled in floodproofing measures carry out the required evaluation and design stages, to ensure that these factors have been critically assessed and duly recognized in the selection of the floodproofing measure(s) deemed appropriate for the given shoreline location.

It is suggested that designs for the following be carried out by a professional engineer or architect skilled in floodproofing measures;

- Where the product of flood depth and velocity of flood water is equal to or greater than 0.4 m^2/s (4 ft^2/s) or where depth exceeds 0.8 m (2.6 ft) or where velocity exceeds 1.7 m/s (5.5 ft/s);
- Where wave impact loads may occur;
- Where wet floodproofing is proposed;
- Where flood depth is in excess of 0.8 m (2.6 ft) and floodproofing involves the use of closures and seals;
- Where floodproofing through the use of fill exceeds depth of 1.8 m (6 ft) or velocities between 0.8 - 1.5 m/s (2.6 - 5 ft/s), depending on soil type, vegetation cover and slope;
- here dykes and floodwalls in excess of 1 m (3.3 ft) in height are proposed; and
- Where piles, columns and posts are proposed.

A summary of floodproofing and access design criteria is provided in Appendix A7.1 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines.

. Bioengineering Measures and Onshore Improvements

Bioengineering measures consist of maintaining and/or enhancing terrestrial and aquatic vegetation at the shoreline, either on its own or in combination with structural elements. Other onshore improvements include: controlling drainage of the surface runoff and/or the groundwater flow; and/or the regrading of the slope. When applying onshore improvements, other sources of water that need to be controlled (e.g., not freely discharged down the slope face) include lawn sprinkling, downspouts, swimming pool drainage and leaks and septic systems.

On their own, bioengineering measures are insufficient to address an erosion hazard on a shoreline that is eroding due to heavy wave action. Structural protection measures may be required to address the hazards. In situations of bluff instability a professional engineer qualified in geotechnical engineering should be consulted. Section 5: Erosion Hazards, of this Technical Guide, provides guidance for reviewing slope stability concerns.

A brief outline of some of the various bioengineering measures and other onshore improvements include:

<u>Vegetation and Biotechnical Methods</u>

Aquatic plants are a natural part of healthy aquatic ecosystems. Plants provide habitat in which fish can spawn, hatch their eggs, feed and hide from predators. Aquatic plants also help to maintain water quality for both fish and humans by stabilizing sediments.

Trees, shrubs, grasses and emergents help control erosion of the shoreline through the combined effects of the roots, stems and foilage. Roots and rhizomes reinforce the soil. Immersed foliage absorbs and dissipates wave energy and may cause sufficient interference with the flow to prevent scour. In sediment -laden water, the foliage may also promote deposition. Vegetation can be used to help stabilize soil on the face of a slope by anchoring the soil with the root mass and by reducing the velocity of the surface runoff flow (see Figure 8.12). The vegetation acts as a buffer strip to control sediment runoff. It can improve the visual quality of a shoreline area and provide wildlife habitat. Specific functions which they can perform include (Hall and Silander 1995):

- absorbing and dissipating wave-wash energy;
- interference and protection of the shoreline bank from the flow;
- reinforcement of the surface soil through the root mat and prevention of scour of the bank material; and
- sediment accumulation brought about by the dense plant stems.

In certain low wave energy environments (refer to Table 8.1), vegetation may be used by itself to provide suitable protection to an eroding shoreline. Reeds and other marginal plants can form an effective buffer zone by absorbing wave energy and restricting the alongshore flow velocity adjacent to the shoreline (see Figure 8.13).

Marginal plants require very wet ground and generally will not survive in water which is more than 0.5 m deep for long periods of time. They flourish in conditions of low flow velocity and their integrity is weakened by wave action in excess of 0.5 to 0.75 m. Different species offer different levels of protection with regard to wave energy dissipation. For wave conditions under 0.5 m, reed beds having a width of 2 to 2.5 m may dissipate 60 to 80% of the incoming wave energy (Hall and Silander 1995). In areas with higher levels of wave energy, natural boulders or rip-rap and geotextiles may be used in conjunction with vegetation to provide effective biotechnical protection (Figure 8.14). In areas of high incident wave energy, an area of low wave energy can be created behind a primary defense such as an offshore rock structure or wave screen, or through the creation of lagoons behind stable control structures.

Natural methods of protection, used by themselves, generally have low capital cost in comparison with conventional engineering methods. However, they may well have higher recurrent cost due to regular inspection, trimming and cutting and repair. Other possible disadvantages are that natural protection schemes take time to mature and to become fully effective. Depending on the type, natural protection may take several growing seasons to reach the desired standard of protection.

Bio-engineering differs from other conventional forms of engineering in two key respects which strongly influence the design approach:

- bioengineering involves considerable practical experience and judgment, as opposed to the application of quantitative theory or rules; and
- careful management is required not only in the establishment of vegetation, but also in its aftercare over the initial growing seasons.

Table 8.3 provides some guidance for using vegetation.

Figure 8.12: Effects of Vegetation

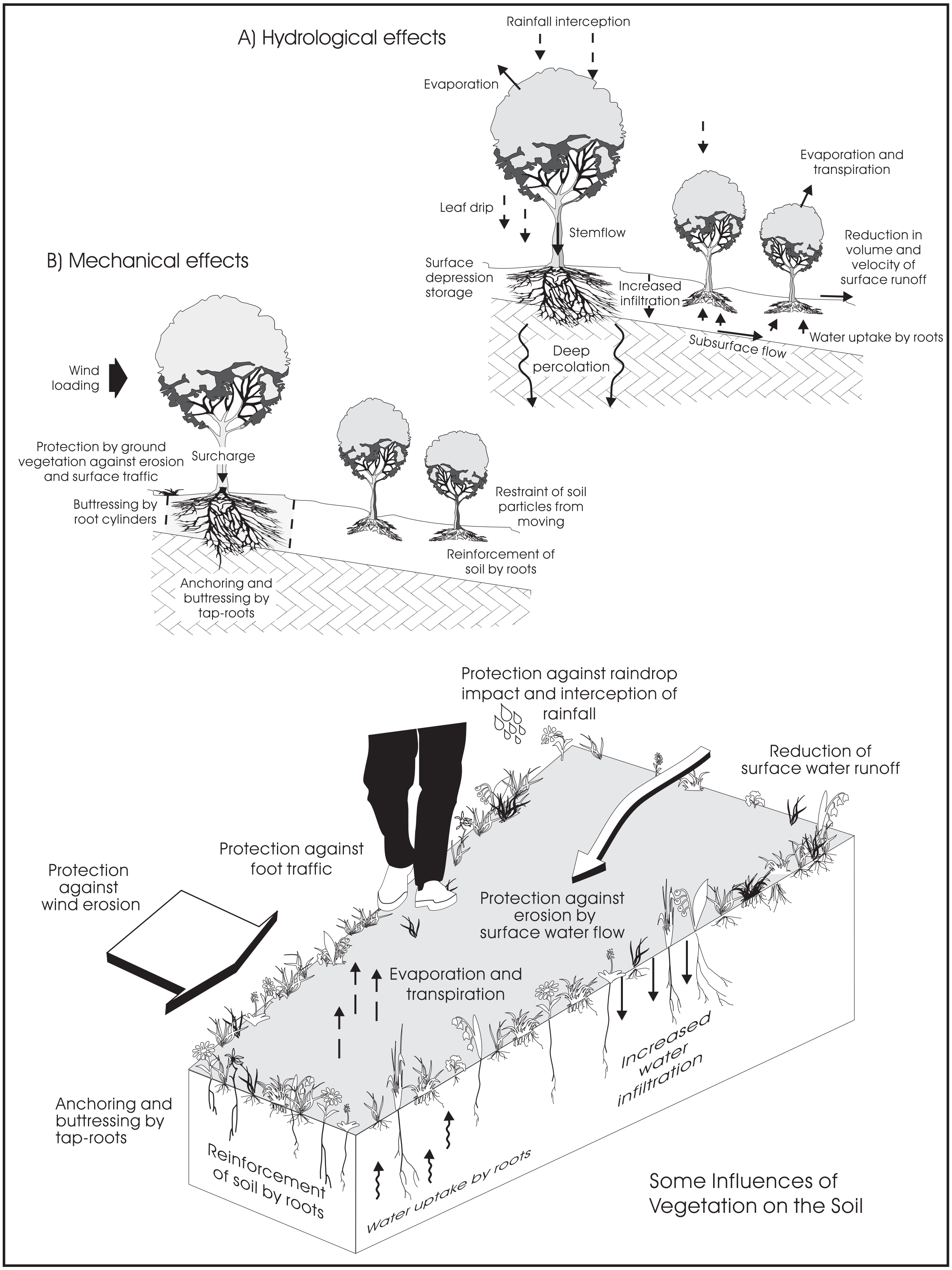


Figure 8.13: Emergent Vegetation

Figure 8.14: Vegetation and Boulders (Biotechnical Approach)

Table 8.3 Use of Vegetation (after Hall and Silander 1995)

Use of vegetation requires the following points to be considered.

Plant Selection: The principal plant groups that can be used are aquatic plants, grasses, shrubs and trees. Selection is based on consideration of the different roles to be performed by the vegetation, taking into account the physical and chemical properties of the soil, the climatic conditions and the soil/water regime under which the plant must survive.

Soil Requirements: Plants must be provided with the correct soil conditions to enable them to achieve their intended growth. The soil profile for the plant generally needs to be designed to at least 0.5 m depth, and sometimes considerably more, in order to optimize the root growth. Requirements for plant growth, such as low soil compaction, may apparently conflict with normal geotechnical requirements for stability and strength of the subsoil.

Surface Preparation: Proper ground preparation can enhance the establishment of vegetation. This may entail:
1. cultivation to produce an acceptable seedbed, or suitable trimming on steep slopes.
2. contouring to provide appropriate surface topography for drainage and future management.
3. scarification or ripping to relieve excessive subsoil compaction.
4. soil amelioration to improve soil structure, water holding capacity and/or fertility.
5. provision for short-term erosion control pending establishment of vegetation.

Vegetation Establishment: Five principal methods of seeding may be considered:
1. drilling, direct placement of seeds in the soil.
2. broadcasting, dry spreading seeds over the soil surface.
3. hydroseeding, spreading the seeds in a water slurry.
4. mulchseeding, wet or dry constituents with a heavy mulch applied dry, including pre-prepared seed mats).
5. hand seeding, including hand broadcasting and localized spot seeding of patches of seeds.

Pre-grown plants may be transplanted as turfs or planted individually as clumps. Vegetation establishment may take several growing seasons and is a seasonal activity that must be managed and maintained. There must be specific management objectives and a management program. This is in order to ensure that the vegetation is maintained in a fit condition to perform its intended roles.

Zones and Horizons of Natural Protection: With natural methods of protection, and particularly methods involving the use of live material, the effectiveness of different materials is strongly dependent on their location in relation both to the dominant external water level and to the subsoil soil/water regime. To achieve effective protection using natural materials, the designer will almost inevitably need to use different methods of protection in different zones and horizons of the shoreline.

Use of Reeds: The emergent and marginal types of aquatic plants, such as the common reed, bulrush and great pond sedge, are frequently used for interference and protection purposes to form a protective margin along the shoreline at the waterline. They also encourage siltation by absorbing current flow energy, and thus reducing the sediment-carrying capacity of the flow. Reeds can be easily weakened by erosion and loosening of the soil around the rhizomes due to wave energy. It is therefore necessary to protect the zone containing roots from high-velocity flow or significant wave attack. Provided this is done, the stems and leaves will protect the shoreline bank above.

Uses of Shrubs and Trees: A limited range or trees are water-tolerant and can be used in bioengineering structures for bank protection in both the aquatic and damp zones. The willow, alder and black poplar are the principal water-tolerant species. In particular, a dense root structure is able to provide some protection as well as substantial reinforcement effect to enhance the stability of the shoreline bank both above and below the mean water level. The willow and poplar are particularly useful for bioengineering because they can be propagated from cut limbs. The cut limbs can be placed such that secondary root growth develops and shoots sprout from dormant buds. Trees which are not water-tolerant do not have any major direct function in shoreline stabilization, although they may provide shade to control the growth of aquatic life as discussed earlier.

Use of Grasses: Grass is used very extensively in bank protection in the zones above the high water level. Grass roots cannot tolerate prolonged submergence periods. A wide variety of grass species and mixtures therefore are appropriate to satisfy the functional, environmental and management requirements for a protection scheme. The principal functions which grass fulfils are those of interference, protection, root reinforcement and soil restraint. The surface root structure forms a composite soil/root mat which enhances the erosion resistance of the bare subsoil, and which is anchored into the subsoil by deeper roots.

The physical attributes of the grass plant which determine the effectiveness of grass for protection are: 1) length and stiffness of the sward; 2) surface area of grass blades; 3) strength and depth of root structure; and 4) density of rhizomes, stolons and surface root structure.

The engineering function of grass may be augmented by the use of geotextile or cellular concrete reinforcement to form composite protection. With both types of reinforcement, the visual effect of grass is retained. Erosion of grass cover by wave runup generally occurs by the scouring of soil from around the roots of a plant, thereby weakening its anchorage until the plant itself is removed by the drag of the flowing water. The effectiveness of grass protection can also be seriously reduced by any localized patches of bare soil or poor grass cover.

The rate of growth of different grasses varies considerably. Complete grass cover should nominally be achieved by the middle of the first growing season while full protective strength of the sward is reached during the second season. Provision should be made for aftercare including mowing, fertilizing and weed control. Grassland will slowly revert to scrub unless woody plants are removed, thus grass swards require continuous maintenance.

Use of Timber and Woody Material: A variety of timber and other dead woody materials can be used in the shore protection scheme usually fulfilling a reinforcement, protection and sometimes drainage functions. Natural hardwoods will retain their integrity for 5 to 10 years if built into the bottom of a bank below the water level. Out of the water they can last longer but the worst environment for timber is the alternately wet and dry zone around mean water level.

Biotechnical methods combine structural measures (e.g., timber cribbing) with live plant materials. Figure 8.15 summarizes some biotechnical measures. Section 10.5 of Geotechnical Principles for Stable Slopes (Terraprobe 1997) provides further description of biotechnical methods. Native plant species which are compatible with the local flora should be used.

The long-term performance of biotechnical shore protection methods is not well established. Practical experience is important in the design process.

Drainage Improvements

The erosive effects of surface drainage on a slope can be reduced by directing water away from the slope (see Figure 8.16a) or by providing an erosion resistant swale or channel which conveys the water down the slope face in a controlled manner (see Figure 8.16b).

Where internal drainage (groundwater) is causing bluff erosion and instability, the drainage can be improved by interceptor drains, french drains or tile drains (see Figure 8.16c).

Where the existing bluff is oversteep and unstable, the bluff can be regraded to a flatter slope (see Figure 8.17). Regrading is often accompanied by drainage improvements and revegetation.

. Dune Enhancement

Sand dunes are fragile features of the shore and as such are easily altered by the actions of people (i.e., pedestrian and vehicular traffic). If the natural vegetation, which stabilizes the dunes, is lost, the sand can more easily be blown away. Dune enhancement involves measures to protect and enhance vegetation and dune growth. These measures include restricted or controlled access points and the re-establishment of dune vegetation (see Figure 8.18). Driftwood and fallen trees help protect dunes and should not be removed. The Beach and Dune Management Manual (OMNR and Geomatics 1995) provides additional information on the importance of dunes and measures for dune enhancement.

c) Structural Protection Works

. Filling and Dyking

Filling and dyking are two forms of structural floodproofing. They are considered to be structural measures, as opposed to non-structural, because they involve the placement of significant additional materials at the shoreline.

Filling is the placement of additional soil material at the site to raise the elevation of the land (see Figure 8.19). Dykes are artificial banks or mounds built around the perimeter of subject area to prevent the entry of flood waters (see Figure 8.20). As with dykes, floodwalls are designed to keep the water away from the house (see Figure 8.21), but are constructed of materials such as concrete or masonry block. Floodwalls are often dependent on the installation of one or more gates to seal openings. Filling and dykes are subject to only occasional inundation and beyond the limit of normal storm wave action. Fill exposed to wave action must be accompanied by suitable erosion protection structures.

Figure 8.15 Summary of Biotechnical Measures

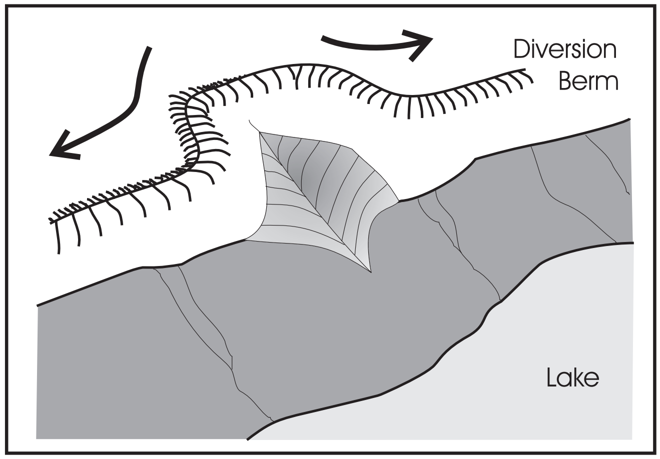
	STABILIZATION MEASURE	DESCRIPTION	Toe Erosion	SLOPE INSTABILITY		Surface Runoff	NOTES
				Shallow Slides	Deep Slides		
Biotechnical, Non-Structural	1. Live Staking	insertion of live plant cuttings in rows or clusters (willow stakes, ½ to 1 m long)		✔		✔✔	suitable for repair of small shallow earth slumps, gullies
	2. Live Fascines, Contour Wattling	bundles of rootable plant stems and branches (willow, dogwood, alder) buried in shallow trenches across slopes and anchored with wood stakes, 1 to 2 m spacing		✔✔		✔✔✔	suitable for control of surface runoff erosion and shallow slides, cut slopes, embankments, max. Steepness 1½ to 1, improves drainage
	3. Brush Layering, Branch Packing	layers of live cut branches (up to 3½ m long, sticking out and criss-crossed) buried across a slope, rows every 1 to 2 m (willow, dogwood, alder)		✔✔✔		✔✔✔	best suited where slope fill is added; protects against surface erosion and shallow slides, improves drainage, max. Steepness 1½ to 1
	4. Vegetated Mesh and Grids	plant brush layers and plastic mesh/grid layers back into slope; provide reinforcing	✔✔	✔✔✔			suitable for very steep slopes; effective against periodic scour, improves drainage, max. Steepness 1 to 1
Biotechnical, Structural	5. Vegetated Crib Walls	near-vertical retaining wall formed by box of stacked timbers filled with earth and layers of live branch cuttings	✔✔✔	✔✔✔			effective as a toe wall on slopes, and against scour, near-vertical wall, max. Height 2 m
	6. Vegetated Rip Rap	(joint planting) live willow cuttings inserted through rip rap	✔✔✔	✔		✔✔✔	flexible, suitable for repair of localized slump areas, along stream banks, max. Steepness 1½ to 1
	7. Vegetated Cellular Grids	lattice-like array anchored to slope and planted in openings	✔✔✔	✔		✔✔✔	flexible, permits vegetation on steep slopes up to 1 to 1, requires little fill
	8. Vegetated Rock Walls, Crib Walls	live branch cuttings inserted into openings of rock breast wall and crib wall	✔✔✔	✔✔✔			effective as low toe walls, protects against scour, max. Height 2 to 3 m

LEGEND

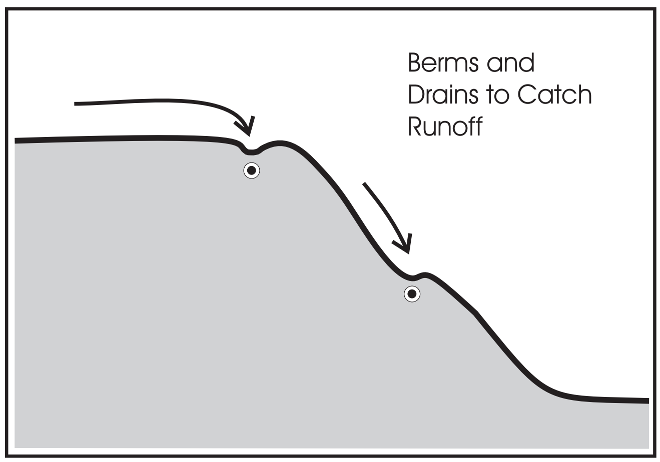
✔✔✔ Recommended to addresshazards.
✔✔ Generally will address hazards.
✔ May be considered but may not provide proper level of protection to address hazards.

Figure 8.16: Drainage Improvements

a) Diverting Surface Runoff



b) Controlling Surface Runoff



c) Internal Drainage Measures

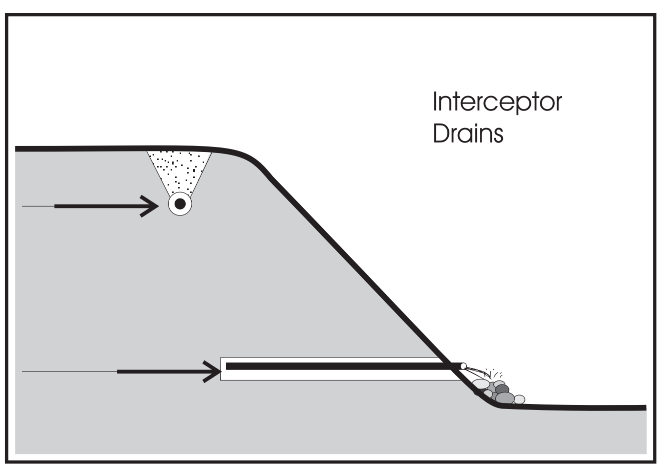


Figure 8.17: Regrading Slope

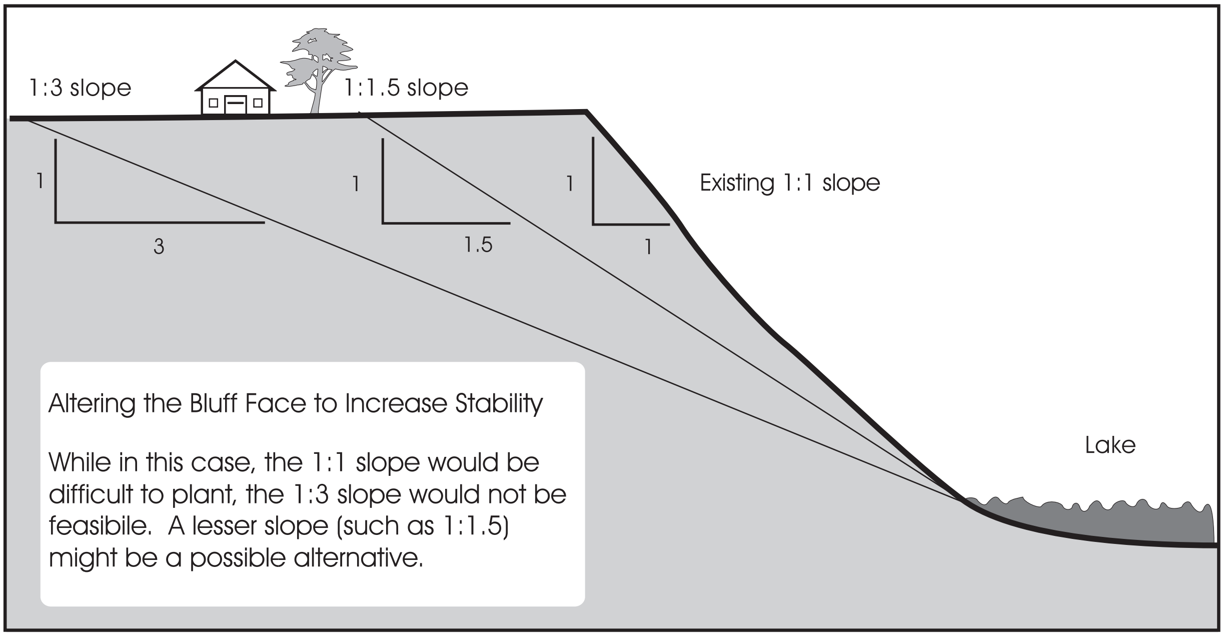
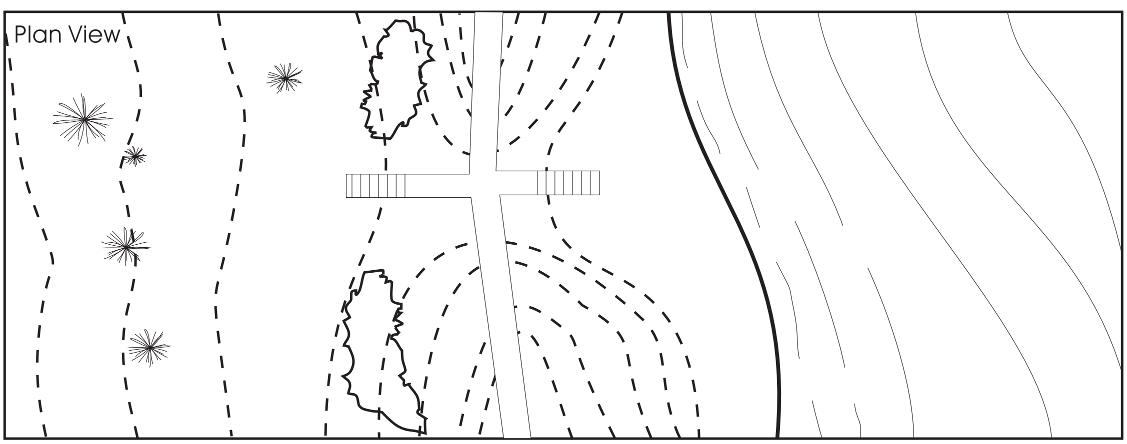


Figure 8.18: Controlled Dune Access



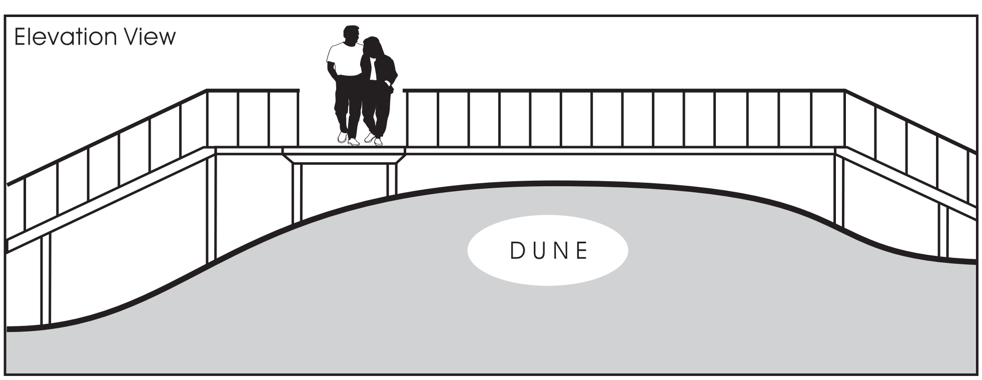


Figure 8.19: Filling (Above 100 Year Flood Level)

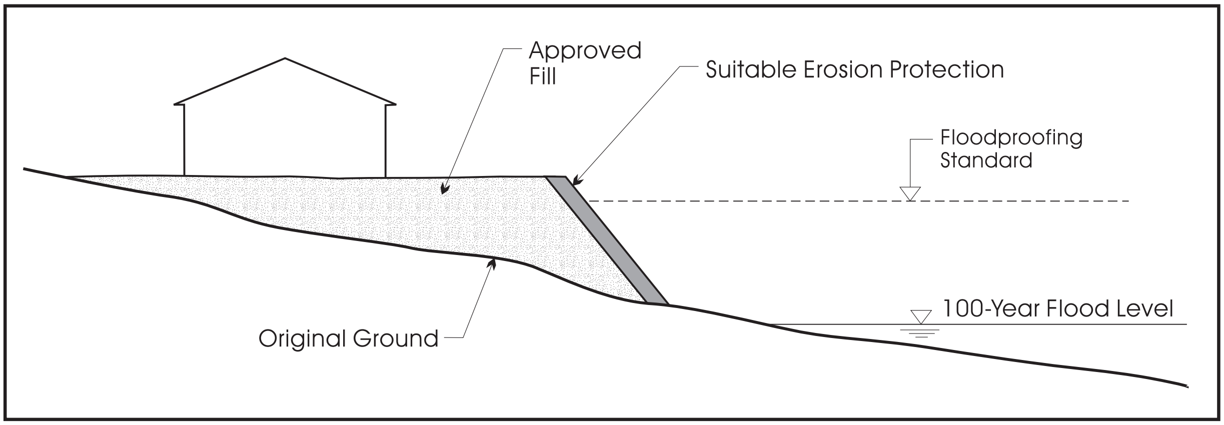


Figure 8.20: Dyke

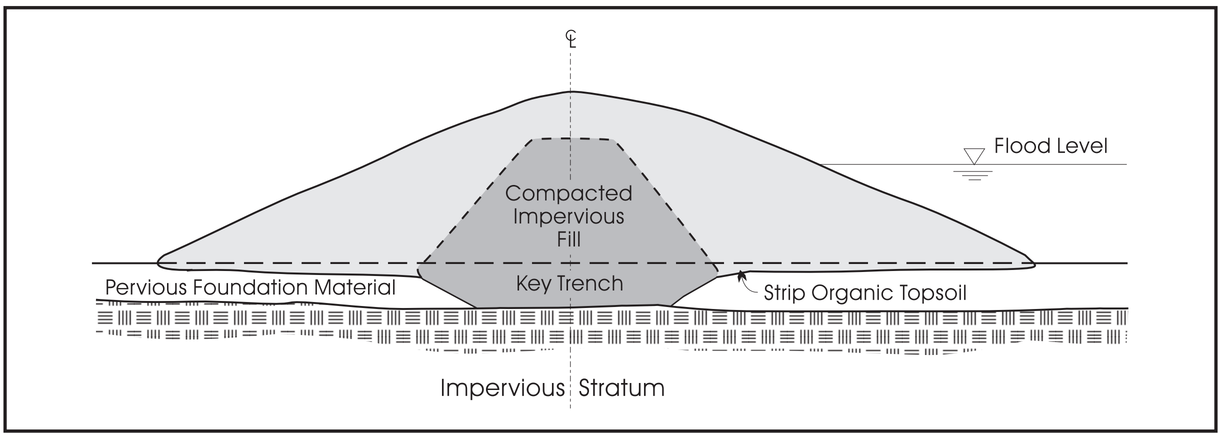
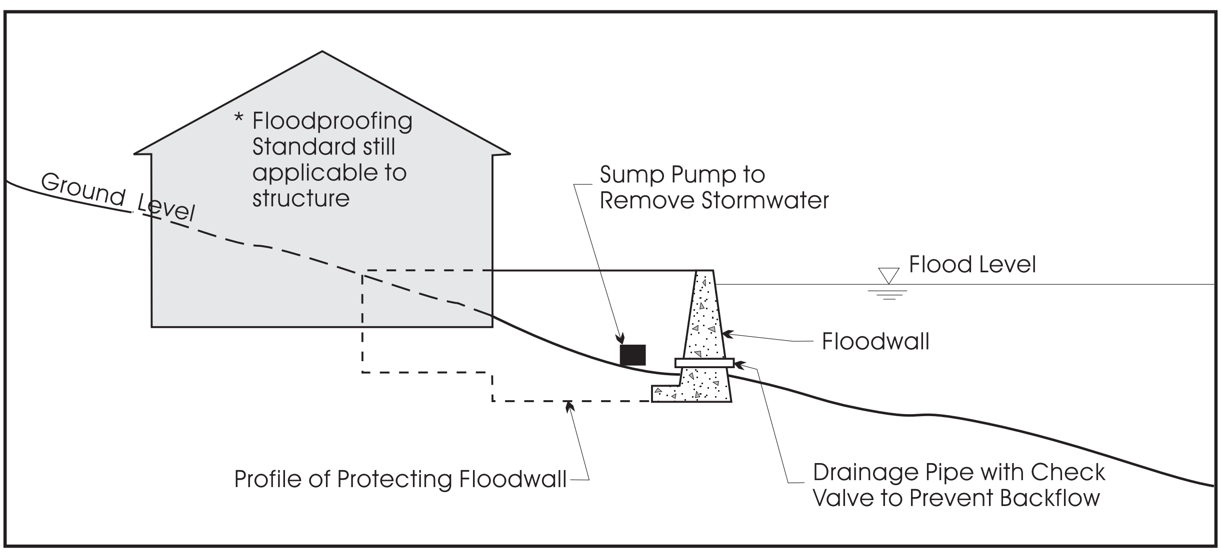


Figure 8.21: Floodwall



Where a dyke or floodwall has been properly designed and constructed and a suitable maintenance program is in place, the area behind the dyke or floodwall may be developed provided the development meets the requirements of the floodproofing standard. Development behind a dyke or floodwall should only be considered under extraordinary circumstances and generally would involve areas of existing development (e.g., usually involving infilling development). Where permitted, the development should be directed to the least hazardous portion of the area and away from those potential high velocity areas immediately adjacent to the dikes. Auxiliary measures that may be needed (e.g., pumps, backflow gates and valves) must be subject to periodic inspections and regular maintenance.

.   Flexible and Rigid Revetments and Seawalls

A revetment is a sloping facing of stone, concrete or other durable materials built to protect a scarp or embankment against erosion by wave action. Revetments can be considered as flexible or rigid. Flexible structures include those constructed of armour stone (i.e., individual quarried stone blocks; see Figure 8.22a), rip-rap, or interlocking concrete block mats. A poured-in-place concrete slab revetment is an example of a rigid structure (see Figure 8.22b). A rigid concrete revetment requires a sound foundation which will not settle over time. Flexible structures can tolerate some settlement without structural failure. An armour stone or rip-rap revetment can tolerate more settlement than an interlocking concrete block revetment. Flexible armour stone or rip-rap revetments can be further classified as static or dynamic.   Static revetments use individual armour units, such as armour stone or mass concrete blocks, which are heavy enough to resist movement by waves during a storm (see Figure 8.23a). Dynamic revetments have smaller armouring material which is designed to shift and reshape in response to the wave action (see Figure 8.23b). Figure 8.24 shows a photograph of a typical static riprap stone revetment.

A seawall is a vertical or near vertical shoreline protection work separating the land and water areas and has the primary purpose of blocking the wave action (see Figure 8.25). Wave action is recognized in the design process to be severe and the resulting hydrodynamic forces are meant to be resisted primarily by the seawall structure itself. To resist the full force of the waves, seawalls tend to be rather massive structures such as rigid concrete gravity walls (see Figure 8.22d) or flexible rubble-mound seawalls (see Figure 8.22(c)). As noted, seawalls can also be classified as rigid (e.g., poured concrete), semi-rigid (e.g., stacked concrete blocks, stacked armour stone), or flexible (e.g., rubble-mound). Semi-rigid seawalls can tolerate somewhat more settlement than rigid walls which require a sound foundation. Damage to flexible rubble-mound structures is usually progressive. An extended period of damaging waves is usually required before the structure ceases to be effective.

A bulkhead differs from a seawall in that, while it also separates the land and water, intercepting wave action is a secondary objective. The primary function of a bulkhead is to retain fill. As such, bulkheads tend to be of lighter construction than seawalls. Bulkheads typically are constructed from light steel sheet piles (see Figure 8.26) or timber. Bulkhead structures, such as anchored steel sheet piles, can be designed to resist wave action, effectively acting as seawalls.

Smooth, vertical, impermeable seawalls (such as concrete, Figure 8.27, and steel sheet pile) reflect more incoming waves than sloping, rough, permeable rubble mound revetments. Wave reflection from structures decreases as the slope of the structure gets flatter and as the structure permeability and surface roughness increase. Waves reflected back outward, as well as downward, can result in scouring of the lakebed.

Revetments and seawalls are typically located in the backshore, along the water's edge and parallel to the shore. The toe, or base, of these structures may extend into the shallow nearshore. They are primarily intended to control the erosion of the backshore (i.e., the land behind the structure) due to direct wave attack. Revetments and seawalls do not protect the nearshore zone where natural downward erosion of the lakebed will continue unabated. Along eroding shorelines, any narrow beaches initially present in front of the backshore works will erode away over time as the downward erosion, lakeward of the revetment/seawall, continues. Along the toe of the revetment or seawall, the natural erosion may be increased by scouring which results from wave reflection. If downward erosion of the nearshore is significant, the onshore structure will eventually be undermined. This is of particular concern along cohesive shorelines with moderate to severe recession rates. Hence, rigid seawall structures which require stable foundations, such as bedrock, for support are not recommended for fine-grained cohesive shorelines (i.e., shorelines with high to severe recession rates). Rigid seawalls will only have limited lifespans along cohesive cobble/boulder till shorelines (i.e., shorelines with moderate to high recession rates). Flexible revetments, or rubble-mound seawalls, can tolerate some settlement and are usually suitable for bedrock and cohesive cobble/boulder till shorelines. As well, flexible revetments may be considered for fine-grained cohesive shorelines but it should be recognized that they will likely have a reduced lifespan.

Figure 8.22: Flexible and Rigid Revetments and Seawalls

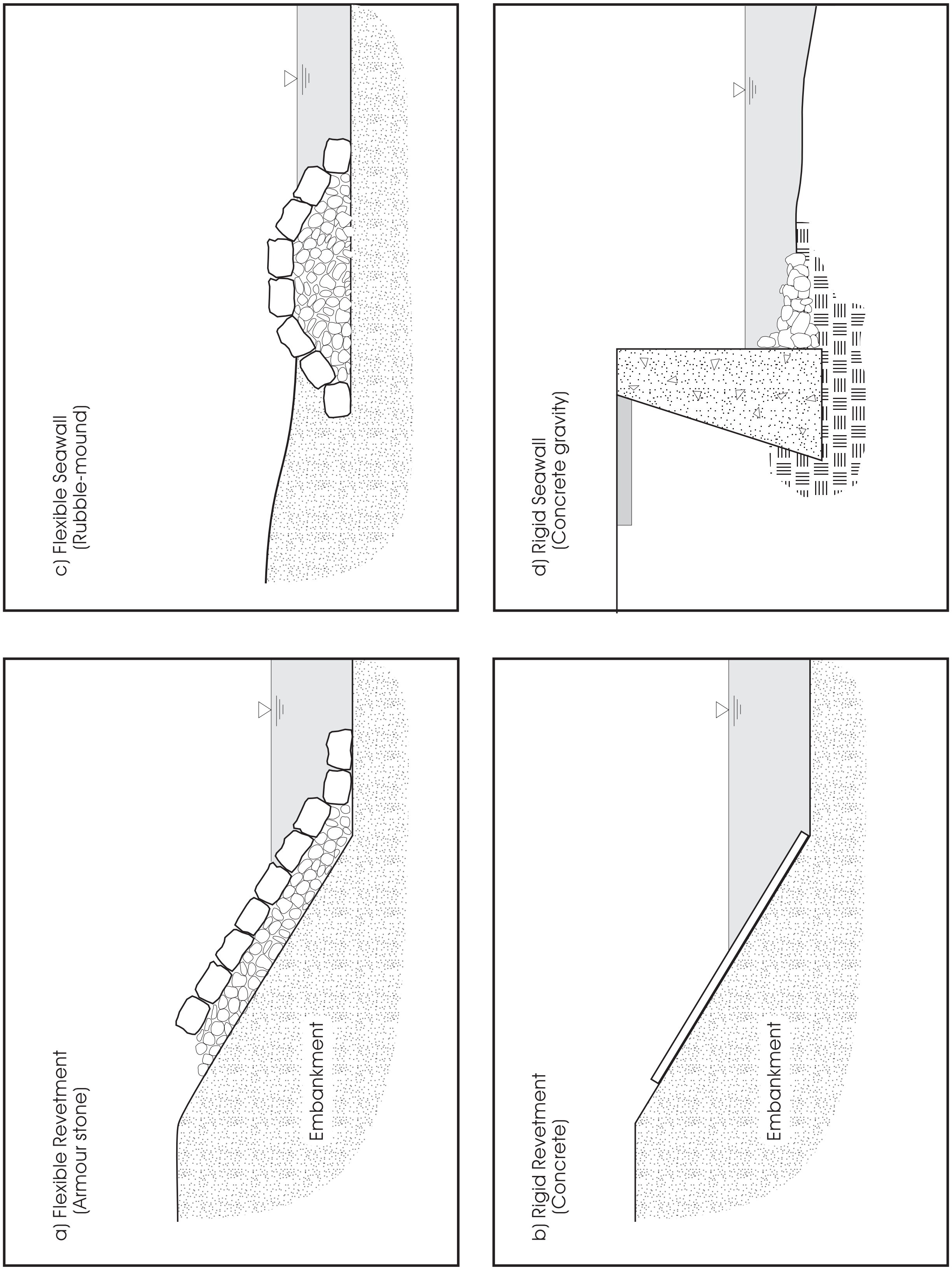
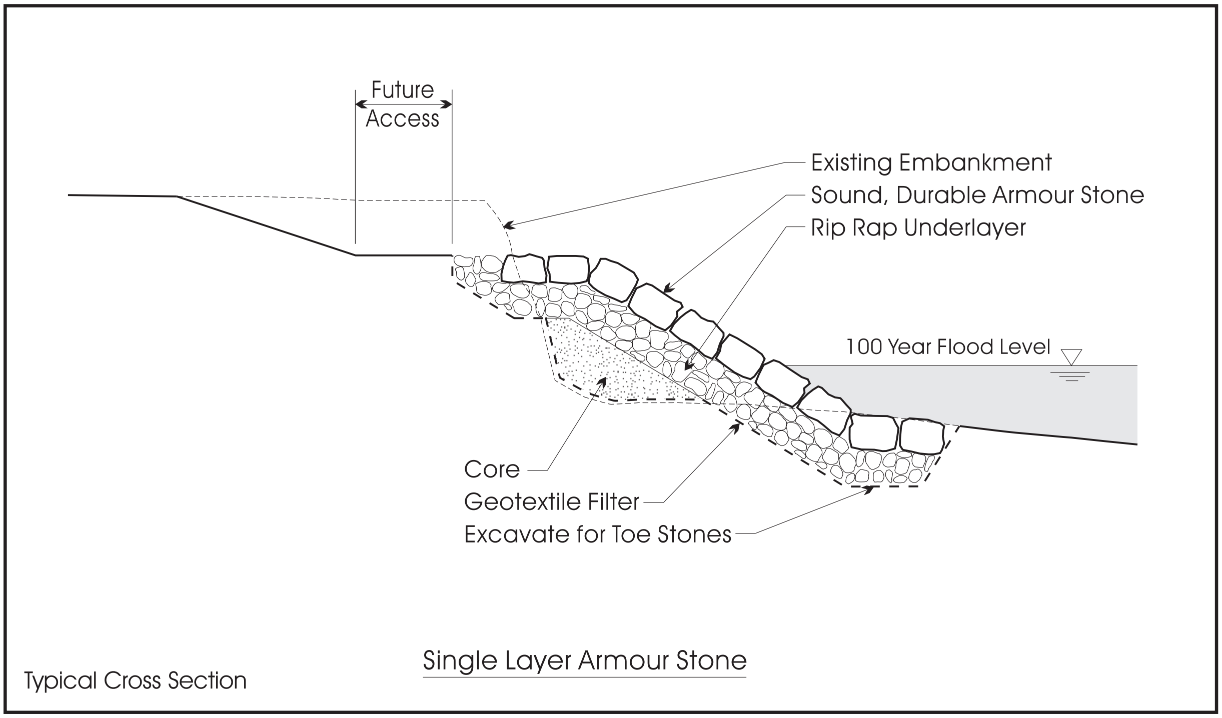


Figure 8.23: Revetment Armouring

a) Static Armouring



b) Dynamic Armouring

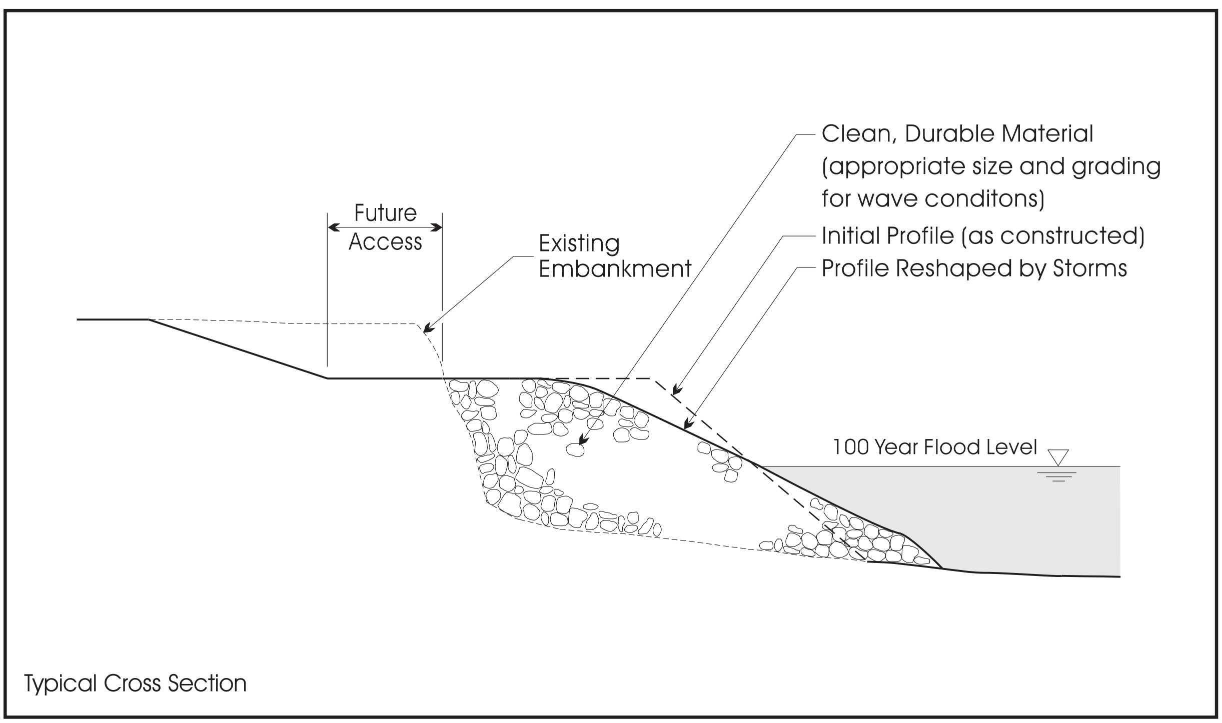


Figure 8.24: Photograph of Riprap Revetment

Figure 8.25: Rigid Concrete Gravity Seawall

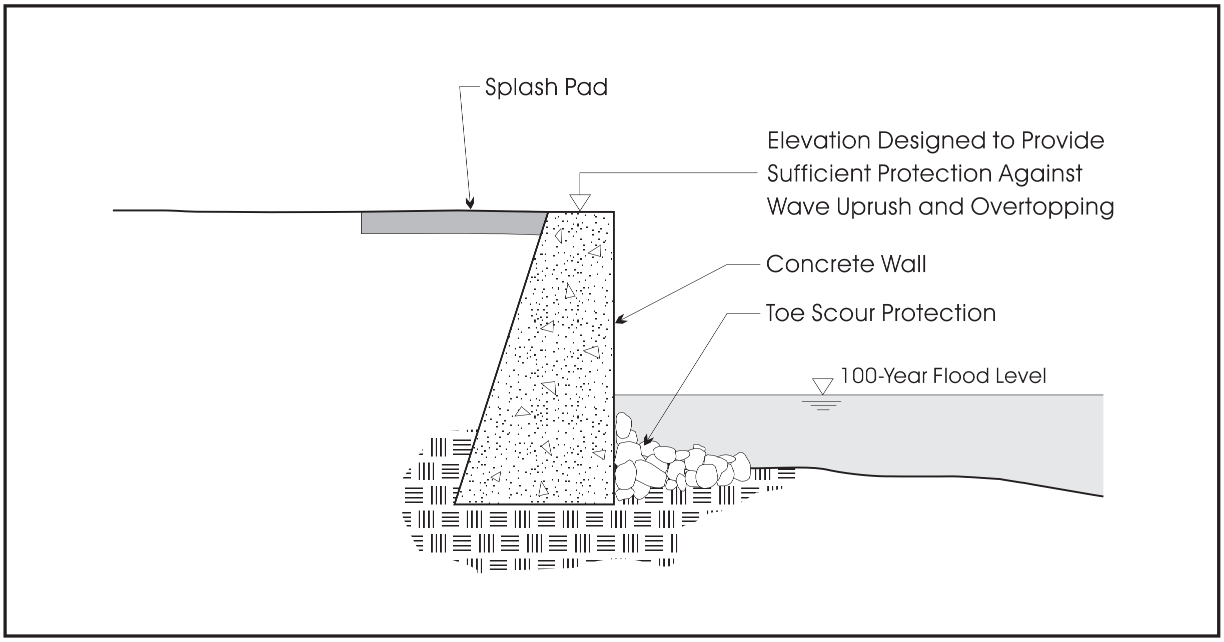


Figure 8.26: Steel Sheet Pile Bulkhead

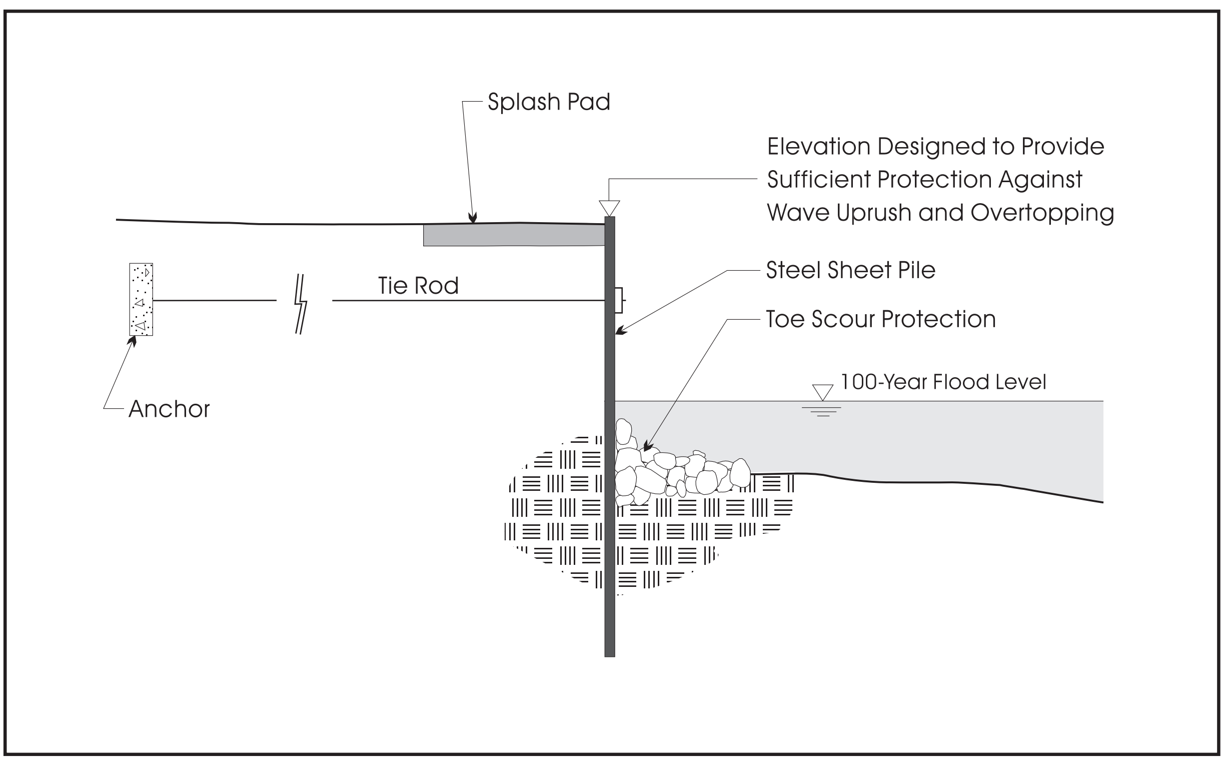


Figure 8.27 Concrete Seawall

. Beach Nourishment

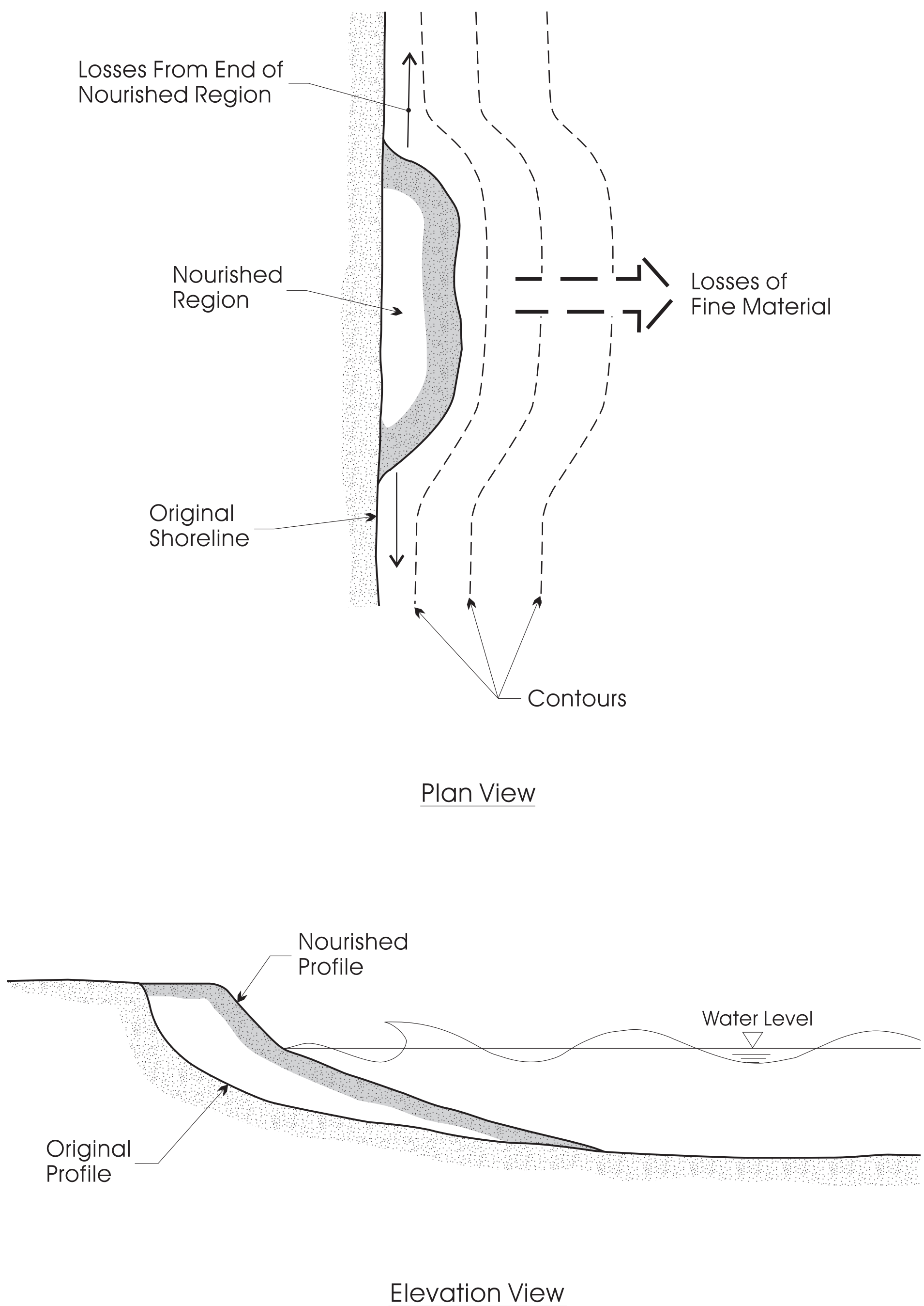
Beach nourishment is the artificial placement of suitable imported beach material on an eroding or sediment deficient beach area in order to replenish, maintain and/or enhance the beach width (see Figure 8.28). Depending on the beach width and slope, the added beach material protects the shoreline from erosion and storm wave damage. The increased beach width can also provide recreational benefits. Nourishment is defined as a structural approach because it is an engineered method that involves the placement of significant quantities of additional material at the shoreline. However, it is considered as "soft" structural protection because it attempts to replicate the natural processes.

The grain size diameter of the imported beach sediment will generally be the same or larger than the native material to reduce the rate of erosion of the imported material after placement. The beach material will be imported from an inland source. In most cases, beach nourishment will have to be periodically replaced as it is moved downdrift and/or offshore by wave action. This requires a commitment by the proponent for future works (i.e., maintenance and renourishment) over the planning horizon of the shore development. The availability and quality of additional beach nourishment material for the complete life-cycle of the project is a major concern. Dedicated sand for the projected life of the project must be identified and committed to the project. **Beach nourishment should be considered as suitable hazard protection for a development only if long-term commitments to maintain the beach nourishment are in place.**

A concern that must be evaluated is the effect of the "loss" of the imported material on aquatic habitats adjacent to the site as well as water quality considerations. The amount of silt/clay in the imported material is important because it will determine how turbid the water becomes during construction, how much fallout and sedimentation will occur, and how much residual silt/clay there will be to be stirred up during storms.

Beach nourishment may be accompanied by "anchoring" or retaining structures, such as groynes, sills, artificial headlands, or detached breakwaters, to reduce the loss of the placed material downdrift due to alongshore transport or towards the offshore due to cross-shore transport. When used with retaining structures, beach nourishment is often termed "beach fill". Without the retaining structures, maintaining the placed beach material would be very difficult in areas of rapid erosion (i.e., along fine-grained cohesive shores) or where no previous beach existed (i.e., bedrock shores).

Figure 8.28: Beach Nourishment



Characteristics of Nourishment Region and Sediment Loss Pathways

Nourishment projects typically involve the cooperation of many adjacent shoreline property owners because it is generally not a viable approach for short reaches of shoreline. The design of a beach nourishment project requires a specialized knowledge of coastal processes (e.g., nearshore waves, littoral transport, interaction with structures) and is often completed with the aid of computer models.

Perched beaches are a form of stepped beach created by placing beach fill behind a beach sill (see Figure 8.29). The beach sill is a submerged structure placed parallel to the shoreline some distance into the water. The sill is used to retain the beach fill at a mild slope on an existing, possibly steeper sloping foreshore. The abrupt change in depth at the beach sill may pose a safety concern for swimmers and boaters. Perched beaches must be implemented as a cooperative measure over numerous properties and involve a significant design effort. There is limited documented information on perched beaches on *large inland lakes* and hence it is difficult to evaluate their effectiveness.

. Groynes

A groyne is a narrow structure projecting from the shoreline into the nearshore, at approximately a right angle (i.e., perpendicular to the shore). A groyne system or groyne 'field' is made up of a number of individual groynes, usually of similar length and installed at regular intervals along the shoreline (see Figure 8.30). Groynes come in various shapes (i.e., straight, L-shaped, T-shaped), sizes and materials (e.g., timber, armour stone, concrete blocks or steel sheet piles with pipe piles used as reinforcement).

At shorelines where there is sufficient alongshore transport of beach material, the intent of a groyne is to act as an artificial physical barrier to the natural alongshore drift (beach material) and trap some or all of it on the updrift side of the groyne. The groynes do little to affect the cross shore transport. Trapping of the alongshore transport causes a sediment deficit at the adjacent downdrift properties. To mitigate the downdrift effects, groynes should be prefilled with imported beach material. Groynes can also deflect the alongshore material further offshore from where it is only then slowly returned to shore further downdrift.

Many of the *large inland lakes* have minimal alongshore transport. When this is the case, groynes will not work. Groynes do not "attract" beach material that does not exist.

Groynes are used in some situations to help anchor beach nourishment.

The use of groynes involves the cooperation of many adjacent shoreline property owners A proper detailed study would only be cost effective for a groyne field which extended across dozens of properties. The design requires a specialized knowledge of coastal processes (i.e., nearshore waves, littoral transport, interaction with structures) and is often completed with the aid of computer models. Numerical modelling of shoreline processes requires a great deal of experience and expertise to be properly utilized. **The use of groynes should not be permitted without an express understanding and documentation of the potential adverse impacts to the littoral system, especially at downdrift properties**.

. Artificial Headlands

Artificial headlands (see Figure 8.31) are designed to combine some of the aspects of groynes (i.e., the shore perpendicular connections trap alongshore transport) and some aspects of detached breakwaters (i.e., the shore parallel "headlands" alter incoming waves through wave diffraction). They have also been referred to as headland breakwaters, headland-bay breakwaters and pocket beach breakwaters. Artificial headlands differ from groynes in that artificial headlands tend to be more massive than groynes in size and the structures themselves have a significant alongshore dimension to influence the incoming waves through diffraction. Artificial headlands differ from detached breakwaters in that artificial headlands are generally constructed closer to the original shoreline and tend to have a fixed connection to the shore. Artificial headlands are often used to protect and retain placed beach fill material.

Figure 8.29: Perched Beach

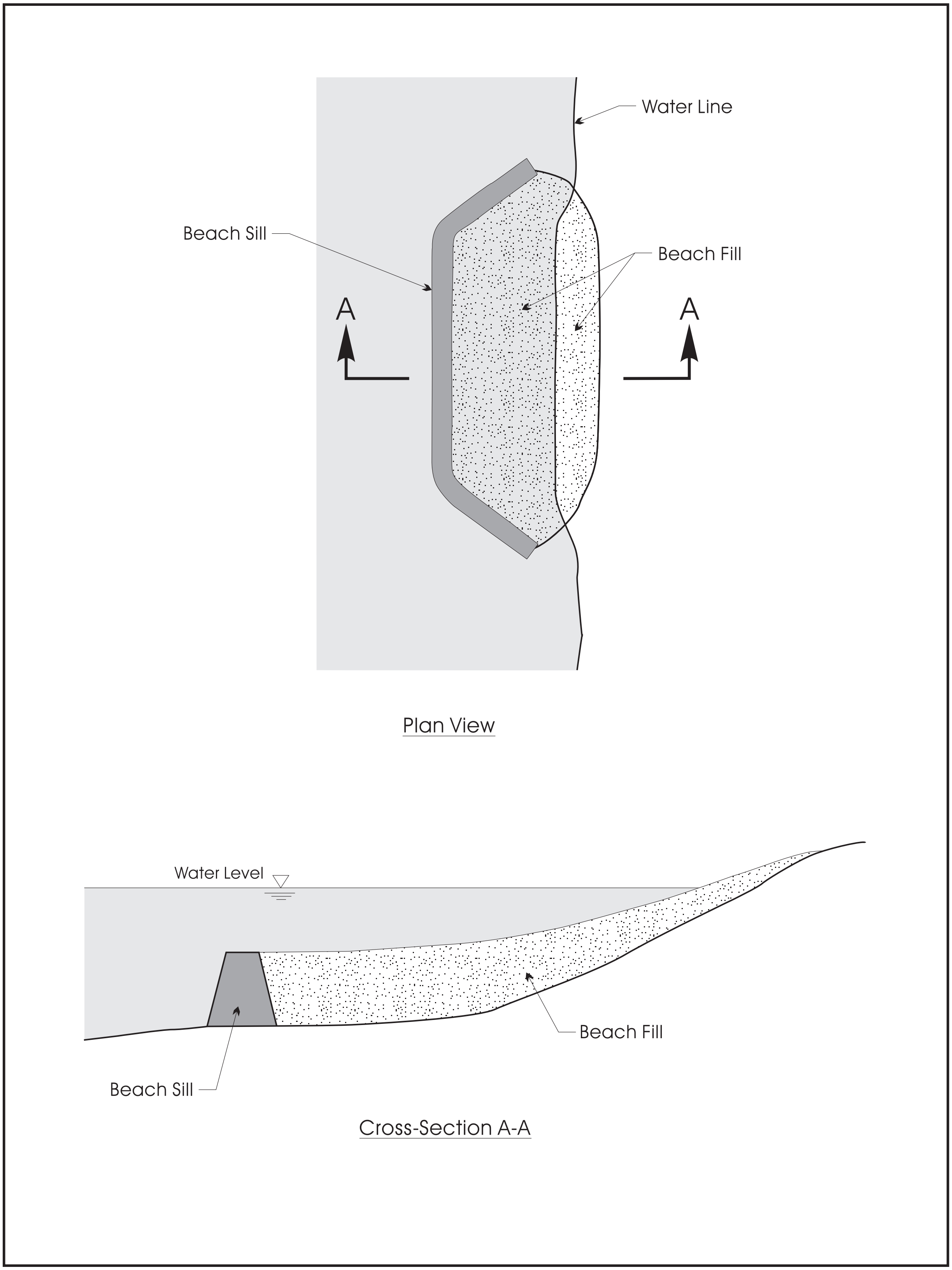


Figure 8.30: Groyne Field

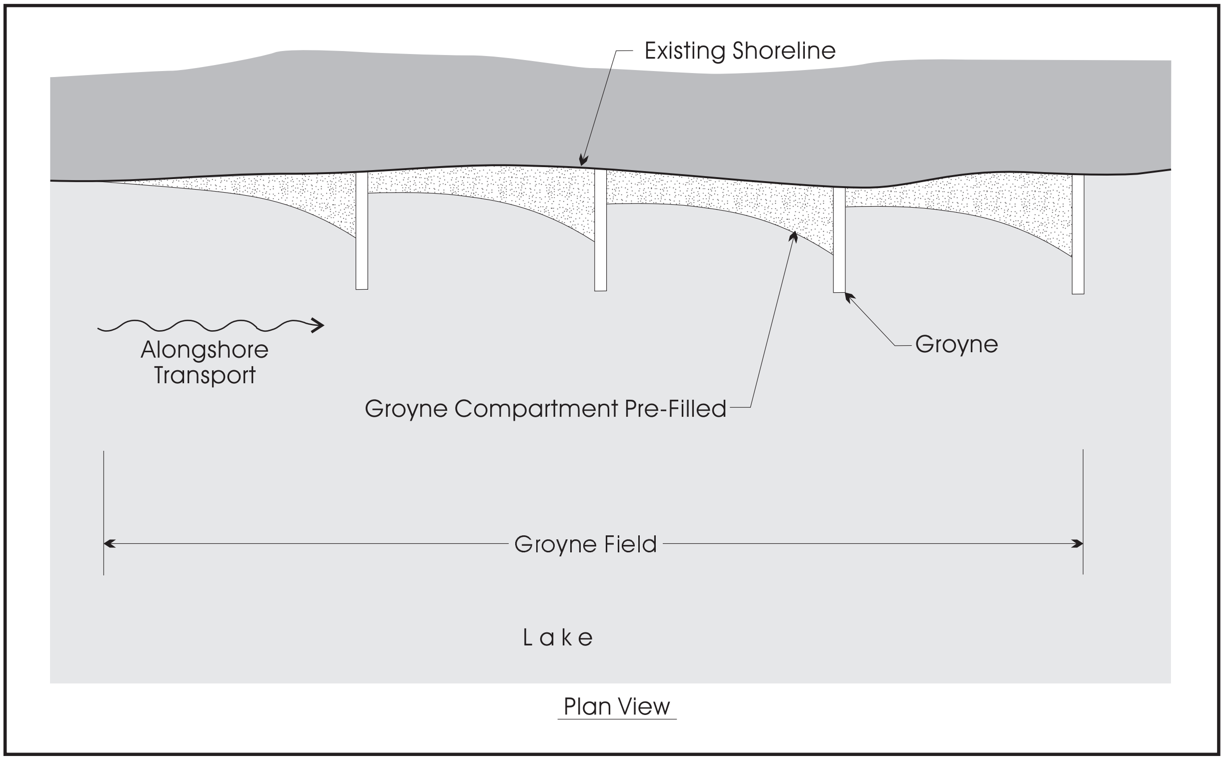
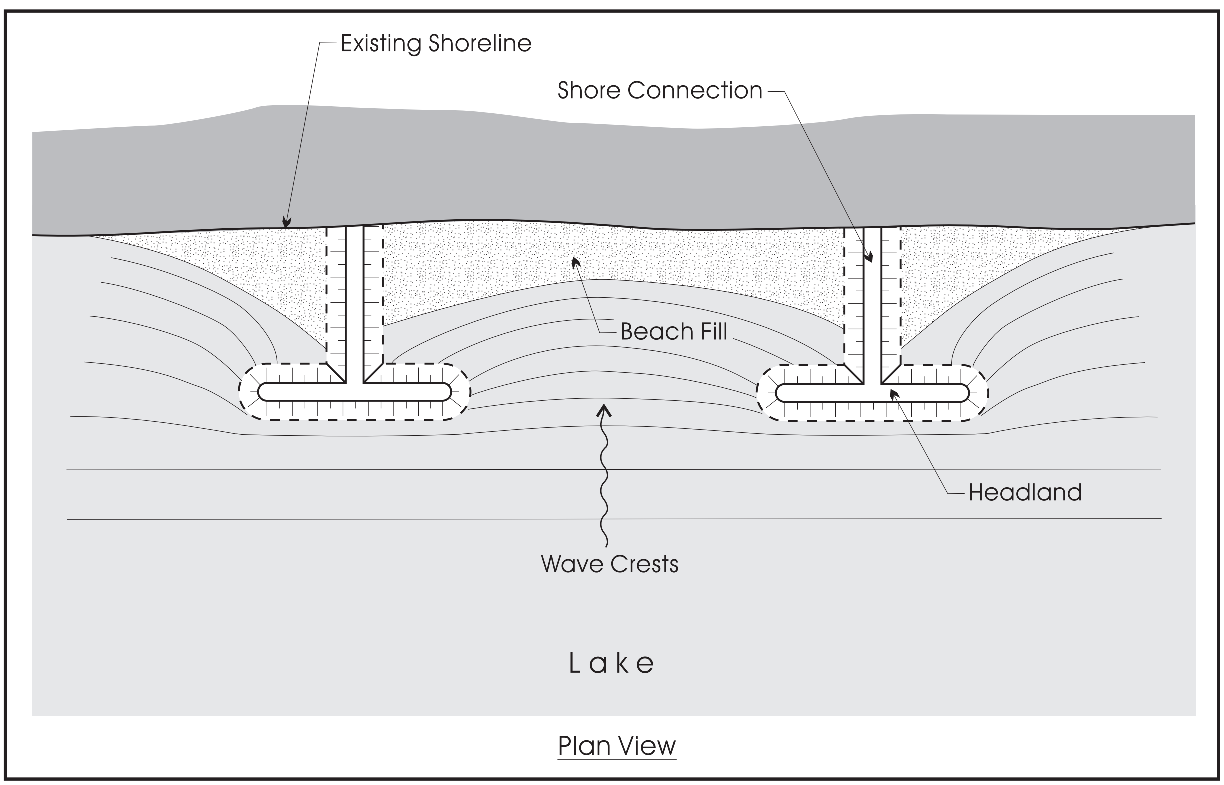


Figure 8.31: Artificial Headlands



Artificial headlands can reduce the sediments available to downdrift shorelines by trapping alongshore transport and by deflecting sediments to deeper water. As with beach nourishment and groynes, artificial headlands typically require a cooperative approach of many adjacent properties and an intensive design effort. **The use of artificial headlands should not be permitted without an express understanding and documentation of the potential adverse impacts to the littoral system, especially at downdrift properties**.

. Detached Breakwaters

Detached breakwaters (see Figure 8.32) are shore parallel structures constructed a significant distance offshore and are not connected to the shore by any sand-retaining structure (i.e., they are "detached" from the shore) Detached breakwaters can be constructed as a single continuous structure or as a series of structures (i.e., two or more structures separated by gaps). A series is referred to as "segmented" detached breakwaters. A "low-crested" detached breakwater has a crest, or top elevation which is at, or just above, the water level (see Figure 8.32). A "reef" breakwater is a detached breakwater with a crest which is submerged significantly below the water level and it is often constructed using a homogeneous stone size (see Figure 8.32). The submerged crest allows a significant amount of wave energy to pass over the top to the leeward side.

Rather than physically trapping alongshore transport, like groynes, detached breakwaters operate by creating an area of reduced wave energy on the leeward side of the structure by dissipating, reflecting or diffracting incoming waves. A reduction in the waves results in a reduction of currents and thus sediment will tend to deposit along the shore. The newly formed beach is called a salient if it does not extend all the way to the detached breakwater. If the wave energy is reduced enough, the new beach area will touch the breakwater, forming a tombolo. If a salient forms, alongshore transport can continue to move through the site to the downdrift shores. A tombolo can act as a total barrier to alongshore transport causing a sediment deficit downdrift.

A properly designed detached breakwater, that addresses the potential impacts on the coastal processes, would require a significant design effort. **The use of detached breakwaters should not be permitted without an express understanding and documentation of the potential adverse impacts to the littoral system, especially at downdrift properties**.

. Other Shoreline Structures

<u>Combination Structures</u>

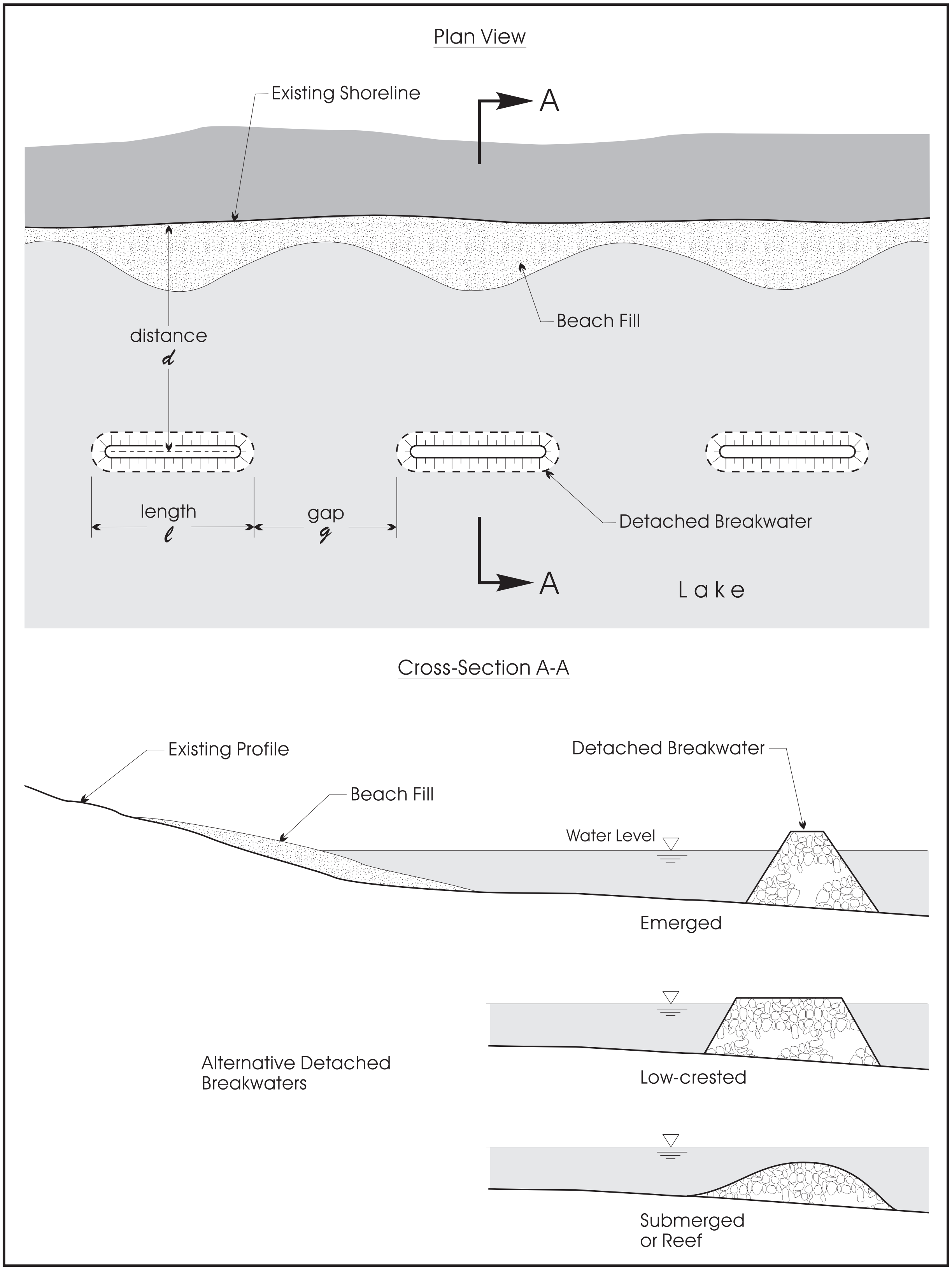
Structures which combine elements of two or more of the eight primary types could be grouped according to the predominant element.

<u>Proprietary Systems</u>

There are a number of proprietary, non-traditional shore protection devices that are being marketed as beach erosion control systems. Many of these devices are "breakwater" systems consisting of precast concrete units of unique geometry or construction. The units are individually placed, side-by-side, to form a continuous structure parallel to the shoreline.

There is very limited data on which to support the proponents' performance claims. There have been problems with displacement of these units (i.e., settlement and sliding). Reported advantages include relative ease of placement and the ability to relocate the units if they are found to be ineffective at the initial location or removed if found to be detrimental. Some of these systems have undergone limited laboratory testing and some have seen limited field testing. "Some apparently have had limited success and some have not. Some may be applicable in one area and not in another. Proponents of various schemes can make unsubstantiated claims of product success. A coastal engineering assessment of the product relative to a specific site is critical prior to its purchase and use" (Chasten, Rosati, McCormick and Randall 1993). Seymour et al. (1996) note that "many non-traditional devices have shown no real capability for shoreline protection over the long term". Prior to their use they should be evaluated "objectively by qualified engineers acting in a third-party role." It is probably most appropriate to consider these proprietary systems as not another type of protection structure but simply as an alternative "material" with which to construct the primary types of structures noted previously.

Figure 8.32: Detached Breakwaters



<u>Docks, Piers and Boat Launch Ramps</u>

Structures that are not primarily intended to address flooding and/or erosion hazards, but are primarily for other purposes, such as boat docks, piers, jetties, boat launch ramps, typically can be grouped according to their location and orientation to the shoreline (i.e., backshore, shore parallel; backshore/nearshore, shore perpendicular; nearshore/offshore, shore parallel) and their impacts judged accordingly. For example, a boat dock on reasonably spaced piles could be considered as a very permeable groyne. Very permeable groynes may not result in a significant impact to the alongshore transport.

8.2.4 Established Standards and Procedures

a) 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* along the shorelines of the *Great Lakes - St. Lawrence River System*. It is acknowledged that this term is somewhat misleading, in the sense that total protection from flood damage cannot be assured. 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. Floodproofing is not intended for all areas subject to *flooding hazards*. In some instances, the flood threat is too severe for "standard" procedures. However, if applied effectively, floodproofing can play a significant role in comprehensive shoreline management planning.

Where it has been determined that *development* and *site alteration* could possibly be located within the less hazardous portion(s) of the *flooding hazard* (i.e., the flood hazard(s) can be safely addressed), mechanisms should be established through the municipal planning process to recognize and address the potential increased risk and/or threat to life and property and to ensure that the development and required floodproofing measures are done in an environmentally sound manner.

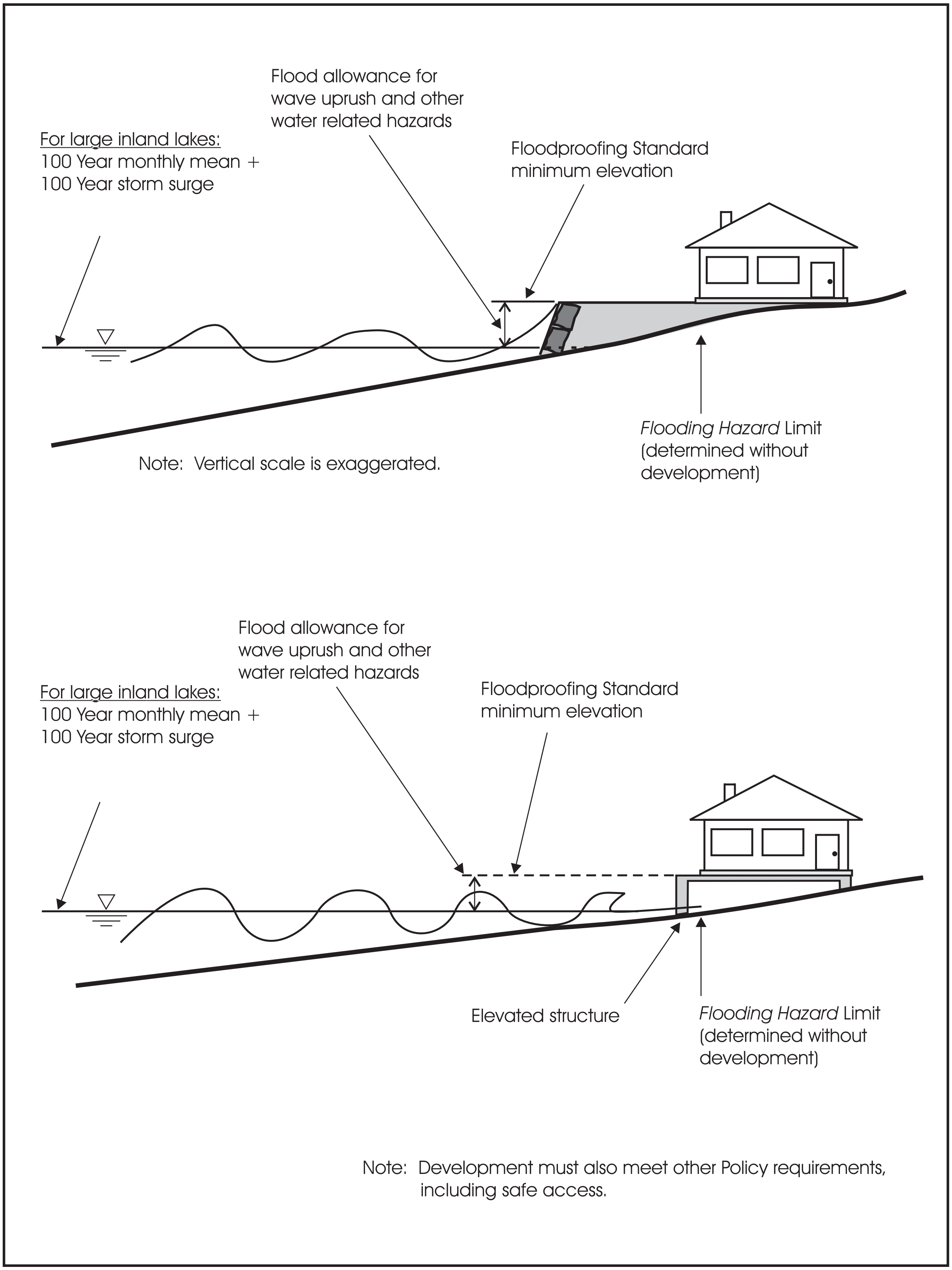
The minimum **floodproofing standard** for *development* and *site alteration* located within the *flooding hazard* limit is as follows:

- **on *large inland lakes*, *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* <u>plus</u> the *100 year wind setup* <u>plus</u> a *flood allowance for wave uprush and other water related hazards*** (see Figure 8.33).

It should be noted that the *flooding hazard* limit defines the area of concern. Development located landward of the *flooding hazard* limit is considered to be adequately safe from *flooding hazards* unless there is sufficient evidence to support otherwise.

Development which by the nature of its use is normally located in close proximity to or within the water (e.g., water intakes, walkways, boathouses, boat ramps, boat docks and landscaping or aesthetic improvements) may be governed by design criteria which provides for a lower floodproofing level. Factors to be considered include the safety of persons using the development during the intended period of use and the structural stability of the works at all times (including the "off-season"). The safety of persons using the development in close proximity to the water will be dependent on the nature of the development, frequency and duration of flooding, flooding depths and velocities, overtopping rates, and degree of available egress.

Figure 8.33: Floodproofing Standard



b) Protection Works

. Protection Works Standard

Protection works are generally defined as a combination of non-structural or structural works or landform modifications designed and constructed to address the impacts of flooding and other water related hazards, to arrest the landward retreat of shorelines subject to erosion, and/or to address dynamic beach hazards. It is acknowledged that this term is somewhat misleading, in the sense that total protection from these hazards cannot always be assured (i.e., structural integrity cannot be assured for the long term). However, if applied effectively, hazard protection works, when done in an environmentally sound manner, can play a significant role in comprehensive shoreline management planning.

In general, where actions intended to address shoreline *hazards* involve the installation of protection works, emphasis should be placed on non-structural or bio-engineering approaches. Protection works using structural approaches should only be considered where such actions are required to protect existing developments that are at high risk, where non-structural or bio-engineering solutions are not feasible, and where environmental impacts have been appropriately addressed and incorporated into the design of the protection works.

Where it has been determined that *development* and *site alteration* could be safely located within the less hazardous portion(s) of the *flooding hazard* (i.e., the flooding and other water related hazards can be appropriately addressed), and/or the *erosion hazard* (i.e., the erosion hazard(s) can be appropriately addressed), and/or the *dynamic beach hazard*, excluding those areas defined by Policy 3.1.2, (i.e., the *dynamic beach hazards* can be appropriately addressed), recognition of the potential increased risk and/or threat to life and property and the need to ensure that such works are done in an environmentally sound manner, should be addressed.

To safely address the *hazards*, protection works must be of sound, durable construction and be designed by a qualified coastal engineer according to acceptable practice. An overview of the design approach for protection works, including shoreline processes and characteristics and design criteria, is presented in Appendix A7.1 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines.

In "addressing the *hazards*" in an environmentally sound manner, where *development and site alteration* may be considered within the *hazardous lands* , the following minimum **protection works standard** should be applied:

- **the installation of protection works should be <u>combined with</u>:**
  - **an allowance for stable slope (3:1 *OR as determined by a study using accepted geotechnical principles)* <u>plus</u>**
  - **a 15 metre hazard allowance *(OR as determined by a study using accepted scientific and engineering principles).***

- **the design and installation of protection works be such that access to the protection works by heavy machinery, for regular maintenance purposes and/or to repair the protection works should failure occur, is not prevented**

It must be recognized that there are no guarantees that any protection works will offer protection for 100 years. There must be a recognition, however, that proper protection works, in combination with appropriate setbacks (stable slope, and hazard allowance) to address *flooding, erosion and dynamic beach* hazards will provide sufficient "protection" to warrant consideration of development within the *hazardous lands*.

Discussions on the stable slope allowance and the hazard allowance are provided in subsequent sub-sections.

Where the *established standards and procedures* for stable slope (i.e., 3:1) or the hazard allowance (i.e., 15 metres) is deemed to be too excessive or insufficient to address the severity of the shoreline *hazards* impacting on a particular site, the flexibility to undertake a study is provided. Municipalities and planning boards should ensure that the municipal planning processes incorporates this added flexibility and includes mechanisms to permit or require the undertaking of a study.

Where the municipality or planning board approves a study to determine the stable slope allowance (using accepted geotechnical principles) and/or a study to determine the hazard allowance (using accepted scientific and engineering principles), the protection works plus the studied stable slope allowance and hazard allowance (addressing f*looding*, *erosion* and/or *dynamic beach hazards*) are to be applied only to the area studied.

Regardless of the stable slope allowance and the scientific/engineered hazard allowance calculated for a given stretch of shoreline, care must be taken to ensure the long-term functionality and level of protection provided by the selected protection works. This is normally achieved by, and dependent on, a commitment to regular inspection and maintenance and/or repair or replacement in the event of failure.

The design and siting of buildings and structures on the subject property should also give consideration to access to the site by heavy machinery for general maintenance and repair of protection works in the event of failure (i.e., buildings with narrow side yards could potentially restrict landside access to a failed protection works). Additional discussion of access is provided in Appendix A7.1 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines.

Protection works proposed to address the *hazards* at a site, can not cause new *hazards* or aggravate existing *hazards* at updrift/downdrift properties. The potential impacts of protection works and the relative significance of the impacts are discussed in Section 8.3.

Finally, the protection works should be designed and installed in an environmentally sound manner to balance the concerns related to the physical *hazards* with the concerns of maintaining, protecting and enhancing the integrity of the shoreline ecosystem (see Section 9: Environmentally Sound Hazard Management).

. Stable Slope Allowance

The stable slope allowance is addressed in Section 5: Erosion Hazard of this Technical Guide and forms an integral component of the overall approach to addressing the *hazard.*

. Hazard Allowances

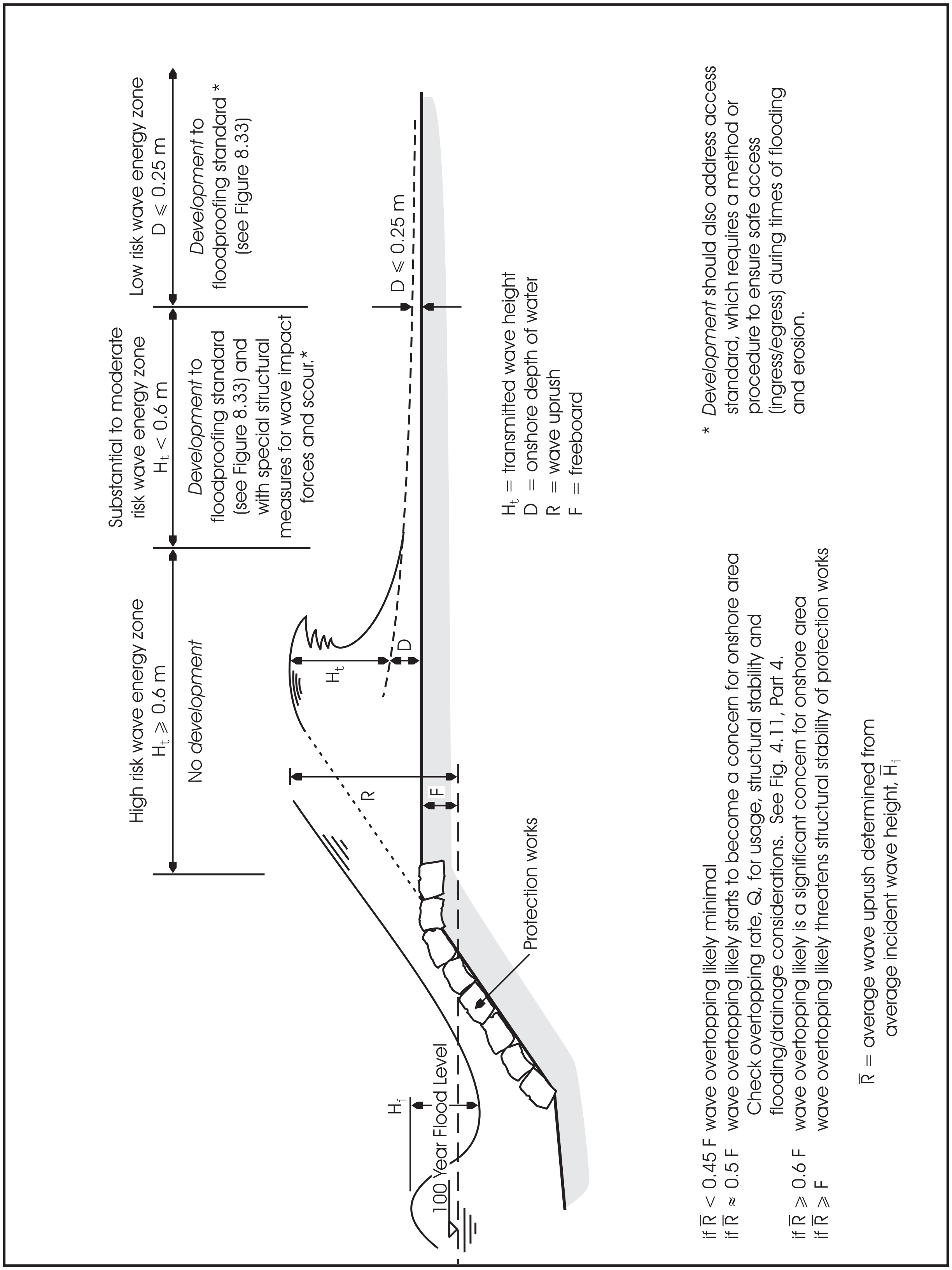
For *development and site alterations* protected by protection works, the protection works standard requires a stable slope allowance plus a minimum hazard allowance of 15 m, or as determined by a study. The hazard allowance is in recognition of several factors including, but not limited to the following:

- uncertainties in recession rate data, nearshore downcutting processes, wave data, shoreline;
- limited design life of protection works;
- wave uprush, overtopping and spray;
- inability to enforce long-term maintenance requirements;
- some uncertainty with respect to structure performance (i.e., armour stability, wave overtopping, toe scour);
- condition and effectiveness of any adjoining protection works;
- provision of an environmental buffer strip along the shoreline;
- provision for maintenance access; and
- provision for ingress/egress during emergencies.

Development located outside the *flooding hazard* and without shoreline protection works is generally considered safe from *flooding hazards*. Where development is being considered within the *flooding hazard* limit, one must first meet the requirements of the floodproofing standard. The floodproofing standard outlines the elevation requirements for development located within the *flooding hazard*. Second, one must fulfil the requirements of the protection works standard, for an appropriate hazard allowance.

A safe hazard allowance for flooding depends on the height of the development above the 100 year flood level (i.e., the freeboard) and the limit of wave uprush (see Figure 8.34). The lower the freeboard and the higher the uprush, the greater the required distance for a safe setback.

Figure 8.34: Protection Works Standard - Flood Allowance



Development located outside the *erosion hazard* limit, and without shoreline protection works, is generally considered safe from erosion *hazards* over a planning horizon of 100 years. Where *development* is being considered within the *erosion hazard* limit, one must first understand how this area of interest is defined. In areas where the average annual recession rate is known using sufficient data, the *erosion hazard* limit is defined by a stable slope allowance <u>plus</u> 100 times the average annual recession rate (Figure 8.35a) <u>or</u> 15 metres from the top of the bank, cliff or bluff, whichever is greater. In areas where there is insufficient average annual recession rate data, the *erosion hazard* limit is defined by a stable slope allowance <u>plus</u> 15 metres <u>or</u> 15 metres from the top of the bank, cliff or bluff, whichever is the greater.

Historical recession rates are based on erosion of the shoreline material present at the time of study (i.e., when the evaluation and calculation of the recession rates were undertaken). If the stratigraphy of shoreline in the cross profile direction changes, the shoreline may become more erodible (or less erodible) than had been previously experienced at the original time of study. Similarly, changes in the volume of littoral sediments in the nearshore (e.g., due to increased protection of updrift bluffs which may be the sediment source, construction of harbour jetties or entrance channels which can block the movement of littoral materials) may reduce the size of protective beaches and/or reduce the volume of sediment cover on the underlying cohesive stratum. This reduction in sediments may result in increased shoreline erosion and nearshore downcutting.

In recognition of the variable nature of the shoreline, the protection works standard allows the hazard allowance to be increased or decreased, as appropriate, based on studies using acceptable scientific and engineering principles. The 15 m allowance may not be sufficient in areas of moderate or high to severe recession. The primary considerations in determining the hazard allowance for erosion include:

- the representative recession rate without protection works (including nearshore profile downcutting);
- the goal of providing a development which is safe from the *hazards* for a planning horizon of 100 years (i.e., equivalent to the *erosion hazard limit*); and
- the design life of the protection works (including durability of materials, stability against undermining, see Appendix A7.1 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines).

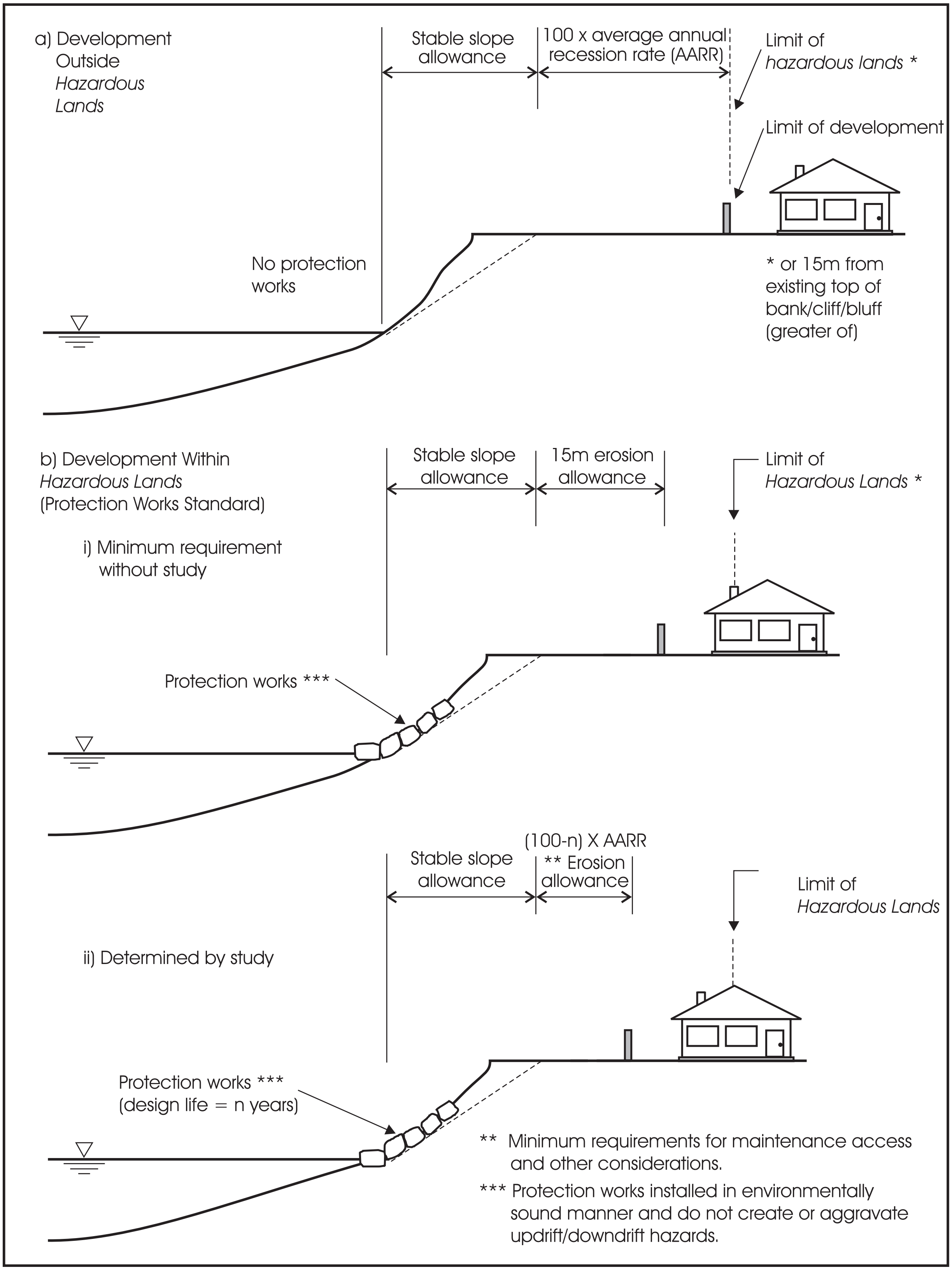
Where *development* is proposed within the least hazardous portion of the *erosion hazard* limit and involves the installation of protection works, the *development* must be setback a distance equivalent to the stable slope allowance (3:1 or as determined by a study) <u>plus</u> a hazard allowance (15 metres (Figure 8.35b(i)) or as determined by a study (Figure 8.35b(ii)). Where a study using accepted scientific and engineering principles is used to establish the hazard allowance, the erosion component of the hazard allowance usually involves two steps.

The first step is to setback the *development* from the stable slope allowance a distance equivalent to:

[100 years <u>minus</u> the initial design life of the protection works] ***multiplied by***
[the average annual recession rate].

This approach (see Figure 8.35b)(ii)) recognizes that most protection works have a design life that is significantly less than the planning horizon of 100 years and that there is no mechanism to ensure that the present owner or subsequent buyers of the property will be able to rebuild or replace the protection works. Design life is discussed in Appendix A7.1 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines.

Figure 8.35: Protection Works Standard - Erosion Allowance



The second step is to evaluate the hazard allowance determined in the first step by using accepted scientific and engineering principles to consider other factors including, but not limited to the following:

- mechanism of failure of the protection works (i.e., rigid structures may fail rapidly and completely, while flexible structure failures tend to be more progressive and provide some residual protection);
- nature of the backshore materials (i.e., erosion resistant consolidated materials, loose, highly erodible materials, fill material) including how quickly they would erode if the protection works were to fail and whether there would there be sufficient time to have repairs carried out;
- consequences and extent of damage to the backshore if structure fails (degree of risk of loss of life, damage to property, social disruption and adverse environmental impacts);
- stable slope allowance;
- the provision of a coastal environmental buffer (habitat corridors, access to the water, sediment controls; see Part 9: Environmentally Sound Hazard Management, of this Technical Guide);
- the nature of the proposed and future development (i.e., public versus private funding; size, land use, and intensity of use; habitable or occupied structures; alterations or additions; hazardous, institutional uses);
- existing protection on adjacent properties (age, condition, effectiveness);
- ingress/egress during emergencies (includes fire department standards);
- allowances (i.e., setbacks) for wave overtopping and spray (see Part 4: Flooding Hazard, including ice buildup during winter);
- volume of overtopping water (drainage provisions, see Part 4);
- access for heavy equipment to repair/maintain protection works (as required by protection works standard);
- proposed action at end of estimated lifespan (i.e., rebuild larger structure, abandon structure and rely on remaining setback or relocation); and
- allowances for uncertainties in the design data (including but not limited to, recession rates and nearshore wave climate), the level of design/analysis effort and the predicted performance of the structure.

It should be noted that where protection works are installed, the landward limit of the *erosion hazard* **does not change**. The protection works standard merely determines where the development can safely be located within the *erosion hazard*.

If no recession rate data exists, extra caution should be exercised in adopting an appropriate hazard allowance due to the uncertainty in the long-term stability of structure. Additional guidance on increasing or decreasing the hazard allowance can be found in Section 5: Erosion Hazard.

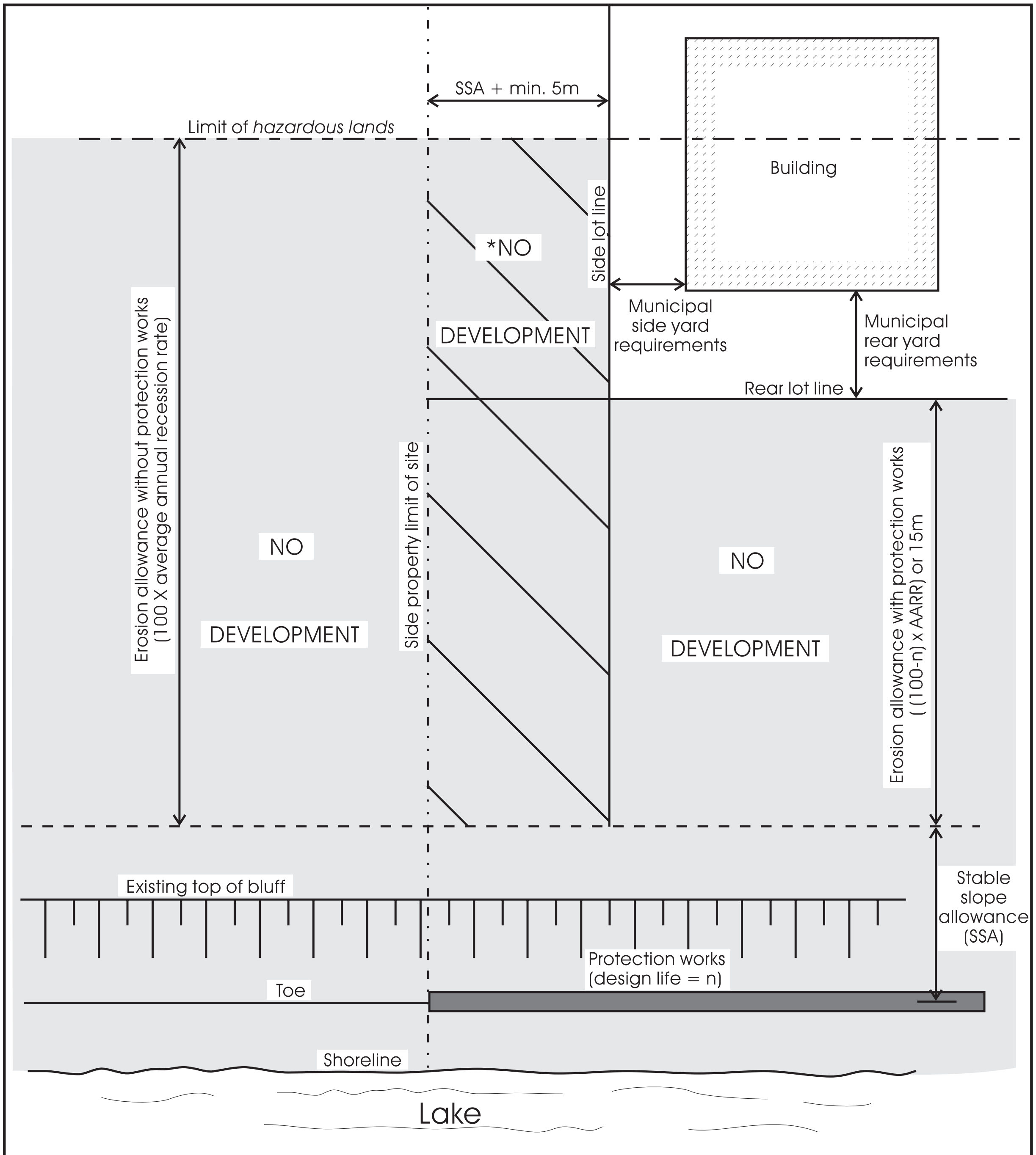
. Hazard Allowance at the Alongshore Limits of a Property

An appropriate hazard allowance for erosion must be provided at the alongshore limits of a property where the adjacent properties have no protection works installed or where the adjacent protection works are insufficient to provide long-term protection. Where protection works are proposed, the "safe" siting of the development must also take into consideration potential for side or "flank" erosion.

At a minimum, determination of the side or "flank erosion allowance" should be based on a distance equivalent to the stable slope allowance <u>plus</u> a 5 metre allowance (Figure 8.36). This side or "flank erosion allowance" can also serve as an access corridor for heavy machinery to maintain and/or repair the protection works in the event that they should fail as required by the protection works and access standards.

As an alternative, the protection works could be extended by the equivalent distance (i.e., stable slope allowance plus 5 m) beyond the property limit and onto the adjacent property. Extending the protection works can only be done with the explicit permission of the adjacent property owner. Where the protection works have been extended onto an adjacent property, access for maintenance and repair of the protection works must still be confirmed and ensured.

Figure 8.36: Flank Erosion Allowance



*Alternative: Extend protection works a total distance of [SSA + minimum 5 metres] beyond side property limit with permission of adjacent owner; then side lot line can extend to side property limit.

**c)		Access**

**.		Access Standard**

Where it has been determined that *development* and *site alteration* could safely be located within the least hazardous portion(s) of the *hazardous lands*, recognition of the potential increased risk and/or threat to life and property must be addressed. For this reason, the issue of access (ingress/egress), from either an individual development site and/or from a development area (e.g., shoreline subdivision, marina development, island communities), during emergencies at times of flood and/or erosion hazards (e.g., storm events), must be addressed.

In keeping with Policy 3.1.3(d), the **access standard** for development located within the *hazardous lands* is as follows:

> **Access standard, which means a method or procedure to ensure safe vehicular and pedestrian movement, and access for the maintenance and repair of protection works, during times of *flooding*, *erosion* and/or *other water related hazards*.**

Access to (ingress) and from (egress) a building can be facilitated by locating parking and driveways, as well as the building, in the area of a site least likely to be flooded. Access is an important concern during flooding events with the primary concern being the ability to ensure that building occupants can safely evacuate and that police, fire protection, ambulance and other essential services can continue to be provided.

Where developments are considered within flood susceptible areas, access roads should approach the buildings from the non-flood susceptible areas to reduce the likelihood that they will be blocked by flood waters and debris. To reduce potential erosion, siltation, and runoff problems, roads should not disrupt drainage patterns, and road crossings should have adequate bridge openings and culverts to permit the unimpeded flow of flood water. If roads are to be raised, the slopes (gradients) of the embankments should be minimized and exposed slope faces stabilized with ground cover or terracing.

The degree to which access (ingress/egress) is available to and from a site to escape from potential danger due to flood *hazards*, especially short-term hazards such as storm surge and wave uprush, should be taken into consideration when establishing the acceptable level of risk for users of the development. For example, a walkway along a low plain shoreline provides egress to safer inland areas at virtually any point along the walkway. In contrast, much lesser degrees of egress are available along a walkway at the toe of a steep bluff where evacuation is only provided at opposite ends of the walkway, and for a walkway on a pier which extends out into the water and provides for evacuation at only one point (i.e., entrance to the pier). Where egress is constrained or limited, the requirements for floodproofing should be carefully evaluated.

The options of ensuring access (ingress/egress) to an individual development site and/or the entire shoreline area (e.g., low-lying, flood susceptible shoreline communities) should also be addressed through the Municipal Emergency Action Plan. Assistance in the establishment of options for site and/or area evacuation, the issuance of flood and storm warning and/or flood/storm alerts from local Conservation Authorities, and the provisions of emergency action programs (e.g., sandbagging, technical advise, etc.) should be developed in consultation with the local Conservation Authority, the Ministry of Natural Resources, the Office of the Solicitor General and other pertinent emergency management agencies.

**.		Access to Protection Works for Maintenance/Repairs**

During its design life, a structure will generally require maintenance to ensure its performance level and structural integrity. Eventually a structure may need to be replaced or extensively refurbished to ensure that the appropriate level of protection is being provided. The designer should keep the maintenance and replacement procedures in mind and make sure that the structure details and layout permit future work on the structure. Typically the access width to the shoreline should be approximately 4 m to 5 m Further details regarding maintenance access are provided in Appendix A7.1 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines.

8.2.5 Existing Protection Works

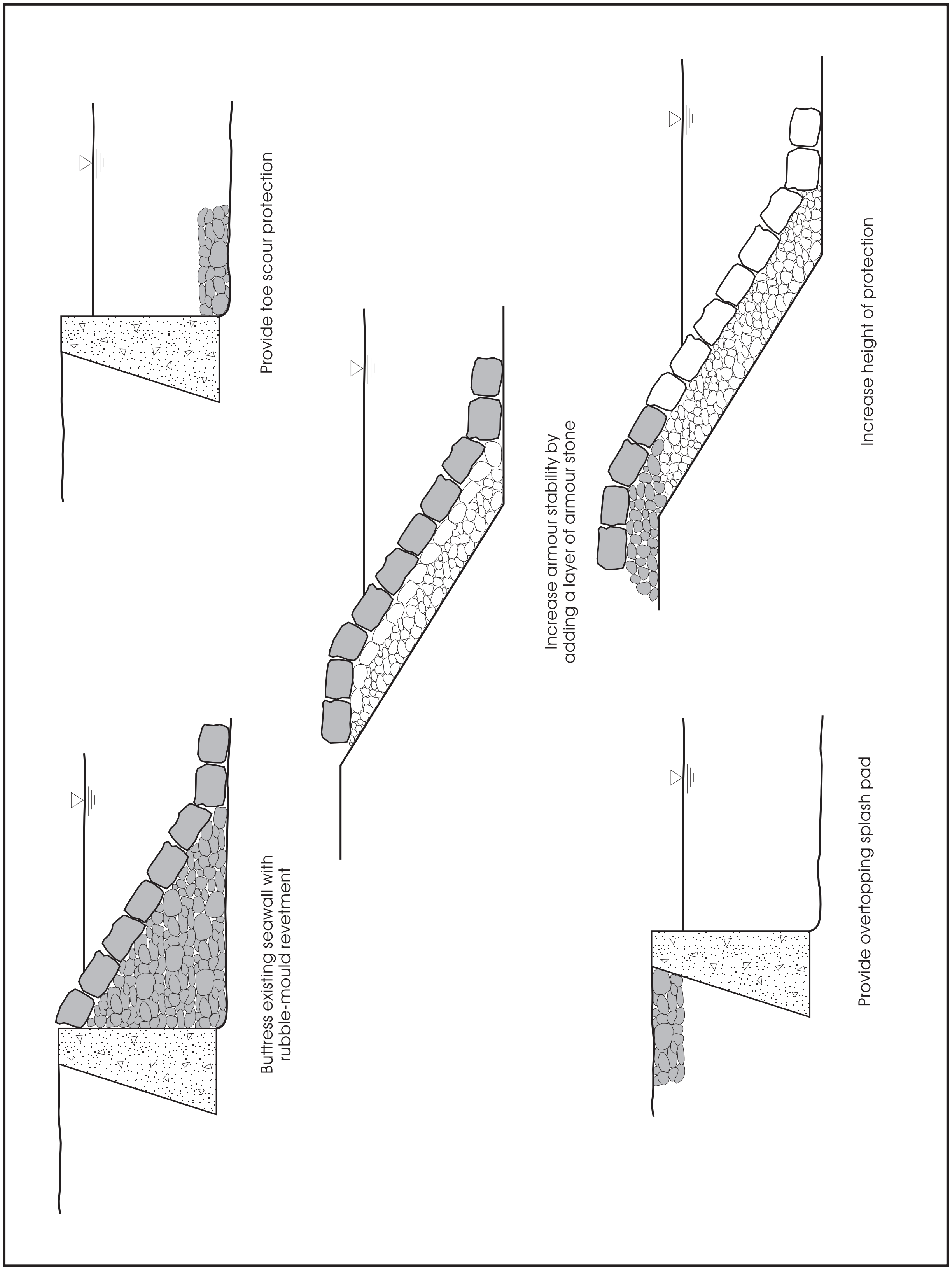
Upgrading existing protection works and/or the installation of new protection works in areas of existing development (where the existing development is to remain unchanged) may be considered if the works are done in accordance with accepted coastal engineering practice, are undertaken in an environmentally sound manner and where they do not create and/or aggravate *hazards* off-site (i.e., updrift and downdrift properties). Where existing works are being upgraded or new protection works are being installed at a site of existing development, it is recommended that the protection works standard (including protection to the 100 year flood level) be fulfilled. Where this is not possible, due to financial or site constraints, the standards applied should be as high as possible. Where the protection works do not fully conform to the protection works standard (including protection to the 100 year flood level), it should be prominently and clearly noted on the proponents' drawing and application for approval that the works do not provide protection to the 100 year flood level and that they do not meet the full intent of the protection works standard requirements for development. In this manner, the "approved" work can not be presented to subsequent potential purchasers of the property as meeting the full protection works standard.

Examples of the type of improvements to existing protection works may include (see Figure 8.37):

- replacing or buttressing deteriorating (i.e., badly damaged and spalled concrete, wall leaning or sliding lakeward) and/or reflective seawall with a less reflective structure such as an armour stone revetment;
- providing scour protection at toe of structure;
- increasing the stability of the armouring by increasing the size of the primary armour or by adding an additional layer of armour; and
- providing increased wave uprush and overtopping protection by increasing the height and/or providing improved splash pad.

Prior to expending significant sums of money on improvements to existing protection works, the property owner should critically evaluate relocation as an option. As well, the owner should examine whether the capital and maintenance costs of the protection works are worth the long-term benefits. The benefits may be limited by ongoing downcutting of the nearshore profile, inadequate protection on neighbouring properties and an insufficient hazard allowance.

Figure 8.37: Typical Improvements to Existing Protection Works



8.2.6 Initial Evaluation of Shoreline Management Approaches

The shoreline management approaches that may be appropriate to address the *hazards*, at a given site, are dependent on the shoreline class and the nature of the hazard. The different processes governing erosion at bedrock, cohesive and beach shorelines, along with the nature of the *hazard* (i.e., the entry of flood waters including wave action, or erosion of the shore) will govern the appropriate approach.

Table 8.4 has been prepared as a summary to aid shoreline managers in the identification of shoreline management approaches that have the potential to safely address the *hazards* at a particular site, for a given shoreline class. Note that all structural options must be accompanied by a stable slope allowance and a hazard allowance. In addition, be advised that Table 8.4 does <u>not</u> include the potential impacts of these approaches and therefore it must be read in conjunction with Section 8.3.

In Table 8.4, the shoreline classes are listed down the left-hand side according to general shoreline type (onshore/backshore composition and profile), controlling nearshore substrate and surficial substrate in the nearshore (see Section 3). For each shoreline classification, it is noted whether that shore type is generally prone to *flooding*, *erosion* and/or *dynamic beach hazards*. The shoreline management approaches are listed across the top of the Table. The individual approaches are divided into the three categories: 1) prevention; 2) non-structural protection; and 3) structural protection. They are further sub-divided by their location; onshore, backshore, and nearshore.

Table 8.4 identifies appropriate shoreline management approaches ("shaded" cells) to address the *hazard(s),* on-site, associated with the general shoreline types, nearshore controlling substrate and surficial sediments. Approaches that are "recommended" are denoted '✓✓✓'. Approaches that are considered to be "generally appropriate" are denoted '✓✓'. Approaches that "may be considered but which may not provide sufficient or proper protection" are denoted '✓'. It should be noted that Table 8.4 also indicates that structural options for development in dynamic beaches, excluding possibly beach nourishment, are not permitted in the *defined portions of the dynamic beach* (Policy 3.1.2(a)). Also, Table 8.4 notes that all structural options must be accompanied by a stable slope allowance and a hazard allowance (see Section 8.2.4).

Table 8.4 is not intended as an automatic endorsement or rejection of any particular shoreline management approach. It is general in nature and is only intended to serve as a guide that will provide an initial indication of whether or not a particular approach may be appropriate for addressing the *hazards* at a particular site along a given shoreline class. In the final analysis, the specific appropriate approach for addressing the *hazard(s)* at a site will depend on the development, the site-specific details and the nature and magnitude of the *hazard(s).*

To use Table 8.4 requires that you first identify the nearshore controlling substrate, the general shoreline type and the surficial substrate and that you determine the nature of the *hazard(s).* The table provides a guide with respect to the *hazards* generally associated with the various shore types. To confirm the hazard, examine the mapping to define the *flooding*, *erosion* and *dynamic beach hazards*. Once you have identified the shoreline class, you can review the various shoreline management approaches which may be appropriate to address the *hazards* at the site.

Consideration of a particular approach from Table 8.4 must be followed by an identification of the potential impacts of the selected approach on the physical shoreline processes and characteristics (see Section 8.3, Table 8.5). The impacts identified in Table 8.5 are then evaluated with respect to their potential for creating or aggravating any updrift/downdrift *hazards* away from the site (see Section 8.3, Table 8.6). As well, the impacts identified in Table 8.5 must be examined to ensure that the selected approach is environmentally sound (see Part 9). It is possible that a review of Tables 8.5 and 8.6 and Part 9 will show that the shoreline management approach which was initially selected, as appropriate for addressing the *hazards* at the site (i.e., meets requirement of Policy 3.1.3(a)), is in fact unacceptable because it does not meet other, equally important requirements: namely, new *hazards* can not be created and existing *hazards* can not be aggravated (Policy 3.1.3(b)); and no adverse environmental impacts will result (Policy 3.1.3(c)).

On site specific cases, the proponent may still be required to demonstrate that the selected approach does not cause and/or aggravate *flood, erosion and/or dynamic beach hazards* elsewhere and that it is environmentally sound.

Table 8.4: Addressing the Hazards for Development: Initial Evaluation of Shoreline Management Approaches by Shoreline Class

Shoreline Class			Typical Hazard(s)[1]	Appropriate Shoreline Management Approaches for Consideration to Address Flooding, Erosion and Dynamic Beach Hazards at the Site													
General Shoreline Type	**Controlling Substrate**	**Surficial Substrate**	• Prone to Flooding • Prone to Erosion • Prone to Influence of Dynamic Beach[5]	Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
Onshore/ Backshore (composition and profile)	Nearshore (predominant underlying material)	Nearshore (can appear above water as a beach)		Onshore		Onshore				Onshore		Backshore		Nearshore[10]			
				HA	PA	Re	FP	BM	DE	FI	D	fR / S	rR/S	BN †	G	AH	DB ‡
Bedrock Cliff[2]	bedrock	bedrock	Typically not prone to flooding and erosion hazards. (Softer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)	✓✓✓[11]	✓✓✓	✓✓✓											
		cobble/boulder															
		sand/gravel															
		silt/organic[4]															
Bedrock Low Plain	bedrock[3]	bedrock	Prone to flooding. Typically not prone to erosion. (Softer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)	✓✓✓	✓✓✓	✓✓✓	✓✓[9]			✓✓[9]	✓✓[9]	✓✓	✓✓				
		cobble/boulder															
		sand/gravel															
		silt/organic[4]															
Cohesive/Non-cohesive Bluff[2]	bedrock	bedrock	Not prone to flooding. Typically prone to low to moderate erosion. (Softer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)	✓✓✓	✓✓✓	✓✓✓		✓[8]				✓✓	✓✓	✓[6] ⇒	⇐ ✓[6]	✓✓	✓✓
		cobble/boulder												✓[6] ⇒	⇐ ✓[6]		
		sand/gravel												✓[6] ⇒	⇐ ✓[6]		
		silt/organic[4]															
	cohesive cobble/boulder till	cobble/boulder	Not prone to flooding. Typically prone to moderate to high erosion.	✓✓✓	✓✓✓	✓✓✓		✓[8]				✓✓	✓[7]	✓[6] ⇒	⇐ ✓[6]	✓✓	✓✓
		sand/gravel												✓[6] ⇒	⇐ ✓[6]		
		silt/organic[4]															
	fine-grained cohesive	cobble/boulder	Not prone to flooding. Typically prone to high to severe erosion.	✓✓✓	✓✓✓	✓✓✓		✓[8]				✓[7]				✓	✓
		sand/gravel															
		fine-grained cohesive															
		silt/organic[4]															

Table 8.4 continued on next page.

Shoreline Class			Typical Hazard(s)[1]	Appropriate Shoreline Management Approaches for Consideration to Address Flooding, Erosion and Dynamic Beach Hazards at the Site													
				Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
				Onshore		Onshore				Onshore		Backshore		Nearshore[10]			
General Shoreline Type Onshore/ Backshore (composition and profile)	**Controlling Substrate** Nearshore (predominant underlying material)	**Surficial Substrate** Nearshore (can appear above water as a beach)	• Prone to Flooding • Prone to Erosion • Prone to Influence of Dynamic Beach[5]	HA	PA	Re	FP	BM	DE	FI	D	fR / S	rR/S	BN †	G	AH	DB ‡
Cohesive/Non-cohesive Low Plain3	bedrock	bedrock	Prone to flooding & typically low to moderate erosion. (Softer bedrock does erode. Resulting nearshore profile may be similar to erosion-resistant cohesive cobble/boulder till.)	✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9]			✓ ✓ [9]	✓ ✓ [9]	✓ ✓	✓ ✓	✓ [6]⇒	⇐ ✓[6]	✓ ✓	✓ ✓
		cobble/boulder												✓ [6]⇒	⇐ ✓[6]		
		sand/gravel												✓ [6]⇒	⇐ ✓[6]		
		silt/organic[4]															
	cohesive cobble/boulder till	cobble/boulder	Prone to flooding & typically moderate to high erosion.	✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9]			✓ ✓ [9]	✓ ✓ [9]	✓ ✓	✓ [7]	✓ [6]⇒	⇐ ✓[6]	✓ ✓	✓ ✓
		sand/gravel												✓ [6]⇒	⇐ ✓[6]		
		silt/organic[4]															
	fine-grained cohesive	cobble/boulder	Prone to flooding & typically high to severe erosion.	✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9]			✓ ✓ [9]	✓ ✓ [9]	✓ [7]				✓	✓
		sand/gravel															
		fine-grained cohesive															
		silt/organic[4]															
Dynamic Beach Backed by Cliff/Bluff[5]	gravel/cobble/boulder	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach.	✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9,12]	✓ [8]	✓ [8]	[12]	[12]	✓ ✓ [12]	✓ ✓ [12]	✓	✓ [12]	✓✓ [12]	✓✓ [12]
	sand	sand		✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9,12]	✓ [8]	✓ [8]	[12]	[12]	✓ ✓ [12]	✓ ✓ [12]	✓	✓ [12]	✓✓ [12]	✓✓ [12]
Dynamic Beach Low Plain[5] (mainland dune)	gravel/cobble/boulder	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach.	✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9,12]		✓ [8]	✓ [12]	✓ [12]	✓ ✓ [12]	✓ ✓ [12]	✓	✓ [12]	✓✓ [12]	✓✓ [12]
	sand	sand		✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9,12]		✓ [8]	✓ [12]	✓ [12]	✓ ✓ [12]	✓ ✓ [12]	✓	✓ [12]	✓✓ [12]	✓✓ [12]
Dynamic Beach Barrier	gravel/cobble/boulder[5]	gravel/cobble/boulder	Prone to flooding, erosion & influence of dynamic beach.	✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9,12]		✓ [8]	[12]	[12]	[12]	[12]	✓	[12]	[12]	[12]
	sand	sand		✓ ✓ ✓	✓✓✓	✓✓✓	✓ ✓ [9,12]		✓ [8]	[12]	[12]	[12]	[12]	✓	[12]	[12]	[12]
Artificial			Prone to flooding & erosion.	✓ ✓ ✓	✓✓✓	✓✓✓	Functional performance and life span of existing structures to be confirmed by engineering study.										

See next page for Table 8.4 legend and notes.

Table 8.4: Addressing the Hazards for Development: Initial Evaluation of Shoreline Management Approaches by Shoreline Class (continued)

LEGEND AND NOTES

TABLES ARE GENERAL IN NATURE AND ARE ONLY INTENDED TO SERVE AS A GUIDE. THIS TABLE DOES NOT INCLUDE CONSIDERATION OF POTENTIAL UPDRIFT/DOWNDRIFT AND ENVIRONMENTAL IMPACTS. (see Notes)

LEGEND

✓✓✓- Recommended to address hazards.
✓✓ - Generally will address hazards.
✓ - May be considered <u>but</u> may not provide proper level of protection to address hazard.

⇒, ⇐ Typically used in conjunction with other structural protection works.

HA - hazard allowances for flooding and erosion
PA - property acquisition
Re - relocation
FP - floodproofing
BM - bio-engineering measures
DE - dune enhancement
Fl - filling
D - dyking
BN - beach nourishment
† typically extends across backshore and into nearshore
fR/S - flexible revetments and seawalls
rR/S - rigid revetments and seawalls
G - groynes
AH - artificial headlands (typically with beach fill)
DB - detached breakwater
‡ can also be located in shallow offshore

[1] - This Table does not include classification of shoreline exposure and planform (exposed, partial headland, headland-bay, well sheltered).

[2] - Cliff/bluff - steeper than 1:3 (vert:horz) and >2 m high.

[3] - Low plain - landward slope flatter than 1:3 (vert:horz) or <2 m high.

[4] - Typically only found in naturally well-sheltered areas where controlling substrate may not be applicable.

[5] - A beach is <u>not</u> classified as a *dynamic beach*, where: 1) beach or dune deposits do not exist landward of the stillwater line; 2) beach or dune deposits overlying bedrock or cohesive material are generally less than 0.3 metres in thickness, 10 metres in width and 100 metres in length; or 3) beach or dune deposits are located in embayments, along connecting channels or in other areas of restricted wave action.

[6] - Typically imported cobble/shingle/gravel beach fill with anchoring groynes.

[7] - Very limited structure lifespan.

[8] - Likely insufficient on its own to fully address hazard - must be accompanied by other measures.

[9] - Addresses flood hazard only.

[10] - Nearshore structures require significant analysis and design effort by qualified coastal engineers.

[11] - Technical Guide provides minimum hazard allowance requirements for bedrock.

[12] - Policy does not permit development within *defined portions of dynamic beach hazard.*

NOTES:

Refer to **Table 8.5**, to assess the potential influences and impacts of shoreline management approaches on the physical shoreline processes and characteristics.

Refer to **Table 8.6**, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood, erosion and dynamic beach hazards.

Refer to **Table 9.2, 9.3 and 9.4, Part 9**, to assess the biological impacts related to shoreline management approaches.

Tables must be read in conjunction with Technical Guide text.

8.3 Influences and Impacts of Shoreline Management Approaches

The shoreline is an environmental system made up of various subsystems which are linked and related to each other through various pathways of interaction. These sub-systems include the physical shore processes (i.e., supply and transport of littoral materials, water circulation) the physical characteristics (i.e., onshore/backshore/nearshore topography, surface and groundwater drainage), water quality and aquatic and terrestrial biota. Rapidly expanding development along the shorelines of the *large inland lakes* has led to increased amounts of shoreline protection works. Protection works can alter one or more of the natural shoreline processes or characteristics, and set off a series of chain reactions among the various sub-systems. The result could be a reduction of the natural supply of beach material provided by erosion of the shore, a blockage of the natural movement of beach materials along the shore, a decrease in the nearshore water circulation and a loss of nearshore aquatic habitat and shoreline wetlands. These potential influences and impacts of shoreline management approaches on the physical shoreline process and characteristics are summarized in Section 8.3.1. The relative importance of these potential impacts on creating and/or aggravating *hazards* off-site (i.e., at updrift and downdrift properties) is discussed in Section 8.3.2. A review of the impacts to the physical processes and characteristics, as identified in this section, with respect to the "environmentally sound" aspects of shoreline hazard management, is outlined in Section 9 of this Technical Guide.

8.3.1 Potential Influences and Impacts

For the purpose of this Technical Guide, shoreline management approaches can be considered as alterations to the shoreline environmental system. Environmental **influences** are defined as the environmental changes that are set in motion, or as the natural physical processes that are accelerated or decelerated, by alterations to the environmental system. The resulting net changes to the environmental system, due to the influences, are defined as **impacts**.

Potential impacts can be categorized as either **major** or **minor**, based on the importance of the coastal physical process affected, the spatial extent of the impact, the duration of the impact, the recovery rate of the process affected, the potential for mitigation and the consideration of cumulative effects. For the purpose of this Technical Guide, the definitions of major and minor are as follows:

- **Minor impacts** are those which can be mitigated, that is, the proposed structure/activity will cause impacts which can be mitigated through changes in design and/or timing of activity. Confining impacts to what is considered a minor (as opposed to a major) level is contingent upon having an impact of short duration, availability of mitigation practices, a high rate of recovery, and a low potential for spin-off effects. A minor impact can occur when the degree of change in the coastal process is comparatively unimportant or small in magnitude and/or of a localized nature.

- **Major impacts** occur when the structure/activity has significant long-term or permanent adverse impacts on the net physical coastal processes on or off site. A major impact can occur when the impact is of long-term duration, the rate of recovery of the coastal process is low, there is a high potential for spin-off or indirect effects and/or the process affected is considered to be a critical process with respect to providing *hazard(s)* protection. A major impact is notable or conspicuous in effect and scope with respect to increasing the *hazard(s).*

Shoreline management approaches may address *hazards* locally on-site. However, the characteristics of structures (i.e., location, orientation to the shore, structural form and slope, size of material, permeability), the methods used in their construction and their maintenance and the post-design life of the structures may directly influence the physical shoreline processes and characteristics which in turn may adversely impact the environment and/or increase the *hazards* for others at updrift and downdrift properties.

The following discussion is general in nature and applies to many situations in the large inland lakes. It is intended to serve as a guide in identifying potential impacts. The discussion is not exhaustive and site-specific conditions may differ.

The potential influences of the various shoreline management approaches on the physical shoreline processes and characteristics and the possible resulting impacts are summarized in Table 8.5. For purposes of identification in this Technical Guide, the influences are identified by an '**A**' followed by a number and the impacts are identified by a '**B**' followed by a number. In Table 8.5, the shoreline management approaches are listed across the top of the chart, grouped according to location (onshore, backshore and nearshore) in the same manner as Table 8.4. The five main categories of physical shoreline processes and characteristics are listed in the first column on the left hand side of the table. The potential influences ("A._"), that shoreline management approaches could have on the general processes or characteristics, are listed in the second column and the corresponding impacts ("B._") are listed in the third column. The potential impacts associated with a given shoreline management approach are identified by a "✓". Further detail discussion is provided in the Technical Guide for Great Lakes - St. Lawrence River Shorelines.

If a particular shoreline management approach is being considered, a look to Table 8.5 will indicate the potential impacts of the proposed approach on the physical processes and characteristics. **The relative significance of these potential impacts with respect to increasing updrift/downdrift *hazards* (i.e., none, minor or major) and by shoreline class (i.e., bedrock, cohesive and dynamic beach) is reviewed in Section 8.3.2.** Environmental considerations regarding terrestrial and aquatic habitat are outlined in Part 9: Environmentally Sound Hazard Management, of this Technical Guide.

The physical processes and characteristics of the shoreline that can be influenced and impacted by shoreline management approaches can be combined into five general categories as follows:

- **Supply and Transport of Littoral Materials**

The availability of littoral zone sediments, derived from erosion of the shoreline (both above and below water) and other sources, such as rivers, may be altered by a shore management approach. By definition, any shoreline erosion control structure that works will stop or slow erosion of the shoreline and will result in a reduction of the natural supply of sediments to the littoral system. Revetments and seawalls on cohesive shores protect only the land behind them; they do not alter the rate of nearshore and/or offshore erosion. Reducing the rate of nearshore downcutting must be accomplished by a reduction in wave energy over the profile (i.e., detached breakwaters) or increasing the protective cover layer (i.e., beach fill with anchor structures).

The alteration of the sediment supply has potentially the furthest ranging impact as its effects can extend throughout the littoral cell. For example, the protection of eroding bluffs updrift will reduce the amount of sand available at a downdrift beach. The reduction of sand supply could then increase the erosion of the beach. Along cohesive shores, the sand cover over the nearshore profile plays a role in the downcutting process.

The location and rate of littoral transport, which plays a large role in the erosion and/or deposition patterns, can be changed by the placement of protection works (see Figure 8.38). Structures which form physical barriers along the shoreline (e.g., groynes (see Figure 8.39), artificial headlands) can trap littoral material and prevent it from moving alongshore to downdrift adjacent shores or can possibly redirect the material away from downdrift properties. Structures which reduce the nearshore currents at a subject site (i.e., in lee of detached breakwaters) can also result in reduced alongshore and cross-shore transport. Localized scour can also occur as a result of protection works (see Figure 8.40).

- **Water Circulation**

The circulation and exchange of water in the nearshore areas is dependent on the intensity and frequency of the wave action and the resulting direction and magnitude of the nearshore currents, other lake-wide currents, as well as thermal upwellings and downwellings. Structures can impact the water circulation by altering nearshore currents and by significantly sheltering the shoreline. For example, a detached breakwater will reduce the wave climate and currents on its lee side. Less circulation or exchange of the offshore and the nearshore waters can increase nearshore water temperatures, reduce nutrient exchange, decrease the oxygen content and reduce the cleansing action of the waves which can "sweep" silt material from the nearshore substrate. The magnitude of these potential impacts would depend on the extent to which the shoreline remains "exposed" to lake action (i.e., function of size of structures and gaps between structures or degree of enclosure).

Table 8.5: Summary of Potential Impacts of Shoreline Management Approaches on Physical Shoreline Processes and Characteristics

General Physical Shoreline Processes and Characteristics	Potential Influences (A._) of Shoreline Management Approaches on Physical Shoreline Processes and Characteristics	Potential Resulting Impacts (B._) on Physical Shoreline Processes and Characteristics	Shoreline Management Approaches													
			Prevention		Non-structural Protection				Structural Protection (plus stable slope & flood/erosion allowances)							
			Onshore		Onshore				Onshore		Backshore		Nearshore			
			HA	PA	Re	FP	BM	DE	FI	D	fR/S	rR/S	BN†	G	AH	DB‡
Supply and Transport of Littoral Materials (Erosion & Deposition Patterns)	**A.1** Decreases supply of sediments to the littoral zone	**B.1** Increased long-term erosional stress to downdrift shorelines									✓	✓		✓	✓	✓
	A.2 Increases supply of sediments to the littoral zone	**B.2** Decreased long-term erosional stress to downdrift shorelines											✓			
	A.3 Impedes alongshore transport of littoral material	**B.3** Accretion updrift and/or in lee of structure											✓	✓	✓	✓
		B.4 Increased erosion of downdrift shorelines until bypassing occurs												✓	✓	✓
	A.4 Diverts littoral sediments from close to shore to deeper water	**B.5** Increased erosion immediately downdrift												✓	✓	✓
	A.5 Reduces cross-shore transport of littoral material	**B.6** Less change of beach and nearshore profile during storms													✓	✓
	A.6 Increases wave reflection from shoreline and increases localized currents	**B.7** Localized erosion (scour) along toe of and at alongshore ends of protection works									✓	✓		✓	✓	✓
Water Circulation	**A.7** Increases sheltering of nearshore waters	**B.8** Decreased nearshore wave action													✓	✓
		B.9 Decreased mass water exchange/ circulation of nearshore waters													✓	✓
Backshore & Nearshore Topography	**A.8** Occupies backshore area	**B.10** Altered backshore topography at site (changes terrain and materials)									✓	✓	✓	✓		
	A.9 Reduces wave action at backshore	**B.10** Altered backshore topography at site (profile becomes more stable)									✓	✓	✓	✓	✓	✓
	A.10 Occupies nearshore area	**B.11** Altered nearshore topography (changes bathymetry and materials)									✓	✓	✓	✓	✓	✓
Onshore Topography	**A.11** Occupies onshore area	**B.12** Altered onshore topography (changes terrain and materials)					✓	✓	✓	✓						
	A.12 Stabilizes toe of cliff/bluff/bank	**B.12** Altered onshore topography (with stable toe, crest retreats, as slope flattens to stable condition - often graded during construction)					✓	✓			✓	✓	✓	✓	✓	✓
Surface & Ground Water	**A.13** Disrupts surface and/or ground water drainage from land to lake/channel	**B.13** Altered surface/ground water drainage pattern in onshore/backshore area					✓		✓	✓	✓	✓				

LEGEND:
✓ - potential impact
HA - hazard allowances
PA - property acquisition
Re - relocation
FP - floodproofing
BM - bio-engineering measures
DE - dune enhancement
FI - filling
D - dyking

fR/S - flexible revetments/seawalls
rR/S - rigid revetments/seawalls
BN - beach nourishment
† in backshore & nearshore
G - groynes
AH - artificial headlands
DB - detached breakwater
‡ can also be located in shallow offshore

NOTES:
This Table is general in nature and applies to many situations in the large inland lakes.
It is intended to serve as a guide in identifying potential impacts. It is not exhaustive and site-specific conditions may differ.

Refer to **Table 8.4**, for initial evaluation of shoreline management approaches.
Refer to **Table 8.6**, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood, erosion and dynamic beach hazards.
Refer to **Tables 9.2, 9.3 and 9.4, Part 9**, to assess the biological impacts related to shoreline management practices.
Tables must be read in conjunction with Technical Guide text.

Figure 8.38: Potential Impacts of a Seawall on a Dynamic Beach Shoreline

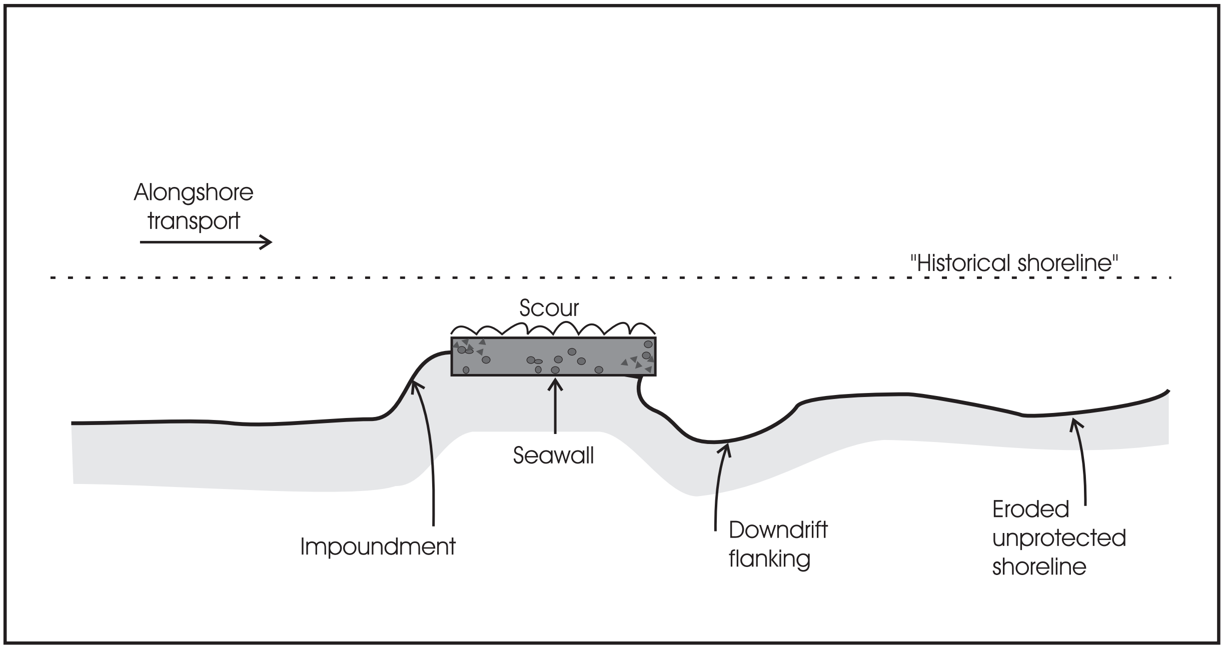


Figure 8.39: Alongshore Transport Trapped and Deflected

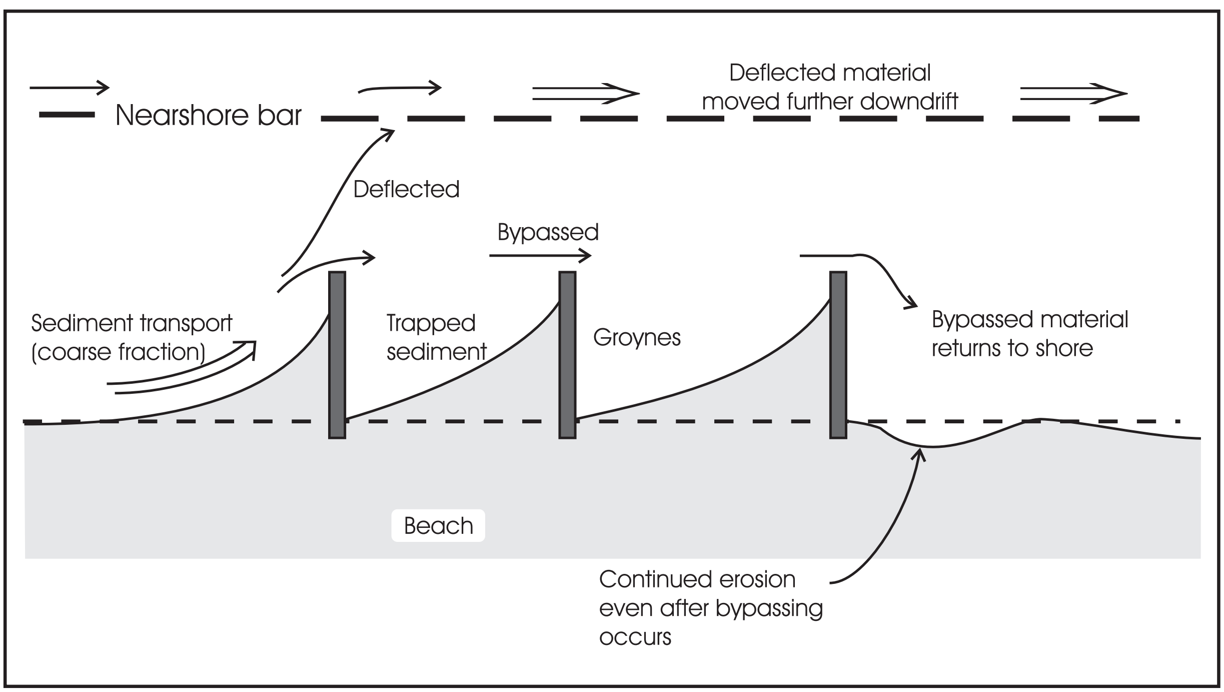
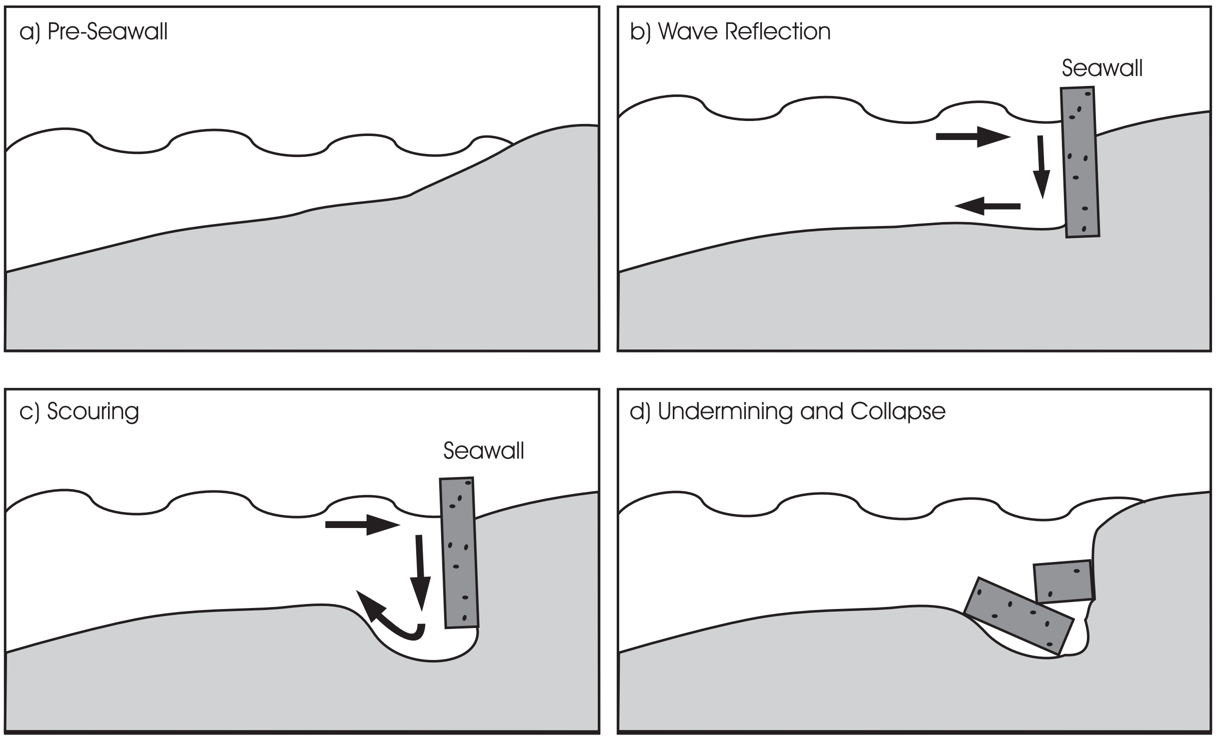


Figure 8.40: Undermining of a Seawall by Wave Scour



. Backshore and Nearshore Topography

The existing surface features of the backshore and nearshore, including relief and terrain may be changed as a result of a shoreline management approach. Protection works directly modify the area where they are located and displace the natural topography. The works can significantly alter the existing surface features, including gradient, texture, interstitial spaces, by covering, replacement and/or removal (see Figure 8.41). For example, an armour stone revetment constructed in the backshore area of a shoreline with a surficial substrate of cobble, would alter the existing gradual slope and native cobble material to a relatively steep slope with large quarried armour stone. Works can also indirectly modify a larger area by altering the wave energy at adjacent shorelines through diffraction and refraction (e.g., sheltering adjacent shoreline may promote sedimentation).

. Onshore Topography

The existing surface features of the onshore area, including relief and terrain may be changed as a result of a shoreline management practice. After protection works are constructed, the slope of the onshore bluff will flatten out as it undergoes self-stabilization. Often, the slope is graded to a stable slope condition as part of the construction. Backshore works often require excavation of the onshore as part of the work.

. Surface/groundwater

The rate and/or direction of flow of the surface and/or groundwater drainage may be altered in the onshore or backshore area by the construction of shoreline protection works. If an impermeable seawall is built in a poorly-drained, low-lying area, the seawall may inhibit the lakeward movement of groundwater causing an increase in the elevation of the water table.

8.3.2 Discussion of Relative Significance of Physical Impacts by Shoreline Class

The following discussion is general in nature and applies to many situations in the large inland lakes. It is intended to serve as a guide in identifying the significance of the potential impacts. The discussion is not exhaustive and site-specific conditions may differ.

The relative significance of the potential physical impacts with respect to increasing the updrift/downdrift flooding, erosion and/or dynamic beach hazards can be evaluated according to shoreline class; dynamic beaches, cohesive shores (fine-grained cohesive and cobble/boulder till), and bedrock. The physical impacts considered are only those associated with the supply and transport of littoral materials. Table 8.6 summarizes the relative significance of the impacts. It was prepared to assist shoreline managers in undertaking a preliminary screening of the potential significance of the impacts with respect to increasing the updrift/downdrift hazards.

The potential impacts, B.1 to B.7, that are related to the supply and transport of littoral materials (see Table 8.5) are listed across the top of Table 8.6. The shoreline classes (general shoreline type, controlling substrate and the surficial substrate) are listed in the first three columns down the left hand side of Table 8.6. The significance of the potential impacts are then identified as none (blank box), minor (hollow circle) or major (filled in circle), for each of the shoreline classes.

a) Dynamic Beaches

Impacts to the supply and transport of littoral materials are generally a major concern along dynamic beach shorelines because these processes govern the behaviour and long-term stability of the beaches. The two primary considerations are that protection works may trap the alongshore sediment transport and that they may divert sediment towards the offshore. Both these influences result in a reduction of sediment, or a sediment deficit, at downdrift properties, which in turn can increase the *flooding*, *erosion* and *dynamic beach hazards*.

Figure 8.41 Backshore/Nearshore Areas Occupied by Protection Works

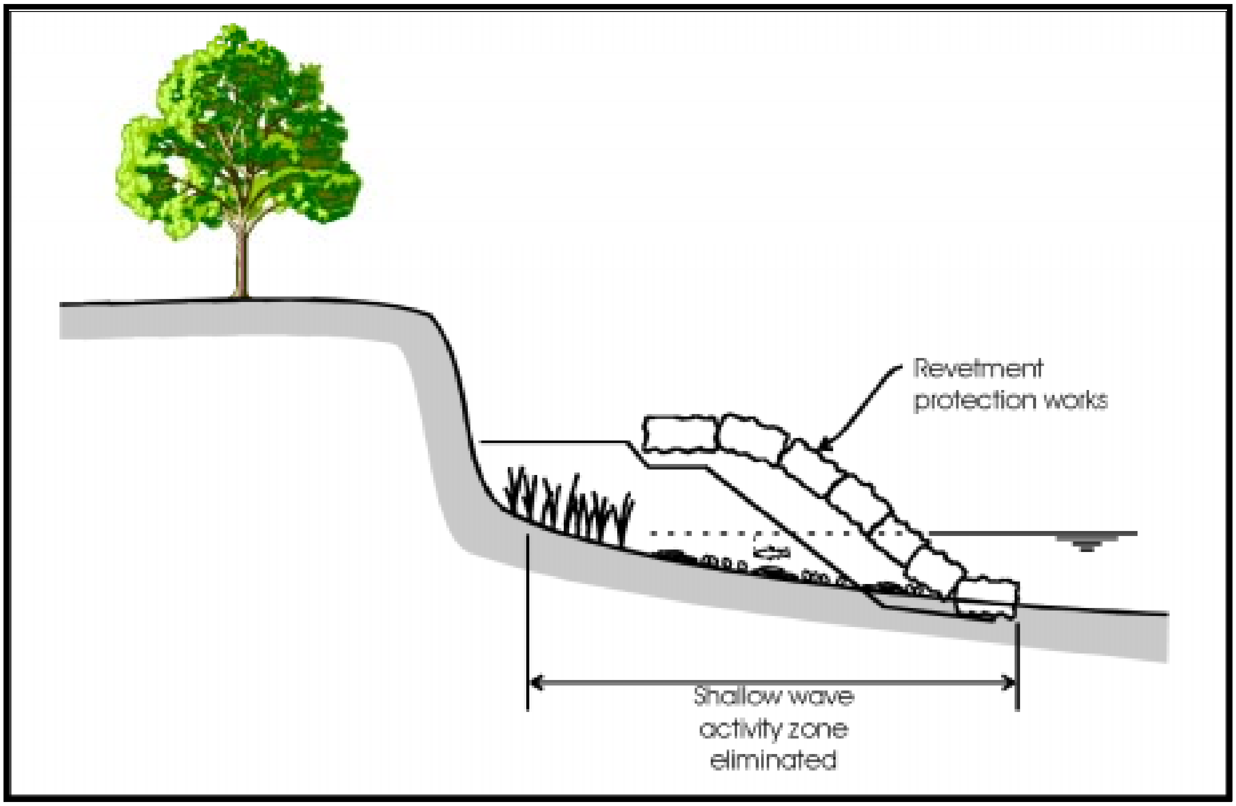


Table 8.6: Likely Significance of Potential Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Flooding, Erosion and Dynamic Beach Hazards

Table 8.6: Likely Significance of Potential Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Flooding, Erosion and Dynamic Beach Hazards

Shoreline Class[1]			Significance of Impacts to Supply and Transport of Littoral Materials with Respect to Increasing Updrift/Downdrift Hazards						
General Shoreline Type Onshore/ Backshore (composition and profile)	**Controlling Substrate** Nearshore (predominant underlying material)	**Surficial Substrate** Nearshore (can appear above water as a beach)[5]	**B.1** - Increased long-term erosional stress downdrift	**B.2** - Decreased long-term erosional stress downdrift	**B.3** - Accretion updrift and/or in lee of structure	**B.4** - Increased erosion downdrift until bypassing occurs	**B.5** - Increased erosion immediately downdrift	**B.6** - Less change of beach and nearshore profile[13]	**B.7** - Localized scour at toe and alongshore ends of works
Bedrock Cliff[2]	bedrock	bedrock							
		cobble/boulder							
	(softer bedrock, such as shale, does erode)	sand/gravel							
		silt/organic[4]							
Bedrock Low Plain[3]	bedrock	bedrock							
		cobble/boulder							
	(softer bedrock, such as shale, does erode)	sand/gravel							
		silt/organic[4]							
Cohesive/Non-cohesive Bluff[2]	bedrock	bedrock							
		cobble/boulder	○[11]						
	(softer bedrock, such as shale, does erode)	sand/gravel	○[11]						○
		silt/organic[4]							
	cohesive cobble/boulder till	cobble/boulder	○[11]			○[11]	○[11]		
		sand/gravel	○[11]			○[11]	○[11]		○
		silt/organic[4]							
	fine-grained cohesive	cobble/boulder	○[11]			○[11]	○[11]		
		sand/gravel	○[11]			○[11]	○[11]		
		fine-grained cohesive	○[11]	○[12]	○[12]				○
		silt/organic[4]							

Table 8.6 continued...(See notes next page)

Cohesive/Non-cohesive Low Plain[3]	bedrock	bedrock							○
		cobble/boulder							
	(softer bedrock, such as shale, does erode)	sand/gravel							
		silt/organic[4]							
	cohesive cobble/boulder till	cobble/boulder				○[11]	○[11]		○
		sand/gravel	○[11]			○[11]	○[11]		
		silt/organic[4]							
	fine-grained cohesive	cobble/boulder				○[11]	○[11]		○
		sand/gravel	○[11]			○[11]	○[11]		
		fine-grained cohesive	○[11]	○[12]	○[12]				
		silt/organic[4]							
Dynamic Beach Backed by Cliff/Bluff[5]	gravel/cobble/boulder	gravel/cobble/boulder	●			●	●		●
	sand	sand	●			●	●		●
Dynamic Beach Low Plain[5]	gravel/cobble/boulder	gravel/cobble/boulder	●			●	●		●
(mainland dune)	sand	sand	●			●	●		●
Dynamic Beach Barrier[5]	gravel/cobble/boulder	gravel/cobble/boulder	●			●	●		●
	sand	sand	●			●	●		●

This Table is general in nature and applies to many situations in large inland lakes. It is intended to serve as a guide in identifying potential impacts. It is not exhaustive and site-specific conditions may differ.

LEGEND:

(empty box) **No Impact**

○ **Minor Impact** - is one which can be mitigated, that is, the proposed structure/activity will cause impacts which can be mitigated through changes in design and/or timing of activity. Confining impacts to what is considered a minor (as opposed to a major) level is contingent upon having an impact of short duration, availability of mitigation practices, a high rate of recovery, and a low potential for spin-off effects. A minor impact can occur when the degree of change in the coastal process is comparatively unimportant or small in magnitude and/or of a localized nature.

● **Major Impact** - occurs when the structure/activity has significant long-term or permanent adverse impacts on the net physical coastal processes on or off site. A major impact can occur when the impact is of long-term duration, the rate of recovery of the coastal process is low, there is a high potential for spin-off or indirect effects and/or the process affected is considered to be a critical process with respect to providing flood and erosion protection. A major impact is notable or conspicuous in effect and scope with respect to increasing the flood, erosion and/or dynamic beach hazard.

NOTES:

- Refer to **Table 8.4**, for initial evaluation of shoreline management approaches.
- Refer to **Table 8.5**, to assess the potential influences and impacts of shoreline management approaches on the physical shoreline processes and characteristics.
- Refer to **Tables 9.2, 9.3 and 9.4, Part 9,** to assess the biological impacts related to shoreline management approaches.
- Tables must be read in conjunction with Technical Guide text.

1 - This Table does not include classification of shoreline exposure and planform (exposed, partial headland, headland-bay, well sheltered).

2 - Cliff/bluff - steeper than 1:3 (vert:horz) and >2 m high.

3 - Low plain - landward slope flatter than 1:3 (vert:horz) or <2 m high.

4 - Typically only found in naturally well-sheltered areas where controlling substrate may not be applicable.

5 - A beach is not classified as a *dynamic beach*, where: 1) beach or dune deposits do not exist landward of the still water line; 2) beach or dune deposits overlying bedrock or cohesive material are generally less than 0.3 metres in thickness, 10 metres in width and 100 metres in length; or 3) beach or dune deposits are located in embayments, along connecting channels or in other areas of low wave action.

11 **May result in major impact at downdrift sink (depositional feature such as a beach) or where existing sand/gravel surficial sediments are of sufficient quantity to affect the downcutting of the nearshore profile and a reduction of the existing surficial sediment quantity will increase the downcutting.**

12 Addition of sand/gravel surficial sediments over a predominantly fine-grained cohesive nearshore profile may increase downcutting.

13 Impact **B.6** is typically limited to the nearshore area in front of, or lakeward, of the subject site and typically does not extend updrift or downdrift. Hence, it is generally not significant with respect to increasing the updrift/downdrift flood and erosion hazards.

The magnitude of the impacts are generally proportional to the alongshore length of the proposed protection works and the distance the structure extends into the nearshore. The longer a structure extends out into the nearshore zone, the greater the volume of littoral material that will be trapped (impact B.3) and the greater the downdrift extent of increased erosion (B.4 and B.5) due to trapping and offshore diversion. All the impacts, except B.4, will occur for the duration of the protection works. Impact B.4 (increased erosion downdrift due to trapping of material updrift) will last only as long as the structure takes to fill up with sediment and bypassing begins to occur.

Impacts can be mitigated by measures which include the placement of imported material compatible with the native littoral material, mechanical bypassing of the trapped littoral material and by reducing the size of the proposed works (e.g., reducing the alongshore length of seawalls and the offshore length of groynes, and increasing the gap-to-length ratio for detached breakwaters). Revetments and seawalls located along beach shores should be positioned as far back from the water as feasible. Reasonable estimates or approximations of the impacts can be made by qualified coastal engineers/scientists. Impacts of protection works on the supply and transport of littoral materials along dynamic beaches can be stopped by removing the protection works. However, removal will often be very difficult and costly and may come too late to prevent downdrift damages.

It is quite evident that groynes and artificial headlands on a dynamic beach can adversely affect the adjacent shorelines by trapping the alongshore sediment transport and by diverting coarse material to the nearshore bar (Philpott 1986; Kamphuis 1990). Evaluation of the impacts can be complex as they depend on many factors including the site characteristics, wave conditions, littoral transport patterns, and the grain size of the beach material. Assessment of the impacts of groynes, artificial headlands and detached breakwaters on dynamic beach shores should be carried out by a qualified coastal engineer.

b) Cohesive Shores

Along cohesive shores, the impact of alterations to the supply and transport of littoral materials is generally not as readily apparent as it is on dynamic beach shores. Previously it had been thought that reducing the sediment supply to all downdrift shores inevitably resulted in increased erosion. However, it is now better understood that this "rule" is mostly applicable only to dynamic beach shores and is not necessarily applicable to cohesive shores.

The recession of a cohesive shoreline primarily depends on the wave forces, the erodibility of the cohesive material and the presence and movement of coarse sediments over the cohesive profile. The importance of the sand cover to the overall erosion of a cohesive shoreline is not very well understood and is the subject of ongoing research.

The coarse sediments which form the narrow beaches along cohesive shores, are typically derived from erosion of the bluffs and the nearshore profile. Where the controlling substrate is cobble/boulder till, nearshore erosion provides only a limited quantity of sediment. Onshore bluff erosion would provide the balance of the shoreline sediment source. Low plain shorelines would also only provide limited sediment supply.

Downdrift littoral sinks (i.e., beaches) can be negatively impacted by a reduction in the sediment supplied by the coarse fraction of eroding cohesive bluffs and nearshore profiles.

Protection works located in the backshore area (seawalls and revetments) can lead to some very localized erosion of the backshore/onshore at the ends of the work. This increased erosion can be the result of wave reflection from the flank wall. This can be mitigated by making a gradual transition (i.e., avoid sharp corners) from the end of the protection work to the adjacent shoreline and/or by ending the works some distance away from the adjacent property.

Silt and organic surficial sediments will accumulate at locations with limited wave action or at significant sink areas. With limited wave action, there will be a lesser concern regarding the supply and transport of littoral materials.

c) Bedrock Shores

The form of bedrock shorelines is not determined by the supply and transport of littoral material. Bedrock erosion is caused primarily by wave action and other processes (wetting/drying, freezing/thawing). These processes are not altered off-site, at updrift/downdrift properties, by shoreline management approaches on-site.

At shorelines where the controlling substrate is bedrock, but the general shoreline type (i.e., onshore/backshore) consists of cohesive or non-cohesive material, erosion of the bluffs, especially at higher water levels, will provide a source of littoral material. Protection of the bluffs may reduce the sediment supply to downdrift beach sinks. The magnitude of the effect will depend on the percentage of beach size material in the bluff material, the bluff height, the length of the proposed protection works, and the overall sediment budget of the littoral cell. For low plain, bedrock controlling substrate shorelines, the volume of littoral material from the onshore will likely be relatively small and the volume from the nearshore will be insignificant.

8.4 Best Management Practices

8.4.1 Environmentally Sound

Ensuring that the protection works can be implemented in an environmentally sound manner is of paramount importance. Environmental considerations, as discussed in Part 9: Environmentally Sound Hazard Management, include but are not limited to:

- enhancing, restoring, rehabilitating and/or creating aquatic, reptile, amphibian and terrestrial habitat where appropriate;
- using diverse aquatic and terrestrial landforms, including the land/water interface, to allow the opportunity to introduce aquatic and terrestrial species and communities to a site (where appropriate) (e.g., undulate the landform and provide a variety of slopes, exposures, elevations and orientations);
- introducing the availability of water (where appropriate) at the site for further opportunity to provide a variety of aquatic and terrestrial habitat; and
- using materials that can provide more "aquatic structure" (i.e., interstitial spaces, variable sizes of materials and vertical relief).

The following best management practices will help ensure that the development and/or protection works will be environmentally sound:

- Locate development landward of the *hazardous lands* and maintain the shoreline in its natural state (see Figure 8.42). Shoreland areas provide a unique ecological zone that is required for certain plant and animal species.

- Native vegetation along the shore presents the most natural edge to water bodies, so preserve it as much as possible (see Figure 8.43). Shoreland areas provide a unique ecological zone that is required for certain plant and animal species. Diverse and balanced species populations are healthier because they are more resistant to disease and other changes to the environment. Maintain as much of the natural landscape as possible to promote a diverse, interesting and heathy environment for plant and animals. Plant additional native vegetation and replace damaged vegetation to improve screening.

- On shorelines adjacent to fish habitat, vegetative buffer strips should extend a minimum of 15 m shoreward from the top of the annual high water mark. A 15 m buffer strip will provide a check on nutrients, contaminants and sediments entering the water, and will help to protect the water temperature of, and food supply to, fish habitat. Additional measures, including a wider buffer strip, may be required to ensure protection of fish habitat if warranted by the site conditions. Areas of particular concern are those immediately adjacent to shorelines with moderately to highly erodible soils, slopes greater than 10 degrees, and long slope lengths. Eroded soil and sediment contain nutrients that promote excessive algae and bacteria in lakes. Excessive suspended sediment levels can be harmful to fish and fish habitat. The addition of bedload/lakebed sediment to waters used a fish habitat is not acceptable.

- Natural stormwater runoff can usually be handled by the natural landscape. Buildings, roads, driveways and patios add “hard” surfaces which are impermeable to water and increase the intensity of the runoff. This an lead to increased erosion. Hard surfaces should be minimized.

- Maintaining a proper sewage system will minimize contaminants from leaking into the ground and surface waters. Nitrate levels should meet specified requirements.

- Construction should be staged to limit the area and duration of soil exposure. The slope length and gradient of disturbed areas should be limited. Disturbance to the existing vegetation should be minimized and disturbed areas should be revegetated as soon as possible. During construction, appropriate sediment control measures should be implemented (e.g., sediments traps, rock check dams, sediment fences, straw bales). Where applicable, ensure that the provisions of the Sedimentation and Erosion Control Plan are implemented. Timing restrictions may apply to avoid impacts to certain life stages of the fish (e.g., spawning, larvae).

- Maintaining natural filter strips and adopting proper hazard allowances should limit the need to alter the shore. If shoreline alterations are necessary they should be sensitively designed, using natural materials such as native boulders or rock (not removed from lakebed) and low growing vegetative screening that will not obscure the view (see Figure 8.44). A combination of vegetative and non-vegetative techniques (see Figure 8.45) is encouraged where permitted by site exposure conditions.

- Aquatic plants are a natural part of healthy aquatic ecosystems. Having too many aquatic plants can interfere with boats swimming and other water activities. At times, some control may be necessary. However, indiscriminate removal of aquatic plants can harm the environment and destroy fish habitat. Permits may be required depending on the location, the method of removal (e.g., mechanical or herbicides) and the quantity to be removed. It is best to consult the local MNR office for further advice.

- Avoid replacing the natural shoreline (see Figure 8.46) with smooth, impermeable seawalls (see Figure 8.47) and revetments (see Figure 8.48). Protection works such as seawall and revetments built in the water cover aquatic plants, rocks and stumps necessary to fish for food, shelter and reproduction. Vertical and/or impermeable walls harden the natural shoreline creating a sterile, unproductive environment.

- Build structures on dry land at or above the high water mark. Select a structure which minimizes disturbance to the lake bottom. The use of revetments constructed of riprap or armour stone are preferred over vertical seawalls constructed from steel sheet pile or concrete. The revetment should conform to the natural alignment of the shore and it should not obstruct the natural flow of water. Revegetation over revetments above the high water mark is recommended. Use clean rocks taken from dry land that are clean and free of soil. The rocks must not be taken from the lake bottom.

- The introduction of sand or gravel (e.g., for dune enhancement, beach nourishment or beach fill) along a shoreline as a protective measure to supplement the natural littoral transport may have detrimental effects on fish habitat. Where such a proposal is considered acceptable, coarse sand, pea gravel or gravel may be necessary.

- Carefully evaluate the need for lawn areas in close proximity to the water's edge (see Figure 8.49). Watering can waste valuable groundwater. Lawn fertilizers, pesticides and herbicides tend to runoff into the water and degrade the lake. Eliminating the lawn adjacent to the lake (see Figure 8.50) will help to preserve the environment. If a lawn is needed, minimize the size and use safe additives in the proper amounts.

Figure 8.42: Development Setback from the Shore and Existing Vegetation Maintained

Figure 8.43: Preserve Shoreline Vegetation

Figure 8.44: Biotechnical Shore Protection

Figure 8.45: Combination of Structure and Vegetation

Figure 8.46: Maintain Natural Shoreline

Figure 8.47: Avoid Smooth, Impermeable Seawalls

Figure 8.48: Avoid Smooth, Impermeable Revetments

Figure 8.49: Carefully Evaluate Need for Lawn Area

Figure 8.50: Eliminate Lawn Area

8.4.2 Aesthetics and Recreational Value

Aesthetics and recreational concerns should be incorporated into the design. Increasing accessibility to the waters edge is desirable but not always feasible. Aesthetic and recreational considerations must not override significant structural performance and stability criteria if the structure is to be considered as addressing the hazard.

Proposed works which will be predominantly for the recreational benefit of one property owner should not be to the aesthetic and/or recreational detriment of adjacent property owners, especially in situations involving Crown land. In these instances, the concerns of the adjacent property owners should be given proper and due consideration.

8.4.3 Design Criteria

Criteria for the design of shoreline protection works include the following:

- project life;
- structure design life;
- acceptable level of risk;
- factor of safety;
- water level and wave conditions (including return period);
- floodproofing criteria;
- ice;
- structure performance and stability analysis;
- response of littoral processes;
- construction materials and methods;
- structure access, maintenance and replacement;
- adjacent protection works (risk of failure, anticipated useful functional life, flooding concerns, reliance of works at site on adjacent works);
- assessment of impacts on coastal processes and impacts to updrift/downdrift shorelines;
- environmental soundness;
- aesthetics and recreational value; and
- benefit-cost evaluations.

The relative importance of these criteria and the rigour with which they are evaluated will vary by project. The type and size of project and the sensitivity of the location will generally determine the level of effort that goes into the design and impact evaluation process.

Protection works intended to protect against long-term erosion and/or which extend below the 100 year flood level should be designed by a professional engineer with experience and qualifications in coastal engineering. Slope stability analysis should be carried out by a professional engineer with experience and qualifications in geotechnical engineering.

Protection works located above the 100 year flood level which are intended to protect only against storm damage (wave uprush, overtopping and other water related hazards) must have due regard for the coastal environment and forces and be of sound construction. Designs can be prepared in accordance with guidelines prepared by various agencies (e.g., USACE 1981, 1984; MNR 1987). Caution should be exercised when considering “low cost” structures as these are typically not recommended for shorelines exposed to moderate to high wave energy.

Further details are provided in Appendix A7.1 of the Technical Guide for Great Lakes - St. Lawrence River Shorelines.

8.4.4 Summary of Conditions to be Satisfied for Shoreline Protection Works

It is recommended that a number of conditions be satisfied prior to new protection works being implemented. They include, but are not limited to, the following:

1) The purpose or objective of the proposed works (i.e., to prevent storm wave damage due to wave uprush, overtopping, or other water related hazards, or to stabilize erosion of the shore over the long-term) should be clearly outlined.

2) The proponent should clearly establish ownership of the land where the protection works are to be constructed. Work proposed for Crown land may require a Work Permit.

3) Protection works intended to protect against long-term erosion and/or that extend below the 100 year flood level should be designed by a professional engineer with experience and qualifications in coastal engineering. Slope stability analysis should be carried out by a professional engineer with experience and qualifications in geotechnical engineering.

4) Protection works located above the 100 year flood level which are intended to protect against storm damage (wave uprush, overtopping and other water related hazards) should have due regard for the coastal environment and forces and be of sound construction. Designs can be prepared in accordance with guidelines.

5) The design and installation of protection works should allow for access to the protection works for appropriate equipment and machinery for regular maintenance purposes and/or to repair the protection works should failure occur.

6) Protection works should be coordinated with adjacent properties for an existing development.

7) The works should not aggravate existing *hazards* and/or create new *hazards* at updrift/downdrift properties.

8) The protection works should be environmentally sound.

9) To demonstrate points 7) and 8), each proposal for protection works should include an impact assessment based on accepted engineering and scientific principles. The assessment should include a detailed description of the site and must address the following requirements:

   - the proposed works will not adversely affect the littoral transport rates;
   - long-term erosion rates at updrift/downdrift properties will not be increased;
   - existing adjacent protection works will not be adversely affected; and
   - the terrestrial and aquatic ecosystem will not be adversely affected.

10) Adjacent property owners, for an appropriate distance on either side of the proposed works, should be given an opportunity to comment. Works that are not primarily for the purpose of addressing the hazards (i.e., the works are primarily for recreational and/or aesthetic purposes) and which are proposed for Crown land should not adversely impair the use and enjoyment of the shoreline by adjacent property owners.

11) Depending on the shoreline ownership issue, consideration should be given for maintaining pedestrian access along the beach (if there is one).

12) Quality control should be exercised during construction. The designer should monitor construction.

13) The completed protection works should be monitored periodically to ensure that any problems are detected in a timely manner in order for corrective action to be taken.

14) All costs associated with the design, study of impacts, construction, future maintenance and monitoring are solely the responsibility of the proponent (landowner).

8.4.5 Common Deficiencies

Aside from the expense of protection works and the potential updrift/downdrift and environmental impacts, all too often, protection works have been inadequate at even addressing the *hazards* at the site. This has been due to the lack of consideration and/or understanding of the relevant coastal processes (e.g., water levels, waves and currents, morphology, sediment processes) and their interaction with shore protection structures, inadequate design procedures, poorly executed and monitored construction and little or no maintenance. Common deficiencies include:

- the structure is not high enough to protect against wave uprush and/or it does not have adequate protection against wave overtopping;
- toe stones of revetment subject to sliding;
- future downcutting of the nearshore profile not considered;
- size of primary armour is insufficient;
- inadequate toe scour protection;
- inadequate underlayer filter;
- inappropriate geotechnical filter;
- intended response of littoral processes is not realized (i.e., groynes do not trap beach material);
- insufficient mass of gravity seawalls;
- insufficient embedment and/or anchoring of steel sheet pile walls;
- nondurable materials (poor quality armour stone, poor quality concrete, lack of cover over reinforcing steel);
- protection is not coordinated on a reach basis;
- poor or no maintenance access;
- visually unattractive; and
- water's edge not accessible.

8.5 Summary

8.5.1 Addressing the Hazards

For certain *development* and *site alteration* to be permitted within *hazardous lands* adjacent to the shorelines of the *large inland lakes*, Policy 3.1.3 states that all of the following requirements must be fulfilled:

- the hazards can be safely addressed, and the *development* and *site alteration* is carried out in accordance with *established standards and procedures* (Policy 3.1.3(a));
- new hazards are not created and existing hazards are not aggravated (Policy 3.1.3(b));
- no adverse environmental impacts will result (Policy 3.1.3(c));
- vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies (Policy 3.1.3(d)); and
- the *development* does not include *institutional uses* or *essential emergency services* or the disposal, manufacture, treatment or storage of *hazardous substances* (Policy 3.1.3(e)).

Section 8 of this Technical Guide provides direction on how to safely address the *hazards.* An overview of the various shoreline management approaches that can be considered for addressing shoreline *flooding, erosion and dynamic beach hazards* is presented. The different types of approaches are broadly grouped into three primary categories: prevention, non-structural protection and structural protection works. The approaches are further grouped according to location: onshore, backshore and nearshore.

Prevention is the orderly planning of land use and the regulation of development in *hazards* susceptible shorelines. Prevention approaches reduce hazard losses by modifying the loss potential (i.e., hazard allowances and property acquisition). Protection approaches are engineered methods for protecting development located within *hazards* susceptible shoreline areas and they reduce hazard losses by modifying the *hazards* at the shoreline. Protection approaches can be further classified as non-structural or structural. Non-structural protection works are activities that do not involve the construction or placement of significant additional structures or material at the shoreline.

There are essentially four basic types of non-structural protection works: relocation, floodproofing, bio-engineering measures and dune enhancement. Structural protection works involve the construction and/or placement of significant additional structures and/or materials at the shoreline. There are eight basic types of structural protection works: filling, dyking, flexible revetments and seawalls, rigid revetments and seawalls, beach nourishment, groynes, artificial headlands and detached breakwaters. Beach nourishment is considered a "soft" structural protection approach.

Prevention approaches are generally the most environmentally sound and cost-effective means of ensuring that buildings and structures are not susceptible to *flooding, erosion and/or dynamic beach hazards* and that adjacent properties and existing developments do not sustain damages as a result of new development. Prevention approaches tend to result in little or no impact on the environment by maintaining the shoreline in its natural state. In addition, prevention is considered to be a proactive practice as opposed to the reactive approaches of protection and emergency response.

While prevention is the preferred alternative for addressing the *hazards*, it is recognized that in certain situations proper non-structural and structural protection works, when used in conjunction with stable slope and hazard allowances may be appropriate. Prior to permitting development within the limits of the *flooding hazard*, *erosion hazard* and/or the *dynamic beach hazard*, outside of the *defined portion of a dynamic beach* and *defined portions of the 100 year flood level on connecting channels* (i.e., Policy 3.1.2 (a) and (b)), through the implementation of protection works, proponents should demonstrate that other alternative approaches have been evaluated and have been found to be not feasible. Once it has been determined that the shoreline *flooding, erosion and/or dynamic beach hazard* requires a shoreline management response and that prevention and nonstructural alternatives are not feasible, structural protection may be considered.

Addressing the *hazards* through the use of *established standards and procedures* (i.e., floodproofing, protection works, and access standards) is discussed. The standards include stable slope and hazard allowances. Table 8.4 summarizes the appropriate shoreline management approaches to address the *hazards* for development based on the different types of shoreline as defined by the recommended shoreline classification scheme.

Determining whether or not a particular shoreline management approach safely addresses the *hazards* at a given site is only the first step in establishing the best overall acceptable approach. In addition to addressing the hazards at the site, the selected management approach must not create or aggravate existing *hazards* off-site (Policy 3.1.3(b)) nor can it result in any adverse environmental impacts (Policy 3.1.3(c)). Evaluating the effects of the works on creating or aggravating *hazards* off-site (i.e., updrift and downdrift properties) is discussed in Section 8.3. The general physical shoreline processes and characteristics, and how they may be influenced by the approaches, are identified. The potential impacts that may result from the influences are outlined. The potential influences and impacts of the various shoreline management approaches are summarized in Table 8.5. Section 9 of this Technical Guide uses the influences and impacts identified in Section 8.3 to assess the environmental impacts of the approaches.

An initial assessment of the relative importance of the potential impacts on the physical shoreline processes and characteristics with respect to increasing the *hazards* off-site is provided. The relative significance of the impacts, identified as major, minor or none, are outlined in Table 8.6.

Following the evaluation of addressing the *hazards* at the site, and the determination of whether or not the proposed approach will cause or aggravate *hazards* off-site, it is required that the approach be assessed for adverse environmental impacts. Potential biological impacts to the environment are outlined in Part 9: Environmentally Sound Hazard Management.

8.5.2 Suggested 7 Step Procedure: Addressing the Natural Hazards

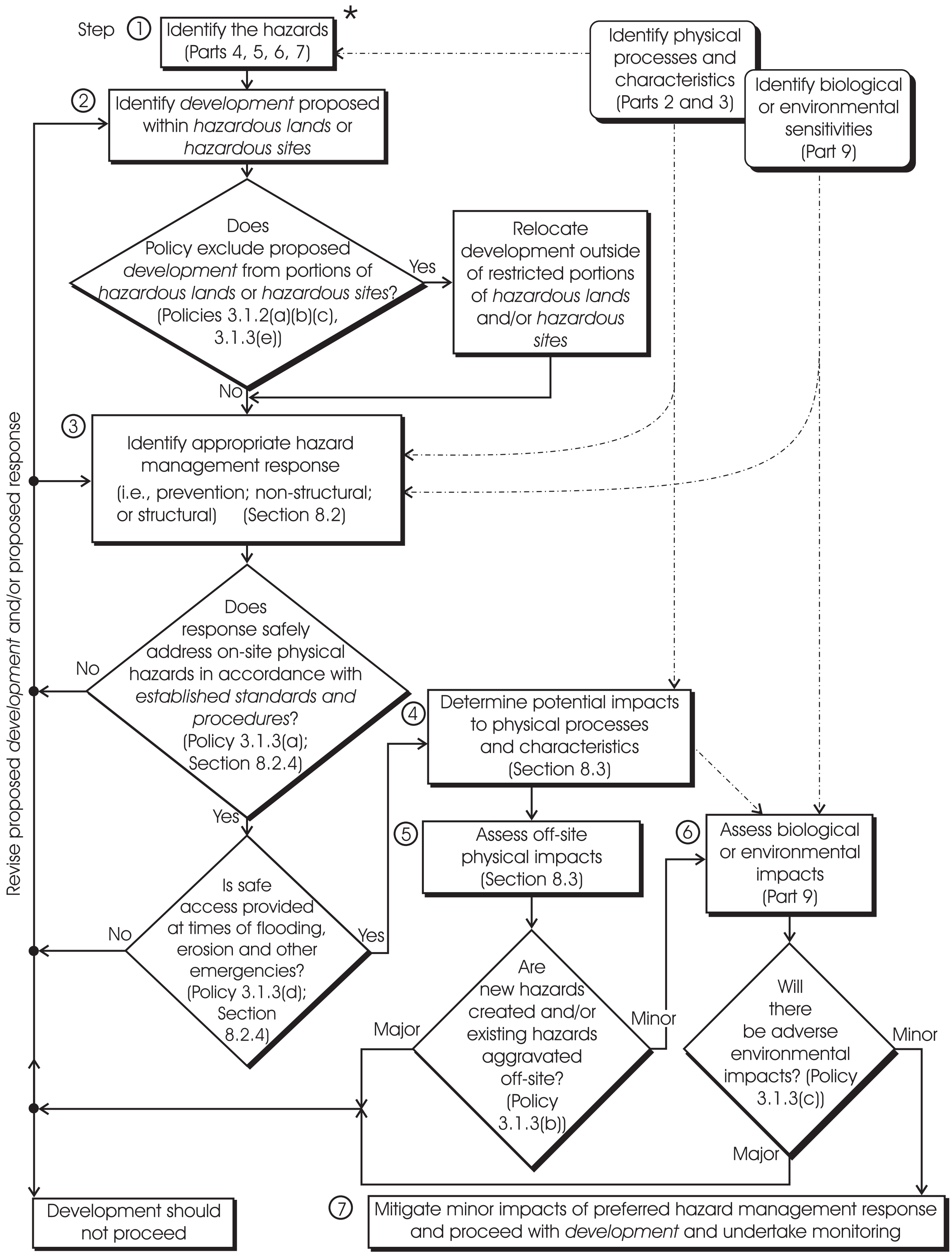
The suggested 7 step procedure is designed to aid decision-makers in evaluating an area, or particular location, within *hazardous lands* and *hazardous sites*. The procedure helps to ensure that consideration is given to both the physical and biological influences and impacts when selecting which, if any, natural hazard management response (e.g., prevention, non-structural protection works or structural protection works) would provide the "best management practice" given local site conditions. The steps include:

- **Step 1:** **Identify Hazards;**
- **Step 2:** **Identify *Development* Proposed Within the *Hazardous Lands* or *Hazardous Sites*;**
- **Step 3:** **Identify Appropriate Hazard Management Response;**
- **Step 4:** **Determine Potential Impacts to Physical Processes and Characteristics;**
- **Step 5:** **Assess Off-Site Physical Impacts;**
- **Step 6:** **Assess Biological or Environmental Impacts; and**
- **Step 7:** **Mitigate Minor Impacts of Preferred Hazard Management Response.**

A flowchart of the Suggested 7 Step Procedure for addressing the natural hazards is presented in Figure 8.51. The procedure focuses on some basic questions and issues regarding the natural hazards that should be addressed in any development decision-making process. The level of evaluation should be site specific and directly proportional to such factors as the size, severity, and type of risks and the potential physical and biological impacts that may result.

It must be pointed out that this 7 step procedure only refers to the natural hazards under Policy 3.1, Public Health and Safety, of the Provincial Policy Statement (May 1996). Proponents should also consider other applicable policies of the Provincial Policy Statement (e.g., Natural Heritage) and any other relevant provincial and federal legislation, including but not limited to: *Public Lands Act*; *Lakes and Rivers Improvement Act*; *Fisheries Act*; and *Navigable Waters Protection Act*. Keep in mind that approval from one government agency does not guarantee approval from another government agency.

Figure 8.46: Suggested 7 Step Procedure: Addressing the Natural Hazards



* NOTE: Proponent must also consider other relevant policies and legislation (including, but not limited to, Public Lands Act, Lakes and Rivers Improvement Act, Fisheries Act, Navigable Waters Protection Act)

The beds of, or land under, most waterbodies in Ontario are legally public land (i.e., Crown land). The construction of most buildings and structures on Crown land normally requires the approval of MNR under the *Public Lands Act* in the form of a land use occupational authority. Since 1989, any construction must be carried out in accordance with a Work Permit.

Recent legislative changes have amended the *Public Lands Act* so that some buildings and structures no longer require work permit approval. However, MNR still requires permits for many other activities on Crown land. Examples of activities for which MNR requires a permit, include:

- docks, boathouses and ramp structures that occupy more than 15 square metres of shorelands (i.e., crib docks and/or boathouses where the total surface of all historical cribs and the proposed new cribs exceeds 15 square metres in surface area; docks and boathouses with solid foundations (e.g., concrete), jetty docks, or docks constructed with steel sheeting);
- dredging (including new boat channels, swimming areas and removal of rocks and boulders) and filling activities;
- construction of breakwalls;
- construction of all new roads;
- construction of trails, other than for mineral exploration purposes;
- construction of bridges and dams;
- installation of large culverts or culverts draining a large area;
- construction of most buildings on public land;
- removal of aquatic vegetation (depending on location and quantity).

Docks and boathouses which will not require a work permit:

- cantilever docks;
- floating docks and floating boathouses;
- docks and boathouses supported by posts stilts or poles;
- boathouses built above the high water mark;
- crib docks and crib boathouses where the total supporting crib structure (including historical crib strcutures) does not exceed 15 square metres in surface area;
- any combination of the above (e.g., a floating dock with a crib less than 15 square metres);
- boat lifts and marine railways;
- removal of aquatic vegetation (depending on location and quantity).

It is recommended that you contact the local MNR office for further details on work permits.

The federal *Fisheries Act* provides for the protection of fish habitat. Under this Act, no one may carry out work that harmfully alters, disrupts or destroys fish habitat unless there is specific project authorization from the federal ministry. Also, it is not permitted to deposit a harmful substance in water frequented by fish. A conviction under the *Fisheries Act* can result in fines of up to one million dollars and/or imprisonment, and you may be required to cover the costs of restoring the site.

9.0 ENVIRONMENTALLY SOUND MANAGEMENT WITHIN HAZARDOUS LANDS

Increasing pressure to develop along shorelines susceptible to *flooding*, *erosion* and *dynamic beach hazards* has resulted in detrimental impacts to the shore and aquatic ecosystem. Effective shoreline management requires implementing agencies to manage not only the hazards (i.e., flooding, erosion, dynamic beach) but also recognize and understand potential impacts of any such actions on the shoreline environment or ecosystem and the mandates and objectives of other resource management programs (e.g., fisheries, wetlands, wildlife).

The purpose of Section 9 is to provide direction in considering the shoreline environment. Through understanding the function and susceptibility of various shoreline ecosystems to disturbance, the potential impacts that may occur as a result of proposed development or remedial works can be identified, and methods of reducing these impacts through design changes or mitigation measures can be implemented.

Environmentally sound refers to those principles, methods and procedures involved in addressing the protection, management and enhancement of the shoreline ecosystem which are used in disciplines such as geology, geomorphology, botany and zoology. These methods and procedures are applied in the study of coastal processes, vegetation, wildlife, and aquatic habitat resource management.

9.1 Provincial Policy And Provincial Natural Hazards Management Program

The direction and intent of Policy 3.1: Public Health and Safety: Natural Hazards (Provincial Policy Statement, May 1996) for *large inland lakes* is to ensure that shoreline environments and related resource management values and programs are given due regard in any decision-making process.

Where *development* and *site alteration* may be considered within the least hazardous portions of the “area of provincial interest”, as defined by the *hazardous lands*, Policy 3.1.3 confirms the standards and requirements which must all be fulfilled. One of the five standards and requirements is that:

"no adverse environmental effects will result" (Policy 3.1.3(c))

To assist in clarifying and ensuring that “no adverse environmental effects will result”, specifically that due regard and recognition is given to environmental concerns and impacts in any decision-making process dealing with the shorelines of *large inland lakes*, **Part 9: Environmentally Sound Hazard Management within the Hazardous Lands** provides the information and direction necessary to assist shoreline managers in achieving this goal.

The management principles to be followed are:

- recognition of the connection between all life within the natural world, including humans;
- preservation of biodiversity;
- integrated resource management;
- prevention of negative environmental impacts in new resource situations; and
- "precautionary principles" in resource use, due to incomplete understanding of ecosystem function.

The objective is to ensure the long-term health of ecosystems by protecting and conserving soil, aquatic, forest and wildlife resources as well as their biological foundations.

9.2 Environmental Receptors And Sensitivities

9.2.1 Shoreline Ecosystem

The environmentally sound management of shorelines requires an understanding not only of the changes to physical processes that result from protection works, as described in Section 8: Addressing the Hazard, but also of the effects of these physical processes on the shoreline ecosystem. The significance and susceptibility of the relationships in this ecosystem to changes resulting from protection works are the focus of this section.

For the purpose of this section, an effect is a change to the existing environment, and may be positive or negative. An impact describes a detrimental change to the environment.

The biological environment is best described in the context of the shoreline ecosystem. An ecosystem is a dynamic network of living organisms interacting with each other and with their environments. The shoreline ecosystem can be described as the ecological unit comprised of terrestrial and aquatic organisms and their physical environment which are inseparably inter-related and interact with each other because of the land/water interface (illustrated in Figure 9.1). This land/water interface is in a state of constant change through the movement, removal and deposition of materials by the action of water. The complexity of the physical characteristics of the shorelines provides a diversity of habitat types for plant and animal species.

For practical reasons, in this document, ecosystems are considered as areas with relative homogeneity which may be described and characterized efficiently. The environmentally sound management of the shoreline ecosystem requires both the recognition of these ecosystem units as well as their functions and interactions including condition, shape, diversity, size, configuration and connectivity in the landscape. The environmentally sound management of shorelines also needs to ensure adequate provision of habitat for viable populations of a diversity of species in areas which are large enough to accommodate natural disturbances.

Habitat is the combination of living and non-living things which provide a particular species with the resources it needs to complete its life cycle. These may include soil, water, air, rocks, rain, heat and the other plants and animals which provide the food needed for survival. The existence of a diversity of habitats is essential to accommodate the needs of many species and to ensure the continued diversity of wildlife.

The area of provincial interest for shorelines of *large inland lakes* extends from the landward limit of the *hazardous lands* lakeward to the limit of significant effect of physical processes, generally a water depth of 2 to 5 m. In some cases, the shoreline ecosystem that is impacted by protection works extends beyond these boundaries. In such cases, the far-reaching biological impacts must be taken into consideration along with the effects of physical processes.

The shoreline ecosystem can be considered in terms of the terrestrial, aquatic and wetland ecological units and the communities they support.

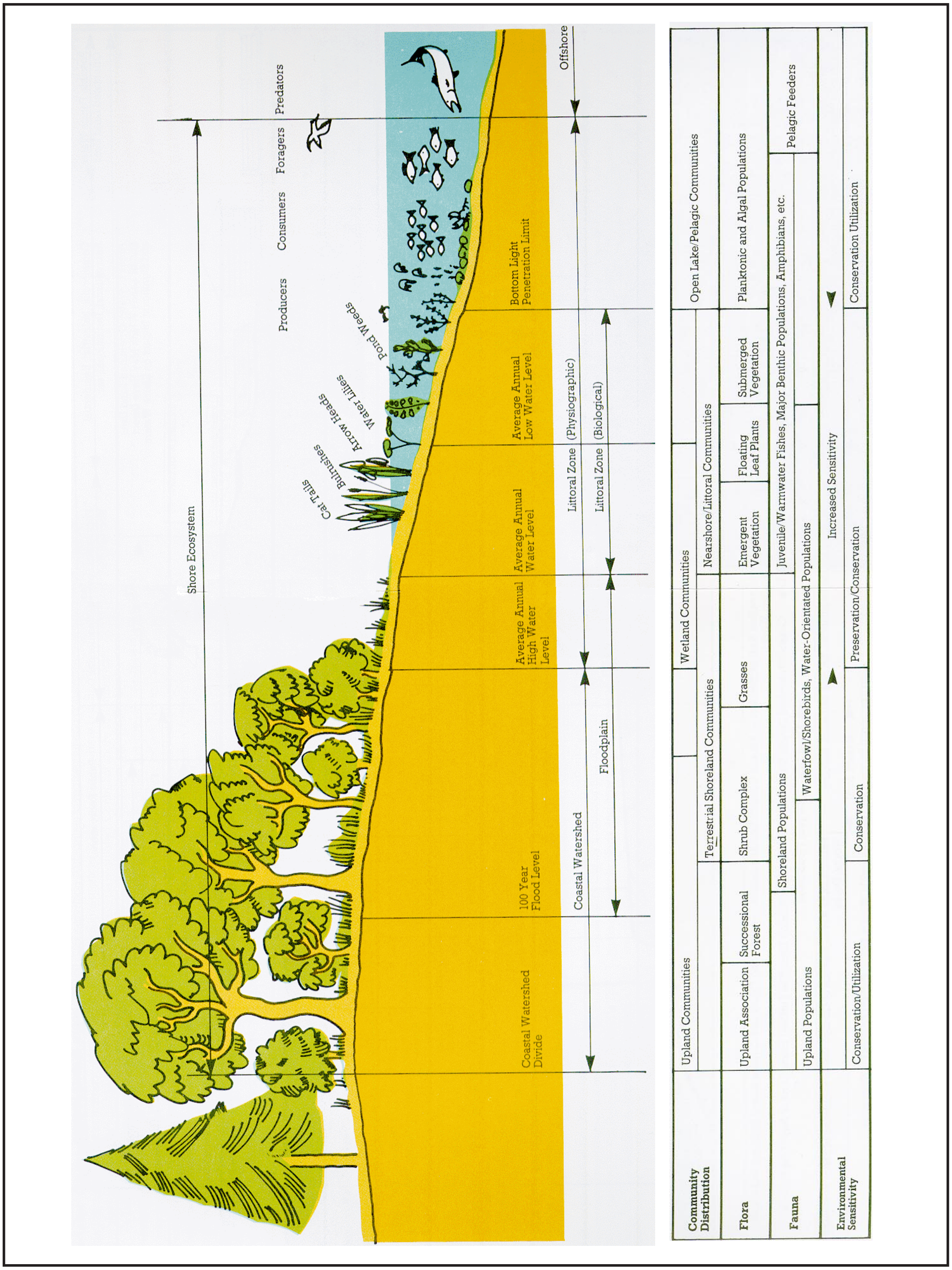
As shown in Figure 9.1, the spatial distribution of these communities overlap. For example, the area between the average low water and the high water level may support terrestrial shoreline, wetland or littoral (aquatic) communities. For the purposes of this Technical Guide, three general classifications will be used:

- **Terrestrial Habitat** includes the plant and animal habitat of predominantly terrestrial species in the upland or backshore areas of the shoreline. Terrestrial communities range from shoreland communities such as herpetofauna found in beach/dune areas to the upland communities which use the shoreline as a migration corridor.

- **Wetlands** by definition, wetlands are those "lands that are seasonally or permanently covered by shallow water, as well as lands where the water table is close to or near the surface (Provincial Policy Statement, May 1996). In either case, the presence of abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic or water tolerant plants".

- **Aquatic Habitat** the *Federal Fisheries Act* (Sec. 34.C1) defines fish habitat as "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes". This includes communities in the nearshore or littoral zones which are the shallow areas close to shore, river mouths, and embayments as well as communities in the open lake.

Figure 9.1: Selected Characteristics of a Shore Ecosystem



For each of these three classifications, the function and significance are discussed below and its susceptibility to disturbance is described. The function and significance of a ecological unit includes the interrelationships between it and other components of the ecosystem, its general importance, in terms of its economic or social value, or its intrinsic value such as providing habitat to endangered species.

The susceptibility of an ecological unit describes the response of that particular area to stress or changes being placed upon it. Areas that can withstand this stress, or can adapt or recover quickly have a low susceptibility to disturbance. Stress or change to the shoreline ecosystem can be caused by natural processes (i.e., large storm) or by human actions such as protection works. The focus of this section is on susceptibility to disturbance resulting from protection works.

As described in Section 8, protection works can be categorized into three groups, each having a different potential to impact on the shoreline ecosystem. These are prevention, non-structural protection, and structural protection.

Prevention techniques, such as the siting of buildings landward of the shoreline hazard limits, property acquisition, and non-structural protection works, such as relocation and floodproofing, do not require alteration to the nearshore and backshore environments. The environmental impacts and potential for long-term disturbance to sensitive habitats from these measures are considered to be negligible.

Other non-structural protection works, such as bluff measures and dune enhancement, require some alteration of the onshore and backshore. These measures may add new stressors to susceptible habitats but often provide an opportunity to enhance environmental conditions if done properly (e.g., stabilization of dune vegetation).

Structural protection works may occupy the onshore (e.g., filling and dyking), backshore (e.g., revetments and seawalls) and nearshore (e.g., beach nourishment, groynes, headlands and detached breakwaters). Protection works have the potential to cause environmental impacts depending on the susceptibility of the biological communities and their associated habitats to disturbance.

9.2.2 Characteristics of the Shoreline Ecosystem: Function, Significance and Susceptibility to Disturbance

a) Terrestrial Habitats

Terrestrial habitat includes the plant and animal habitat of predominantly terrestrial species. These include communities that are not necessarily water-oriented but may inhabit the upland or backshore area.

. Function and Significance

Terrestrial habitats play an important role in the shoreline ecosystem. Key roles of shoreline vegetation include:

- providing shelter and protection for a variety of wildlife species;
- providing linkages along the shoreline for the movement of wildlife;
- stabilizing slopes as shallow rooted grasses hold soil particles in place while deeper roots of woody vegetation prevent slippage of soil layers;
- slowing wind velocity and trapping wind blown sediments; and
- helping prevent erosion by removing water from bluff areas through uptake and transpiration and absorbing the energy of falling rain.

Wildlife that use shoreline areas are invaluable in their own right. They are also a renewable resource that provide many benefits and socio-economic advantages to Canadians. Other activities such as hunting also provide economic benefits. It is vitally important to treat habitats on which various wildlife depend as a precious resource and to manage those habitats in such a way that future generations will receive the full benefits in perpetuity.

Extensive shoreline development, Intensive agriculture and urban development have resulted in the elimination and fragmentation of wildlife habitats. This often results in a replacement of the former habitat with less complex and less stable ecosystems, characterized by reduced biodiversity. Pre-disturbance species are replaced by the opportunistic species which adapt to the altered environment. Fragmentation also results in the disruption to movement corridors or linkages along the shoreline.

Large inland lakes support many different types of terrestrial habitats. For example, wooded bluffs provide shelter and corridors for wildlife movement but on unprotected beaches, the conditions may be hostile to many wildlife species. The beach/dune environment provides habitat for a variety of plants and wildlife. Birds such as semipalmated piper and whimbrel use beach systems during migration. They are also used for breeding by kingfisher, bank swallow, piping plover, killdeer, and spotted sandpiper. Turtles, snakes and other herpetofauna use sandy beaches and dunes for laying eggs.

The beach dune is also a feeding area for birds, mammals, and herpetofauna. Many shorebirds and gulls use the beach zone for feeding, utilizing material carried on shore by waves as well as invertebrates. Nests of birds and herptiles provide food for other birds and mammals.

. Susceptibility to Disturbance

Terrestrial habitats are most susceptible to disturbance from structural protection works which change the topography of the backshore or which result in the removal of vegetation.

An important characteristic of the shoreline for mammals such as raccoons, deer, moose, fox and skunk is the availability of drinking water. Therefore these areas are sensitive to any changes that may affect the safe access of animals to the water's edge. This may include changes to the topography or slope that restricts access, or the clearing of vegetation which removes the protective vegetative cover. The clearing of vegetation may also increase the susceptibility of the backshore to erosion and may disrupt wildlife movement corridors along the shoreline.

Beach dunes are susceptible to a number of stresses. The beach wave zone receives nutrient and energy inputs from the body of water. The presence of washed up vegetation, fish and other organisms results in significant local nutrient inputs to the beach zone for plant growth and for many scavengers. Beach cleaning and sweeping results in the removal of this material.

Turtles, snakes and other herpetofauna utilize the shallow water, beach and backshore areas of the shoreline. These creatures serve an important role in providing food for both higher and lower levels of the food chain. Tadpoles, turtle hatchlings, frogs and toads are a very important food source for many species of marsh birds, fish and riverine animals. Many herpetofauna begin the decomposition phase by feeding on carrion and plants that other animals have left. Herpetofauna habitat includes driftwood, debris, quiet backshore lagoons, vegetation and rock crevices which provide necessary cover and protection. The removal of this material, particularly the removal of shoreline vegetation and dredging of soil, reduces not only the food sources available to herpetofauna but also places stress on other organisms.

b) Wetlands

Wetlands, which interface between aquatic and terrestrial environments, are defined as lands where the water table is at, near or above the land surface long enough each year to support the formation of hydric soils and the growth of hydrophytes, as long as other environmental variables are favourable.

Shoreline wetlands provide an important source of fish and wildlife habitats. Shoreline wetlands types include:

.	Open Shoreline Wetlands	usually exist as a hydrophytic vegetation fringe adjacent to the shoreline. The fringe generally tends to expand inland or lakeward in response to lake effects such as wave action. The dominant vegetation is usually emergent, however submergent vegetation may also be present, although not necessarily bordering on the shoreline.
.	Unrestricted Bays	are characterized by a marshy fringe along a bay shoreline, having natural protection from such lake effects as wave action. Depending on its size and depth, the whole bay could be vegetated. Submergents can be a part of those vegetative communities. This wetland type also includes typical open shoreline areas that are sheltered by an island or peninsula.
.	Shallow Sloping Beach Wetlands	are typically areas with very gentle to almost flat slopes on sand substrates. Very small variations in lake levels have widespread effects on vegetation zones. Sand bars, if present, provide some wave protection.

. Function and Significance

Wetlands serve many important functions within the ecosystem. These functions, which may be described as the biological, physical and socio-economic interactions that occur in an environment as a direct result of the properties of the wetland, include:

- groundwater recharge and discharge;
- flood and/or erosion damage reduction;
- shoreline stabilization;
- sediment trapping;
- nutrient retention and removal;
- food chain support;
- habitat for fish and wildlife;
- corridors for wildlife movement; and
- social and economic benefits.

Along the shorelines of large bodies of water, wetlands can act as a buffer between open water and uplands. The dense root systems and stems of wetland vegetation break up wave energy and stabilize the shoreline as well as trap silt and organic materials carried by overland runoff.

Wetlands help to purify water by converting nitrates and phosphates into protein and other nutrients and putting oxygen back into the water. Recent research indicates that plants growing in wetlands may act as a sink for heavy metal contaminants such as mercury, lead, zinc and copper by trapping them in their roots and removing them from certain foodchains, but not from the foodchains of herbivores (i.e., some waterfowl and fish).

Wetlands are important to the productivity of the entire ecosystem. They provide essential habitat for a wide variety of plants and animals. Many forms of wildlife depend on wetland habitats for resting, breeding and feeding. For example, one of the most important habitat requirements for waterfowl is access to shallow waters that contain extensive beds of submerged aquatic vegetation and that produce high numbers of small aquatic invertebrates. This provides a high-quality diet for egg-laying females and actively growing young. Wetlands with a high proportion of edge between emergent vegetation and water, such as found in the shoreline in quiet bays and inundated backshore areas, provide particularly good waterfowl habitat. These areas are highly sensitive to disturbance from the removal of aquatic vegetation, prolonged fluctuations in water level and shifts in substrate material that may cover benthic invertebrates.

Waterfowl also depend on wetlands for feeding and resting areas during their spring and fall migration.

Reptiles and amphibians return to wetland areas to breed. The invertebrates that form the food of birds and fish also rely on water for most if not all phases of their existence and are most numerous in wetland areas. Many other plants and animals live in areas adjacent to wetlands and are directly dependent on them for survival.

Wetlands serve three major kinds of functions for fish communities. They provide breeding grounds, nursery grounds, and act as a source of food and provide cover from predators, especially for young fish. Most species of freshwater fish are dependent on wetlands for one or more of these functions.

Wetlands provide essential habitat for a wide variety of endangered species. Some of the threatened and endangered species, nest in marshy areas of lakes and feed on small wetland-dependent fish species. Wetlands also provide valuable renewable resources of fur, wild rice, fish, bait, cranberries and game. They are rich in plant and animal life and are ideal for scientific studies and educational purposes.

. Susceptibility to Disturbance

Human impacts on wetlands vary depending on the scope, intensity and duration of the impact. The most serious type of impact results in the total displacement or removal of the wetland (e.g., infilling or draining). This results in the loss of the wetland functions in that area and may have indirect effects, such as increased flooding on adjacent areas.

The loss of wetland areas creates isolated patches of wetlands. The greater the distance between these patches, the fewer number of bird species that are attracted to each wetland area.

Wetlands are also sensitive to fluctuations in water levels. In most shoreline wetlands, cyclic changes or fluctuations in water levels are required to stimulate plant regeneration, promote diversity of plant growth, and encourage the release of nutrient material from organic debris through oxidation. When water levels are controlled for an extended period of time (about seven years), the productivity of the wetland declines.

Some species utilizing wetlands are highly sensitive to disturbance. For example, many birds require undisturbed habitat during the nesting season from May to June.

c) Aquatic Habitats

The topography and physical processes of *large inland lakes* give rise to a variety of nearshore and offshore substrates which in turn provide habitats for small aquatic organisms, fish and wildlife. For example, erosion over time on a bedrock cliff may cause chunks of rock to break off and fall into the shallow nearshore area. The flood prone beach low plain, on the other hand, frequently provides conditions suitable for growth of submerged and emergent aquatic vegetation. Sediments that have accumulated over time in shallow protected embayments often provide excellent conditions for wetlands which in turn provide significant habitats for fish and wildlife.

Fish have evolved to carry out their life processes (i.e., reproduction, feeding, rearing of young) in specific habitats. Smallmouth bass, for example, lay their eggs in exposed rock/cobble areas and guard them until they hatch. Pike, however, leave their eggs among vegetation in sheltered areas where they remain hidden until they hatch.

Many fish species found in Ontario are near the northern limit of their range and as a result have very specific habitat requirements. Therefore, knowledge of the aquatic habitat or bottom substrate type along a piece of shoreline can be used with some certainty to predict its importance to the fish community of the lake.

Fish habitats adjacent to areas along the shorelines of *large inland lakes* which have undergone development (e.g., urban, recreational, resource extraction) are subject to numerous stresses. Loss of significant habitat for certain species has resulted in severe declines of those species. Of particular note is the destruction of shoreline wetland areas which have been dredged or filled to create hard shorelines to support residential development, marinas and ports and farmland.

The federal *Fisheries Act* provides for the protection of fish habitat from harmful alteration, disruption or destruction. A framework for habitat protection is provided in the Policy for the Management of Fish Habitat (DFO 1986). The long-term policy objective is the achievement of an overall net gain of the productive capacity of fish habitats. This objective can be met through fish habitat conservation, restoration and development. Fundamental to the conservation goal is the guiding principle of "no net loss". When a fishery resource and its supporting habitat are put at risk by a proposed undertaking, a hierarchy of preferences will be used to achieve no net loss. The first preference is the maintenance of habitat without disruption and may be achieved through the redesign or relocation of the project or use of suitable mitigation measures. If this is not possible or practical, compensation measures will be required including like-for-like compensation, or replacement of habitat off-site. The least preferred method of compensation is artificial production to supplement the fishery resource.

In Ontario, MNR is responsible for administering and enforcing the *Fisheries Act* and implementing the Policy for the Management of Fish Habitat (DFO 1986). Approval must be obtained by DFO for any project that may result in the harmful alteration, disruption or destruction of habitat.

. Function and Significance

The importance of aquatic habitats in the shorelines of lakes and rivers for fish spawning, feeding and rearing activities has long been acknowledged. The littoral zone, that area where light reaches the bottom enabling photosynthesis in algae and aquatic plants to occur, is particularly important. Plants and substrates such as cobble and boulders add structure and diversity to the aquatic habitat by providing attachment surfaces for the small aquatic organisms upon which fish feed (e.g., insect larvae, snails and other aquatic invertebrates). They also provide protective cover for small fish species and young-of-the-year, enabling them to hide from predators.

Aquatic habitats in the nearshore/offshore areas of large inland lakes can be broadly classified based on the surficial nearshore substrate. The surficial substrate is the material found in the top layer of the lake bottom. In some cases the surficial substrate will be the same as the underlying controlling substrate as discussed in Section 3. In other areas, the surficial substrate has been deposited by coastal processes acting along the shoreline reach and are not the same as the underlying or controlling substrate. A surficial substrate such as sand overlying a controlling substrate such as a cohesive material is an example.

The five categories of surficial nearshore substrate are as follows:

- bedrock — This surficial substrate is generally flat and hard and provides habitat for few species.
- cobble/boulder — This surficial substrate consists of large rocks on a hard surface and provides significant spawning and nursery habitat for many species (e.g., salmonoid species such as lake trout). Larger aquatic invertebrates such as crayfish and dragonfly nymphs favour this habitat and provide a food supply for predators such as rock bass and smallmouth bass.
- sand/gravel — This surficial substrate consists of small particles which provide good spawning, feeding and nursery habitat for a variety of fish species and bottom-dwelling organisms upon which they feed. Where physical conditions are suitable, aquatic plants may grow in these areas and provide rich and diverse habitats for a wide range of aquatic organisms.
- fine-grained cohesive — This surficial substrate is a hard packed fine-grained material with a significant proportion of clay and silt material as well as sand and gravel.

- silt/organic — This surficial substrate is generally found in sheltered or deeper areas where sediments are allowed to settle; where physical conditions are suitable, aquatic plants may become established and increase the productivity and diversity of these areas for aquatic organisms.

Typical characteristics for each of these habitats are shown in Figures 9.2 to 9.7.

Aquatic habitats can also be discussed in terms of exposure to wave action. Open coast areas are unsheltered and are exposed to extensive wave action, resulting in a relatively hostile environment for aquatic organisms. These habitats occur to some degree throughout Ontario's Lakes and generally provide living space for the same fish species throughout all lakes. There are, however, some differences in the resident fish communities of these lakes which are influenced by the physical characteristics of the lakes themselves (e.g., shoreline configuration, depth, coastal processes, chemical and temperature regime, etc.). These areas are also susceptible to hypolimnetic upwellings, which result in cold subsurface water introduced to the warmer nearshore area. These upwellings may affect the survival rate of warmwater species inhabiting the nearshore area.

Open coast areas generally support a coolwater and coldwater fish community. Some of these species are migratory and may utilize reefs and shoals for natural reproduction (i.e., lake trout, lake whitefish, lake herring). Prey species, including alewife and smelt, also occupy these areas seasonally, particularly during spawning runs. The action of waves on the shoreline also provides oxygen to the shallow nearshore area.

Figure 9.2: Exposed Bedrock (Above Water)

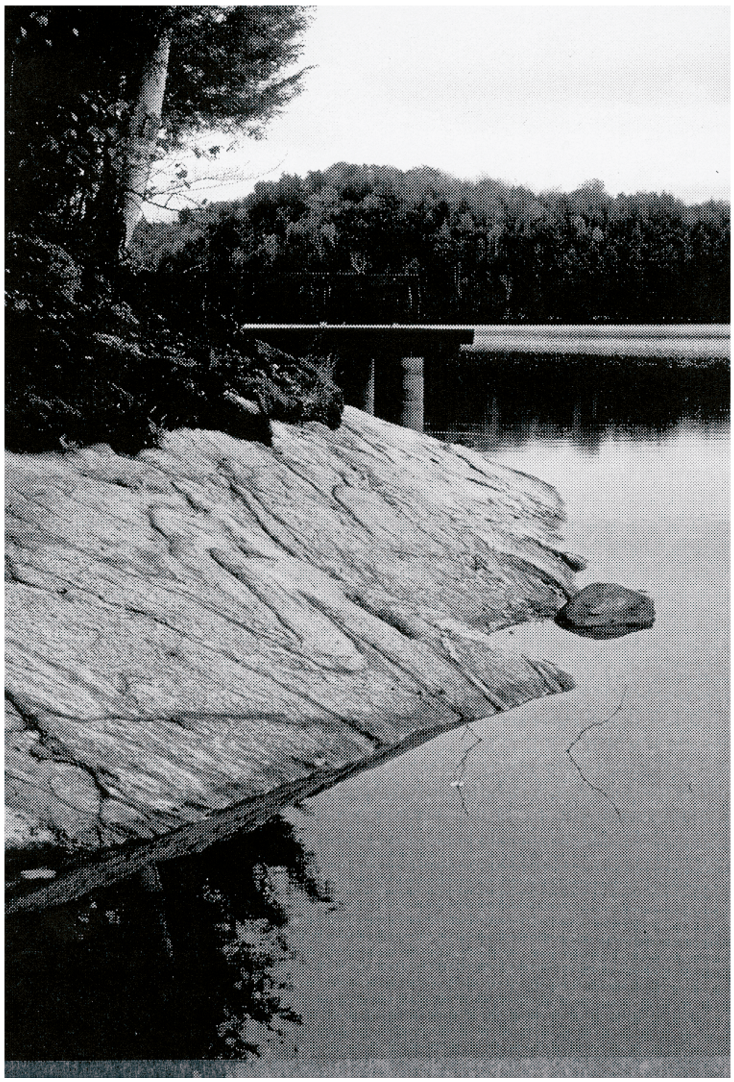


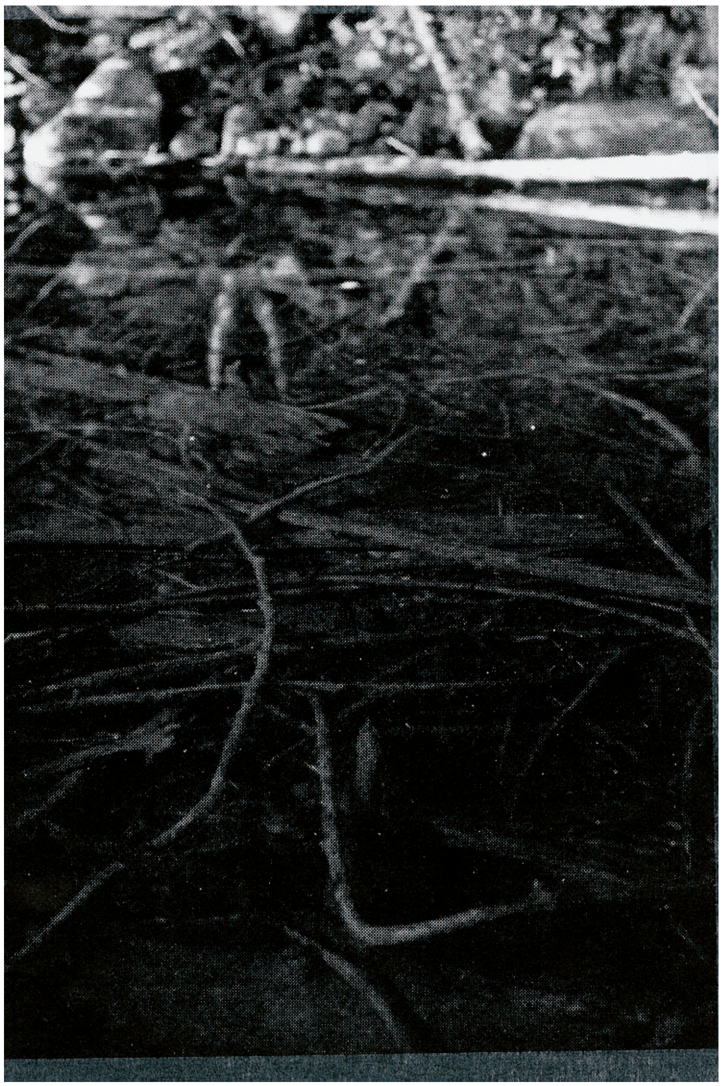
Figure 9.3: Exposed Bedrock (Below Water)

Figure 9.4: Cobble Boulder

Figure 9.5: Sand/Gravel

Figure 9.6: Silt/Organic (Above Water)

Figure 9.7: Silt/Organic (Below Water)



Other areas of the shoreline such as river mouths, estuaries and embayments are sheltered from the open coast effects. The deposition of fine materials in these areas often allows the establishment of aquatic vegetation. Warmwater fish communities typically utilize these refuse areas. Warmwater fish may also utilize nearshore zones as linkage corridors when migrating between warmwater production areas.

. Susceptibility to Disturbance

The susceptibility of each of the surficial substrate categories to disturbance is summarized on Table 9.1.

Open coast areas are susceptible to changes which affect the wave zone. The most important open coast habitats are usually rocky areas in deeper water that are kept clean of fine sediments by current and wave action. Where this is disturbed, the suitability of the substrate for spawning declines.

TABLE 9.1
Aquatic Habitat in the Large Inland Lakes:
Susceptibility to Disturbance

Surficial Substrate	Susceptibility to Disturbance
Exposed Bedrock	• not sensitive to disturbance • in exposed, open coast areas the nearshore area may be utilized for spawning by alewife and whitefish • low productivity for aquatic organisms (e.g., fish and invertebrates) due to lack of habitat structure
Cobble/Boulder	• moderately susceptible to sedimentation and alteration from removal or disruption of rock/cobble substrate • provides spawning substrate for a variety of warmwater species (e.g., smallmouth bass), and coldwater species (e.g., lake trout) • provides habitat structure and diversity for aquatic organisms
Sand/Gravel	• moderately susceptible due to potential for movement of substrate which can change habitat character and productivity • moderate productivity for aquatic plants and benthic organisms • provides habitat for a variety of warmwater fish species
Fine-Grained Cohesive	• not sensitive to disturbance • hard-packed surface has limited internal spaces for invertebrates • often exposed to wave activity • low productivity for aquatic organisms due to lack of habitat structure
Silt/Organic	• highly susceptible to removal of aquatic plants or disruption of currents and/or wave action • high productivity in areas where aquatic plants growth or organic litter occur • provides habitat for a very wide variety of warmwater fish species • wetlands may occur in these substrates if topography and other conditions are suitable • generally found in sheltered embayments and estuaries

9.3 Biological Impacts Related to Shoreline Protection Works

The gradual encroachment of human developments has impaired the shoreline ecosystem in many areas. The impacts expanding urban shoreline areas are cumulative and, as such, may be overlooked until it is too late to recover sufficient habitat for wildlife and nearshore fish and aquatic communities. It is essential that environmental concerns be considered as an integral part of managing the shoreline, and not as an isolated study component at a later stage in a project. If environmental concerns are to be satisfactorily dealt with, they must be considered at all stages of the land use planning process, from formulation of alternative strategies through to plan implementation.

9.3.1 Criteria to Evaluate Impacts on the Shoreline Ecosystem

The impacts on the shoreline ecosystem resulting from the installation of flood and erosion protection works can be considered according to a number of criteria including importance, spatial extent, duration of impacts, recovery, mitigation, and cumulative effects.

a) Importance

This criterion addresses the significance or the value attached to the potentially affected area as a result of such things as its location, uniqueness or importance for wildlife.

There are areas along the shorelines of *large inland lakes* that are identified as having high value or significance due to the special functions or habitat they provide. Examples include endangered species habitat, spawning areas, Areas of Natural or Scientific Interest (ANSI), Provincially and locally significant wetlands and Environmentally Significant Areas (ESA). Any activity that has the potential to impact on these areas requires attention.

Possible data sources include, ESA reports, ANSI reports, Official Plan documents, and wetland inventories.

b) Spatial Extent

The environmental impacts associated with shoreline structures can occur in the immediate site vicinity as well as further updrift and/or downdrift of the site.

Impacts in the immediate vicinity of the work can result from both large-scale activities (e.g., construction of a large breakwater at a harbour entrance) and small scale activities (e.g., clearing of vegetation for a revetment).

Typical on-site environmental impacts of protection works include:

- placement of fill material which covers aquatic plants and bottom substrates resulting in disturbance to various aquatic habitat and food supplies;
- change to topography and nearshore substrate upon which fish species may spawn (e.g., cobbles);
- alteration of water levels in periodically flooded areas which may restrict spawning areas and waterfowl habitat;
- removal or clearing of shoreline vegetation which provides shade, bank stabilization, and habitat for wildlife; and
- removal of material from the nearshore such as boulders, cobble, and stumps can affect habitats and feeding grounds by reducing the potential of food organisms.

Typical effects to updrift and downdrift areas result from physical processes such as release of sediments into the water column; and changes in sediment supply and alongshore sediment transport.

The release of sediments into the water column may cover essential spawning habitat, restrict light penetration, reduce the visibility for fish species, reduce submergent vegetation growth and may result in increased egg mortality. Persistent turbidity may also impair feeding efficiency of filter feeders such as mussels and clams and in the long-term effect the growth and survival of resident fish species.

There are numerous potential impacts on the biological community resulting from changes in sediment transport. For example, existing sand bars and shallow water areas protect the shoreline from significant wave and ice action and provide quiet, protected areas for the establishment of aquatic vegetation, benthic invertebrate habitat and nursery areas for fish. The removal of this protective material may result in the loss of this habitat.

The increased deposition of fine material carried in alongshore transport also influences the downdrift areas. Aquatic macrophytes that provide fish habitat may be covered. Due to the continued addition of material, new aquatic growth may be restricted. The mouths of small streams that serve as fish migration routes may be filled in making passage by fish difficult.

Other effects on updrift and downdrift areas include disruption to the nesting habitat of bird species which may be sensitive to noise and disturbances in the surrounding area.

c) Duration of Impact

This criterion addresses the length of time associated with the activity and its possible impact. An impact can be described as being of either short-term or long-term duration. Protection works generally have a defined design life, and as such it is perhaps more useful to discuss temporal aspects of the potential impact on the environment based on the life phase of the structure under consideration.

The three key phases are construction-related activities, operation and function of the structure during its design life, and post design life.

Short-term impacts are generally associated with construction activities and may often be avoided through project design or construction practices. For example, during construction it is often necessary to build access roads to the shoreline. These may require the clearing of vegetation thus increasing the potential for erosion. These areas may be restored/rehabilitated to their original condition after construction so during the design life phase, these impacts no longer occur. The construction phase often involves the highest level of disruption to the site vicinity compared to the other phases. Noise, dust, trampling of vegetation, and increased sedimentation are all examples of short-term construction-related impacts. The disturbances to local wildlife, waterfowl and fish can be avoided or minimized by planning activities around critical nesting and spawning periods.

Long-term impacts are generally related to the project design and occur during/following construction. For example, the direct loss of a fish spawning bed by the placement of a groyne would be considered a long-term impact. During the life of a properly constructed and designed structure which is not situated in a sensitive or critical area, the most prevalent type of impact will be associated with indirect effects in the updrift and downdrift areas, such as changes to alongshore transport. There is potential to incorporate mitigation measures to the design of a structure to significantly reduce impacts.

During the post-design life phase, the structure is no longer functioning as designed. Impacts during this stage may be more difficult to predict and will likely occur on-site, as well as updrift and downdrift.

d) Recovery

The susceptibility of habitat and its ability to recover following a stress placed on it must be considered. For example, the re-establishment of a small area of shoreline vegetation when a construction access road is no longer required, may be quick and require little input. Other impacts, such as the alteration of drainage patterns to a wetland may be irreversible.

e) Mitigation

Standard practices may be available to alleviate or reduce impacts of an activity. Mitigation measures can be employed during the construction phase and in the design of the protection works to reduce impacts on the environment. The net environmental impact or residual impact of a structure is therefore lessened.

Mitigation may include changes to the project design, rescheduling of construction activities to avoid critical periods (i.e., nesting, spawning or migration), or the use of well established methods of reducing or controlling impacts. It is important to differentiate those impacts which can be controlled through mitigation and those for which it is not possible. For example, the use of silt curtains during construction may be effective to reduce sedimentation in the site vicinity. The loss of spawning substrate by the construction of a vertical seawall may be more difficult, or even impossible to mitigate. Mitigation measures should favour the use of soft-engineering approaches wherever possible. Soft-engineering approaches combine elements of the natural system with structural methods. Section 8 outlines bio-engineering techniques that may be implemented on *large inland lakes*.

When standard mitigation measures will not substantially reduce impacts (i.e., a loss of habitat occurs), compensation for displaced habitat may be required. This may involve the replacement of similar habitat on-site or in a suitable location off-site. Compensation plans for any destruction or alteration of fish habitat must be approved by the Department of Fisheries and Oceans (DFO).

In order to provide a truly integrated, innovative and effective design, one should consider the following design principles, where appropriate:

- enhance, rehabilitate or create aquatic, terrestrial or wetland habitat;
- use a diverse landform (i.e., undulate the landform to provide a variety of slopes, exposures, elevations, orientations and aspects; and
- diversity of substrate types in combination with varying bathymetry encourages a variety of aquatic vegetation communities.

f) Cumulative Effects

The impact from the proposed activity may be minimal, however, the addition of this new impact on an already stressed ecosystem from a previous activity may cause serious degradation.

9.3.2 Definition of Major and Minor Environmental Impacts

Potential impacts can be categorized as either major or minor, based on the importance of the ecosystem affected, the spatial extent of the impact, the recovery rate of the ecosystem, the potential for mitigation and the consideration of cumulative effects. For the purpose of these technical guidelines, the definitions of major and minor are as follows:

- **Minor impacts** are those which can be mitigated, that is, the proposed structure/activity will cause impacts which can be mitigated through changes in design and/or timing of activity. Confining impacts to what is considered a minor (as opposed to a major) level is contingent upon having an impact of short duration, availability of mitigation practices, a high rate of recovery, and a low potential for spin-off effects.

- **Major impacts** occur when the structure/activity has significant long-term or permanent adverse impacts on the net productivity of the habitat on or off site. A major impact occurs when the rate of recovery of the habitat is low, there is a high potential for spin-off or indirect effects and/or the area affected is considered to be critical habitat.

9.3.3 Potential Biological Impacts Resulting From Protection Works

The environmentally sound management of shorelines requires that the change to the physical processes associated with protection works be understood, but also that the impacts of these processes on the biological environment be considered. Specific physical impacts for various protection works were identified in Section 8. In this section the potential biological impacts will be identified.

The location of protection works (e.g., onshore, backshore, or nearshore) dictates to a large degree the biological community which may be potentially affected. For example, structures which occupy the onshore have a greater probability of directly affecting terrestrial habitat than the fish and aquatic habitat in the area. However, the indirect impacts of protection works located on the onshore on aquatic habitat must also be considered. For example, fish and aquatic habitats and wetland areas may be affected by the disruption of surface and groundwater drainage, or an increase in erosion and sedimentation resulting from onshore works.

The physical impacts associated with protection structures located on the onshore, backshore and nearshore are summarized on Table 9.2 and are discussed in more detail in Table 9.3. The potential for biological impacts on aquatic habitat, terrestrial habitat and wetlands are indicated.

Table 9.3 provides a general summery of typical physical and biological impacts of protection works and measures that could be carried out to mitigate these impacts. Readers of this Technical Guide must note that ***the information provided in Table 9.3 is general in nature and is intended to serve as a guide in identifying potential impacts and possible mitigation measures. The discussion is not exhaustive, and impacts which require specialized mitigation measures may occur in site-specific cases.*** Table 9.3 is made up of 3 tables, th first, Table 9.3a, provides information on onshore structural protection works (e.g., filling and dyking) , the second, Table 9.3b, on backshore structural protection works (e.g., revetments and seawalls) and the third, Table 9.3c, on nearshore protection works (e.g., beach nourishment, groynes, artificial headlands, and detached breakwaters).

Table 9.2: Potential Influences and Impacts of Shoreline Management Approaches on Physical Shoreline Processes and the Shoreline Environment

General Physical Shoreline Processes and Characteristics	Potential Influences (A._) of Shoreline Management Practices on Physical Shoreline Processes and Characteristics	Potential Resulting Impacts (B._) on Physical Shoreline Processes and Characteristics	Shoreline Management Approaches													
			Prevention		Non-structural Protection				Structural Protection (plus stable slope & flood/erosion allowances)							
			Onshore						Onshore		Backshore		Nearshore			
			HA	PA	Re	FP	BM	DE	FI	D	fR/S	rR/S	BN†	G	AH	DB‡
Supply and Transport of Littoral Materials (Erosion & Deposition Patterns)	**A.1** Decreases supply of sediments to littoral zone	**B.1** Increased long-term erosional stress to downdrift shorelines									A	A		A	A	A
	A.2 Increases supply of sediments to littoral zone	**B.2** Decreased long-term erosional stress to downdrift shoreline											A			
	A.3 Impedes alongshore transport of littoral material	**B.3** Accretion updrift and/or in lee of structure											A	A	A	A
		B.4 Increased erosion of downdrift shorelines until bypassing occurs												A	A	A
	A.4 Diverts littoral sediments from close to shore to deeper water	**B.5** Increased erosion immediately downdrift												A	A	A
	A.5 Reduces cross-shore transport of littoral material	**B.6** Less change of beach and nearshore profile during storms													A	A
	A.6 Increases wave reflection from shoreline and increases localized currents	**B.7** Localized erosion (scour) along toe of and at alongshore ends of protection works									A	A		A	A	A
Water Circulation	**A.7** Increases sheltering of nearshore waters	**B.8** Decreased nearshore wave action													A	A
		B.9 Decreased mass water exchange/ circulation of nearshore waters													A	A
Backshore & Nearshore Topography	**A.8** Occupies backshore area	**B.10** Altered backshore topography at site (changes terrain and materials)									T	T	T	T		
	A.9 Reduces wave action at backshore	**B.10** Altered backshore topography at site (profile becomes more stable)									T	T	T	T	T	T
	A.10 Occupies nearshore area	**B.11** Altered nearshore topography (changes bathymetry and materials)											A	A	A	A
Onshore Topography	**A.11** Occupies onshore area	**B.12** Altered onshore topography (changes terrain and materials)					T	T	TW	TW						
	A.12 Stabilizes toe of cliff/bluff/bank	**B.12** Altered onshore topography (with stable toe crest retreats, as slope flattens to stable condition - often graded during construction)									T	T	T	T	T	T
Surface & Groundwater	**A.13** Disrupts surface and/or groundwater drainage from land to lake/channel	**B.13** Altered surface/groundwater drainage pattern in onshore/backshore area							TWA	TWA	TA	TA				

LEGEND:

- **T** - terrestrial habitat
- **A** - aquatic habitat
- **W** - wetland
- HA - hazard allowances for flooding and erosion
- PA - property acquisition
- Re - relocation
- FP - floodproofing
- BM - bio-engineering measures
- DE - dune enhancement
- FI - filling
- D - dyking
- fR/S - flexible revetments/seawalls
- rR/S - rigid revetments/seawalls
- BN - beach nourishment
- † typically extends across backshore and into nearshore
- G - groynes
- AH - artificial headlands (typically with beach fill)
- DB - detached breakwater
- ‡ can also be located in shallow offshore

NOTES:

Refer to **Table 8.4**, Part 8, for initial evaluation of shoreline management practices.

Refer to **Table 8.5**, Part 8, to assess the potential influences and impacts of shoreline management approaches on the physical shoreline processes and characteristics.

Refer to **Table 8.6**, Part 8, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood and erosion hazards.

Refer to **Table 9.3**, Part 9, to assess the biological impacts related to shoreline management approaches.

Tables to be read in conjunction with accompanying text.

Table 9.3a Summary of Typical Physical and Biological Impacts of Onshore Structural Protection Works and Mitigation Measures

Types of Onshore Structural Protection Works

- filling
- dyking

Physical Impacts	Biological Impacts	Mitigation
B.12 • Altered onshore topography	• Displaces natural terrain and relief	• None available.
	• May require the removal of natural vegetation which provides food and cover for terrestrial species	• Revegetate area with compatible, native species.
	• Increased soil erosion due to the removal of existing vegetation	• Revegetate area with compatible native species.
	• Trees adjacent to the construction site may be affected by the severing of roots or the suffocation of roots in the area due to a change in slope	• Construct or excavate outside the dripline of tree roots or move specimen trees prior to construction and replant after construction completed.
	• May limit access for wildlife from upland areas to the water's edge	• Design structure to provide access.
	• May disturb shore vegetation and wildlife corridors along shoreline	• Minimize area of vegetation removed. Revegetate area.
	• May disturb the nesting activities of shorebirds, waterfowl and herpetofauna	• Timing of construction should avoid nesting periods.
	• Increased soil compaction and erosion due to grading and construction of access road	• Standard sedimentation and erosion control measures (e.g., silt fences, sand bags, straw bales) should be used during construction. Stabilize route with a grass cover or appropriate native vegetative species and regrade to natural contours after construction in order minimize erosion and disruption of the cleared area.
B.13 • Altered surface/groundwater drainage pattern in onshore/backshore area	• Change to groundwater seepage areas may be significant to the spawning habitats of certain fish species such as brook trout. This species may spawn in gravel shallows of lakes if there is a spring upwelling and a moderate current.	• Determine contribution of groundwater to adjacent shoreline areas prior to construction. Provide for infiltration if necessary.
	• If the drainage channel is altered or realigned, fish habitat may be disrupted. This is especially important in drainage channels used for spawning.	• Maintain the existing flow and channel configuration of streams flowing into lakes. Control sediment entering drainage channels. Construction activities should avoid migration and spawning.
	• Disruption may influence the water retention and filtering capacity of adjacent wetland areas.	• In areas where surface drainage patterns have been degraded, opportunities for enhancement should be explored. In areas where a provincially significant wetland is adjacent to the site (within 120 m), investigations must be undertaken to determine the effects on wetland functions (Wetlands Policy Statement).

Table 9.3b Summary of Typical Physical and Biological Impacts of Backshore Structural Protection Works and Mitigation Measures

Types of Backshore Structural Protection Works (Table 9.3b)

- revetment
- seawall

Physical Impacts	Biological Impacts	Mitigation
B.1 • Increased long-term erosional stress to downdrift shorelines	• Changes to existing fish and aquatic habitats, such as removal of surficial sand/gravel/cobble that may be used for spawning	• Determine the presence of spawning activity in downdrift areas prior to construction. Replace materials lost (e.g., gravel, cobble, boulders).
B.7 • Localized erosion (scour) along toe of and at alongshore ends of protection work	• May increase turbidity and smothering of benthic invertebrates	• Increase porosity and roughness of the structure and flatten the slope to increase absorption of wave energy
	• Increases depth of water along shore edge	• Provide suitable scour protection
B.10 • Altered backshore topography at site	• Often requires the displacement of the natural terrain and relief, which may restrict the access of wildlife, amphibians and reptiles to the shoreline	• Design structure to provide access
	• Construction activities may disturb the nesting and migration periods of waterfowl	• Timing of construction should avoid nesting and migration periods
	• Clearing of vegetation may reduce wildlife habitat, cause an increase in surface runoff and the amount of suspended sediment reaching the watercourses	• Natural vegetation should be preserved where possible or be replanted immediately after construction • Use bio-engineering approaches where possible • Removal of overhanging vegetation adjacent to the shoreline should be avoided where possible • Employ Best Management Practices during construction to minimize sedimentation
	• Clearing or removal of vegetation in the backshore may result in the fragmentation of corridors along the shoreline. This may interfere with wildlife movements adjacent to the shoreline	• Minimize area of vegetation removed - revegetate cleared areas
	• Structures that extend into the nearshore may alter the shallow (active) wave zone used for spawning by fish species such as alewaife and smelt.	• Reduce extent of structure into nearshore
	• Construction usually involves introduction of new materials to the shore zone which may alter the nearshore habitat	• Materials used should attempt to add internal spaces to the protection works. For example, stones and rocks provide structure and protective crevices; vertical walls with smooth, uniform surfaces provide no habitat value.

Types of Backshore Structural Protection Works (Table 9.3b)

- revetment
- seawall

Physical Impacts	Biological Impacts	Mitigation
B.12 • Altered onshore topography	• Displaces natural terrain and relief	• None available.
	• May require the removal of natural vegetation which provides food and cover for terrestrial species	• Revegetate area with compatible, native species.
	• Increased soil erosion due to the removal of existing vegetation	• Revegetate area with compatible native species.
	• Trees adjacent to the construction site may be affected by the severing of roots or the suffocation of roots in the area due to a change in slope	• Construct or excavate outside the dripline of tree roots or move specimen trees prior to construction.
	• May limit access for wildlife from upland areas to the water's edge	• Design structure to provide access.
	• May disturb shore vegetation and wildlife corridors along shoreline	• Minimize area of vegetation removed. Revegetate area.
	• May disturb the nesting activities of shorebirds, waterfowl and herpetofauna	• Timing of construction should avoid nesting periods.
	• Increased soil compaction and erosion due to grading and construction of access road	• Standard sedimentation and erosion control measures (e.g., silt fences, sand bags, straw bales) should be used during construction. Stabilize route with a grass cover or appropriate native vegetative species and regrade to natural contours after construction in order minimize erosion and disruption of the cleared area.
B.13 • Altered surface/groundwater drainage pattern in onshore/backshore area.	• Change to groundwater seepage areas may be significant to the spawning habitats of certain fish species such as brook trout. This species may spawn in gravel shallows of lakes if there is a spring upwelling and a moderate current.	• Determine contribution of groundwater to adjacent shoreline areas prior to construction. Provide for infiltration if necessary.
	• If the drainage channel is altered or realigned, fish habitat may be disrupted. This is especially important in drainage channels used for spawning.	• Maintain the existing flow and channel configuration of streams flowing into lakes. Control sediment entering drainage channels. Construction activities should avoid migration and spawning.
	• Disruption may influence the water retention and filtering capacity of adjacent wetland areas.	• In areas where surface drainage patterns have been degraded, opportunities for enhancement should be explored. In areas where a provincially significant wetland is adjacent to the site (within 120 m), investigations must be undertaken to determine the effects on wetland functions (Wetlands Policy Statement).

M

Table 9.3c Summary of Typical Physical and Biological Impacts of Nearshore Structural Protection Works and Mitigation Measures

Types of Nearshore Structural Protection Works (Table 9.3c)

- beach nourishment
- groynes
- artificial headlands
- detached breakwaters

Physical Impacts	Biological Impacts	Mitigation
B.1 • Increased long-term erosional stress to downdrift shorelines **B.2** • Decreased long-term erosional stress to downdrift shorelines	• Changes to existing aquatic habitats, such as the removal of surficial sand/gravel/cobble that may be used for spawning	• Determine the presence of spawning activity in downdrift areas prior to construction
B.3 • Accretion updrift and/or in lee of structure	• May cover substrate (i.e., cobble) with finer sediments, thus disturbing fish spawning areas or smothering eggs	• The potential for fish spawning activity in the area updrift of site should be determined prior to construction • Design protection works to minimize intrusion into the nearshore
	• May result in alteration to the active wave zone, used by some species of fish for spawning.	• Determine spawning activity prior to construction.
B.4 • Increased erosion at downdrift shorelines **B.5** • Increased erosion immediately downdrift	• Loss of fish habitat (e.g., substrate, vegetation)	• Utilization of the area by fish for spawning and nursery areas should be determined prior to construction.
	• Invertebrates that are carried in the current may be deflected to deeper water where survival rates may be reduced	• Impacts may be reduced by designing the structure to minimize intrusion into the nearshore
B.6 • Less change of beach and nearshore profile during storms	• Dynamic beach profile will be more stable during storm events. This more protected environment may encourage benthic invertebrates to inhabit these areas.	
B.7 • Localized erosion (scour) along toe of and at alongshore ends of protection works	• May increase turbidity and smothering of benthic invertebrates	• Increase porosity and roughness of the structure and flatten the slope to increase absorptions of wave energy.
	• Increases depth of water along lakeward edge	• Provide suitable scour protection
B.8 • Decreased nearshore wave action **B.9** • Decreased water exchange/circulation of nearshore waters at site	• May reduce wave activity and water circulation in the nearshore, which may reduce oxygen supply to the aquatic community in this area	• Placement of culverts or openings in the structure to allow some water circulation
	• Placement of structures offshore may influence temperatures in the nearshore.	
	• May interfere with the spawning activity of species such as alewife and smelt which use the active wave zone	• Detached breakwaters may have fewer impacts than headland breakwaters

Types of Nearshore Structural Protection Works (Table 9.3c)

- beach nourishment
- groynes
- artificial headlands
- detached breakwaters

Physical Impacts	Biological Impacts	Mitigation
B.10 • Altered backshore topography at site	• Often requires the displacement of the natural terrain and relief, which may restrict the access of wildlife, amphibians and reptiles to the shoreline	• Design structure to profile access
	Construction activities may disturb the nesting and migration periods of waterfowl	Timing of constructions should avoid nesting and migration periods
	• Clearing of vegetation may reduce wildlife habitat, cause an increase in surface runoff and amount of suspended sediment reaching the watercourses.	• Natural vegetation should be preserved where possible or be replanted immediately after construction • Use bio-engineering approaches where possible • Removal of overhanging vegetation adjacent the shoreline should be avoided where possible • Employ Best Management Practices during construction to minimize sedimentation
	• Clearing or removal of vegetation in the backshore may result in the fragmentation of corridors along the shoreline. This may interfere with wildlife movements adjacent to the shoreline	• Minimize area of vegetation removed - revegetate cleared areas
	• Construction usually involves the introduction of new materials to the shore zone which may alter the nearshore habitat	• Materials used should attempt to add internal spaces to the protection works. For example, stone and rocks provide structure and protective crevices; vertical walls with smooth, uniform surfaces provide no habitat value.
B.11 • Altered nearshore topography	• Placement of structure in the nearshore will result in the direct covering of bottom substrate and a possible loss of fish habitat	• The potential for spawning activity on the existing substrate should be determined prior to the alteration of substrate material. No mitigation available on-site. These may be opportunities to enhance degraded spawning habitat in the site vicinity. • Materials used should attempt to add internal spaces to the protection works. For example, stones and rocks provide structure and protective crevices; vertical walls with smooth, uniform surfaces provide no habitat value
	• Possible increase of suspended sediments during construction may irritate the gills of fish, place stress on filter feeders and smother benthic invertebrates	• Silt curtain should be used during construction to minimize area impacted by increased sedimentation
	• May result in loss of frequently flooded areas which are important fish spawning and nursery areas.	• Design modification may include lower structures
	• Removal of aquatic vegetation which provides food and shelter for aquatic organisms	• Plant aquatic vegetation in adjacent areas (This may not be possible due to wave and current environment.)

Types of Nearshore Structural Protection Works (Table 9.3c)

- beach nourishment
- groynes
- artificial headlands
- detached breakwaters

Physical Impacts	Biological Impacts	Mitigation
B.12 • Altered onshore topography	• Displaces natural terrain and relief	• None available.
	• May require the removal of natural vegetation which provides food and cover for terrestrial species	• Revegetate area with compatible, native species.
	• Increased soil erosion due to removal of existing vegetation	• Revegetate area with compatible, native species.
	• Trees adjacent to the construction site may be affected by the severing of roots or the suffocation of roots in the area due to a change in slope	• Construct or excavate outside the dripline of tree roots or move specimen trees prior to construction.
	• May limit access for wildlife from upland areas to the water's edge	• Design structure to provide access.
	• May disturb shore vegetation and wildlife corridors along shoreline	• Minimize area of vegetation removed. Revegetate area.
	• May disturb the nesting activities of shorebirds, waterfowl and herpetofauna	• Timing of construction should avoid nesting periods.
	• Increased soil compaction and erosion due to grading and construction of access road	• Stabilize route with a grass cover to reduce erosion of the cleared area. Standard sedimentation and erosion control measures should be used.

9.3.4 Assessment of Major and Minor Impacts

Based on the descriptions of ecosystem susceptibility to disturbance (Section 9.2.1), and potential effects on the biological and physical environment (Section 9.3.3) an assessment of the potential level of impact (e.g., major, minor, none) can be made.

As discussed in Section 9.3.2, major impacts occur when a protection measure occupies a portion of the shore considered to be sensitive from a biological standpoint and where habitats and their associated communities may be permanently lost. Exceptions may occur when the area disturbed is not considered to be biologically productive.

The potential impacts to terrestrial habitat from protection work generally occur as a result of changes to the onshore or backshore topography. Changes to the slope or material, or the removal of protective cover (i.e., vegetation) may limit the access of wildlife from upland areas to the water's edge and may also restrict movement from one portion of the shoreline to another (i.e., migration corridors).

Other related impacts include the clearing of vegetation which provides a source of food and disturbance to wildlife during critical periods (i.e., nesting, migration).

Generally, impacts to terrestrial habitats from protection works are of a minor nature. Protection works may be designed to allow for the movement of wildlife from upland areas to the shoreline. The removal of vegetation should be minimized and may be re-established to provide suitable habitat. Construction periods should avoid critical seasons.

Impacts may be of a major nature if the proposed site is located within an important wildlife habitat area. These may include the habitat of an endangered species. Other habitat areas of local or regional significance should also be determined.

The potential for impacts to wetland communities occurs when a protection work directly displaces a wetland or wetland vegetation or from indirect impacts such as filling and dyking the onshore. The area most affected by the latter activity occurs in the periodically flooded zone landward of the protection work during high water levels (separately or annually). This zone may support aquatic vegetation and be used for spawning and nursery areas for fish species such as pike and nesting sites for waterfowl.

The result of such an impact will be of a long-term duration and is considered major. The provincial policy addressing wetlands (i.e., Policy 2.3, Provincial Policy Statement, May 1996) prohibits development in provincially significant wetlands and requires an environmental impact statement to be completed for proposed work in the 120 m area adjacent to the wetland. The location of provincially significant as well as other locally significant wetlands is available at District MNR offices (see also Glooschenko et al.,1987).

The potential for impacts resulting from protection works is generally the greatest on fish and aquatic habitat. These range from direct impacts on the habitat from the placement of a structure on the nearshore to indirect impacts due to increased sedimentation, decreased supply of new coarse material to the nearshore area, etc.

Protection works which cover existing habitat (nearshore substrate) should be considered major. These impacts are of long-term duration and may occur in an important spawning, nursery or migration area. Any harmful alteration, disruption or loss of fish habitat requires compensation and approval by DFO. The District MNR Office should be contacted regarding possible critical habitat areas.

Indirect impacts on aquatic habitat occur predominantly from changes to the erosion and depositional patterns. As discussed in Section 9.2, some nearshore substrates are more susceptible to disturbance than others. The magnitude of this type of impact is greater in sand/gravel environments, typically where supply of sediments is the greatest. The potential for major physical effects is also great in gravel/cobble/boulder nearshore of beach environments. Cobble/boulder substrates are also important to the fish and aquatic community. The many crevices of this substrate provide protective cover for species such as crayfish, etc., and spawning activity for many fish species.

The impact on substrates such as bedrock and fine-grained cohesive may be of a minor nature as these areas are not as susceptible to disturbance and are not generally as biologically productive.

Table 9.4 summarizes the level of impact (none minor, major) that is likely to occur on the terrestrial, wetland and aquatic habitat of the shoreline ecosystem if a particular protection work were put in place. Onshore, backshore and nearshore locations are considered, as are the various types of shores and nearshore substrates. These are discussed in Table 9.5

Table 9.4 Significance of Potential Impacts to the Shoreline Environment

Shoreline Class[1]			Significance of Potential Impacts to the Shoreline Environment													
General Shoreline Type	**Controlling Substrate**	**Surficial Substrate**	Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
Onshore/ Backshore (composition and profile)	Nearshore (predominant underlying material)	Nearshore (can appear above water as a beach)[7]	Onshore		Onshore				Onshore		Backshore		Nearshore			
			HA	PA	Re	FP	BM	DE	FI	D	fR/S	rR/S	BN†	G	AH	DB‡
Bedrock Cliff[2]	bedrock	bedrock							t	t	ta	ta	ta	A	A	A
		cobble/boulder							t	t	tA	tA	tA	A	A	A
		sand/gravel							t	t	ta	ta	tA	A	A	A
		silt/organic[4]							tw	tw	taw	taw	taw	AW	AW	AW
Bedrock Low Plain[3]	bedrock	bedrock							t	t	ta	tA	tA	A	A	A
		cobble/boulder							t	t	tA	tA	tA	A	A	A
		sand/gravel							t	t	ta	ta	ta	A	A	A
		silt/organic[4]							tw	w	tAw	taw	taw	AW	AW	AW
Cohesive/ Noncohesive Bluff[2]	bedrock	bedrock					t		t	t	ta	ta	ta	A	A	A
		cobble/boulder					t		t	t	ta	tA	tA	A	A	A
		sand/gravel					t		t	t	ta	ta	ta	A	A	A
		silt/organic[4]					t		tw	tw	taw	taw	taw	AW	AW	AW
	cobble/boulder till	cobble/boulder					t		t	t	tA	tA	tA	A	A	A
		sand/gravel					t		t	t	ta	ta	ta	A	A	A
		silt/organic[4]					t		tw	tw	taw	taw	taw	AW	AW	AW
	fine-grained cohesive	cobble/boulder					t		t	t	tA	tA	tA	A	A	A
		sand/gravel					t		t	t	ta	ta	ta	A	A	A
		fine-grained cohesive					t		t	t	ta	ta	ta	A	A	A
		silt/organic[4]					t		tw	tw	taw	taw	taw	AW	AW	AW
Cohesive/ Noncohesive Low Plain[3]	bedrock	bedrock							t	t	ta	ta	ta	A	A	A
		cobble/boulder							t	t	tA	tA	tA	A	A	A
		sand/gravel							t	t	ta	ta	ta	A	A	A
continued...		silt/organic[4]							tw	aw	taw	taw	AW	AW	AW	AW

Table 9.4 (Continued)

Shoreline Class[1]			Significance of Potential Impacts to the Shoreline Environment													
General Shoreline Type	**Controlling Substrate**	**Surficial Substrate**	Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
Onshore/ Backshore (composition and profile)	Nearshore (predominant underlying material)	Nearshore (can appear above water as a beach)[7]	Onshore						Onshore		Backshore		Nearshore			
			HA	PA	Re	FP	BM	DE	FI	D	fR/S	rR/S	BN†	G	AH	DB‡
Cohesive/ Noncohesive Low Plain[3] (continued)	cobble/boulder till	cobble/boulder							**t**	**t**	**tA**	**tA**	**tA**	**A**	**A**	**A**
		sand/gravel							**t**	**t**	**tA**	**tA**	**ta**	**A**	**A**	**A**
		silt/organic[4]							**tw**	**w**	**taw**	**taw**	**taw**	**AW**	**AW**	**AW**
	fine-grained cohesive	cobble/boulder							**t**	**t**	**tA**	**tA**	**tA**	**A**	**A**	**A**
		sand/gravel							**t**	**t**	**ta**	**ta**	**ta**	**A**	**A**	**A**
		fine-grained cohesive							**t**	**t**	**ta**	**ta**	**ta**	**A**	**A**	**A**
		silt/organic[4]							**tw**	**tw**	**taw**	**taw**	**taw**	**AW**	**AW**	**AW**
Dynamic Beach Backed by Cliff/Bluff[2,7]	gravel/cobble/boulder	gravel/cobble/boulder					**T**		**t**	**T**	**TA**	**TA**	**TA**	**A**	**A**	**A**
	sand	sand					**T**		**t**	**T**	**Ta**	**Ta**	**Ta**	**A**	**A**	**A**
Dynamic Beach Low Plain[3,7] (mainland dune)	gravel/cobble/boulder	gravel/cobble/boulder							**t**	**T**	**TA**	**TA**	**TA**	**A**	**A**	**A**
	sand	sand							**t**	**T**	**Ta**	**Ta**	**Ta**	**A**	**A**	**A**
Dynamic Beach Barrier[7]	gravel/cobble/boulder	gravel/cobble/boulder							**t**	**T**	**TA**	**TA**	**TA**	**A**	**A**	**A**
	sand	sand							**t**	**T**	**Ta**	**Ta**	**Ta**	**A**	**A**	**A**

LEGEND:

T - major impact on terrestrial habitats
t - minor impact on terrestrial habitats
A - major impact on aquatic habitats
a - minor impact on aquatic habitats
w - major impact on wetlands

HA - hazard allowances for flooding and erosion
PA - property acquisition
Re - relocation
FP - floodproofing
BM - bio-engineering measures
DE - dune enhancement
FI - filling
D - dyking
BN - beach nourishment
† typically extends across backshore and into nearshore

fR/S - flexible revetment/seawall
rR/S - rigid revetment/seawall
G - groynes
AH - artificial headlands (typically with beach fill)
DB - detached breakwater
‡ can also be located in shallow offshore

1 - This Table does not include classification of shoreline exposure and planform (exposed, partial headland, headland-bay, well sheltered).
2 - Cliff/bluff - steeper than 1:3 (vert:horz) and >2 m high.
3 - Low plain - landward slope flatter than 1:3 (vert:horz) or <2 m high
4 - Typically only found in naturally well-sheltered areas where controlling substrate may not be applicable.
5 - Very limited structure lifespan.
6 - Typically imported cobble/shingle/gravel beach fill with anchoring groynes.
7 - a beach is not classified as a Dynamic Beach, where: 1) beach or dune deposits do not exist landward of the still water line; 2) beach or dune deposits overlying bedrock or cohesive material are generally less than 0.3 metres in thickness, 10 metres in width and 100 metres in length; or 3) beach or dune deposits are located in embayments, along connecting channels or in other areas of restricted wave action.

NOTES:

Refer to **Table 8.4**, Part 8, for initial evaluation of shoreline management practices.

Refer to **Table 8.5**, Part 8, to assess the potential influences and impacts of shoreline management practices on the physical shoreline processes and characteristics.

Refer to **Table 8.6**, Part 8, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood and erosion hazards.

Refer to **Tables 9.2 and 9.3**, Part 9, to assess the biological impacts related to shoreline management practices.

Tables to be read in conjunction with accompanying Technical Guide text.

Table 9.5 Assessment of Typical Major and Minor Impacts Structural Protection Work

ONSHORE

Terrestrial Habitats	Aquatic Habitats	Wetlands
Major • In sensitive habitat areas (i.e., ESA's, ANSI's, rare or endangered species habitat nesting areas) • In dune environments where the placement of a structure may alter the development and maintenance of the dune ecosystem	Major • May occur where substantial alterations to drainage channels are required (this is not associated with many protection works)	Major • In areas backed by wetlands, alterations to groundwater inputs may disrupt wetland communities. Usually confined to poorly drained, low plain shorelines with silt/organic surficial sediments.
Minor • Impacts are minor on most shoreline types. Impacts are generally of a short-term duration, and can be reduced through the re-establishment of vegetation, the timing of construction, and/or the provision of wildlife access. The effects are generally on-site with no updrift or downdrift effects.	Minor • Impacts are minor on most shoreline types. • Impacts are of a short duration and may include increased sedimentation during construction. Best Management Practices should be employed.	

BACKSHORE

Terrestrial Habitats	Aquatic Habitats	Wetlands
Major • May occur in sensitive habitat area (i.e. ESA's, ANSI's, rare or endangered species habitat and nesting areas) • May occur in beach/dune areas where the presence of structure alters the topography such that vegetation cannot re-establish.	Major • May occur where spawning habitats in downdrift areas experience increased erosion. This is most likely in areas with a cobble/boulder surficial sediment. • Changes to ground water upwelling areas may be major in spawning areas.	Major • In areas backed by wetlands, alterations to groundwater inputs may disrupt wetland communities. Impacts are usually confined to poorly drained, low plain shorelines with silt/organic surficial sediments.
Minor • Potential for minor impacts along all shoreline types. Impacts relate to removal of vegetation, interruption to wildlife corridors and restriction of wildlife access to the water. Most impacts can be mitigated to reduce impacts.	Minor • Potential for minor impacts along all shoreline types. Impacts relate to increased sedimentation and turbidity. Most impacts can be mitigated to reduce impacts.	Minor • May occur where surface water affects the water retention and filtering capacity.

NEARSHORE

Terrestrial Habitats	Aquatic Habitats	Wetlands
Major • Major impacts are generally restricted to aquatic habitats and wetlands	Major • Are likely to occur where protection structure covers bottom substrate. The significance of impacts on the productive capacity of fish are likely to be related to nearshore habitat type. Impacts are major in spawning and nursery areas but may be minor on substrates with low productivity such as cohesive materials. • May occur where existing spawning areas in updrift or downdrift areas are covered by sediments or removed due to new erosional/deposition patterns.	Major • May occur where the placement of the structure affects wetland functions.
Minor • The removal of vegetation immediately adjacent to the shoreline may reduce wildlife access to the water's edge, and reduce food source and shade for aquatic organisms.	Minor • Short-term impacts may result from the removal of shoreline vegetation. • Construction related impacts such as temporary suspension of sediments. • Changes to water circulation which may be mitigated.	Minor • Construction related impacts such as temporary suspension of sediments.

9.4 Glossary of Terms

The following terms and their definitions are intended for the purposes of the interpretation and implementation of the shoreline policy and supporting technical guidelines:

- **Biodiversity** is a short form for biotic or biological diversity and refers to the variety of wildlife species, the genetic variability of each species, and the variety of different functions they perform.
- **Ecosphere** the thin layer at the surface of the earth in which life is possible
- **Ecosystem** the physical and biological sphere of the environment comprised of terrestrial and aquatic organisms and their physical environment.
- **Effect** a change to the existing environment, and may be either positive, negative or neutral.
- **Environment** can be generally defined as air, land, water, plant and animal life including man, and the social, economic and cultural conditions that influence the life of a community.
- **Environmentally Sound Management** refers to those principles, methods and procedures involved in addressing the protection, management and enhancement of the shoreline ecosystem which are used in disciplines such as geology, geomorphology, botany and zoology and applied in the study of coastal processes, vegetation, wildlife and aquatic habitat resource management.
- **Habitat** is the combination of living and non-living things which provide a particular species with the resources it needs to complete its life-cycle; soil, water, air, rocks, rain, heat and the other plants and animals which provide the food needed for survival.
- **Impact** a detrimental change to the environment.
- **Wild Life** includes all wild mammals, birds, reptiles, amphibians , fish, invertebrates, plants, fungi, algae, bacteria, and other wild organisms

10.0 REFERENCES AND BIBLIOGRAPHY

Section 4.0 Flooding Hazard

Ahrens, J.P. 1981. Irregular wave runup on smooth slopes. Coastal Engineering Research Center, CETA 81-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Ahrens, J.P. and Heimbaugh, M.S., 1988a. Irregular wave runup on riprap revetments. Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE, Vol. 14, No. 4, July, pp.524-530.

Ahrens, J.P. and Heimbaugh, M.S., 1988b. Seawall overtopping model. Proc. of the 21st International Conference on Coastal Engineering, Malaga, Spain, ASCE, pp.795-806.

Ahrens, J.P. and McCartney, B.L., 1975. Wave period effect on the stability of riprap. Proceedings of Civil Engineering in the Oceans, Vol. 3, ASCE, pp.1019-1034.

Allsop, N.W.H., 1983. Low-crest breakwaters, studies in random waves. Proc. Coastal Structures '83, Arlington, Va., ASCE, pp.94-107.

Atria, 1997. Wave Uprush and Overtopping: Methodologies and Applications, Great Lakes - St. Lawrence River System. Report prepared for Ontario Ministry of Natural Resources by Atria Engineering Inc., April, 144p + app.

Bishop, C.T., Donelan, M. and Kahma, K., 1989. Shore protection manual's wave prediction reviewed. National Water Research Institute contribution 89-91.

Bremner, W., Foster, D.N., Miller, C.A., and Wallace, B.C., 1980. The design concept of dual breakwaters and its application to Townsville, Australia. Proc. 17th International Conf. on Coastal Engineering, ASCE, pp.1898-1908.

CIRIA/CUR, 1991. Manual on the Use of Rock in Coastal and Shoreline Engineering. UK Construction Industry Research and Information Association and the Netherlands Centre for Civil Engineering Research and Codes, A.A. Balkema, Rotterdam and Brookfield.

Cox, J.C. and Machemehl, J., 1986. Overload Bore Propagation Due to an Overtopping Wave. Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 112, No. 1, January, pp161-163.

Dewberry and Davis, 1994. Basic Analyses of Wave Action and Erosion With Extreme Floods on Great Lakes Shores. Draft Report prepared for Federal Emergency Management Agency, prepared by Dewberry and Davis, November, 71pp.

Environment Canada 1993. St. Lawrence River Flood Levels. Inland Waters Directorate, July.

Federal Emergency Management Agency (FEMA), 1991. Guidelines for Great Lakes Wave Runup Computations and Mapping. Federal Emergency Management Agency, Federal Insurance Administration, Washington, D.C., June.

Federal Emergency Management Agency (FEMA), 1989. Guidelines for specifications for wave elevation determination and V Zone mapping. Federal Emergency Management Agency, Federal Insurance Administration, Washington, D.C., Third Draft, July.

Goda, Y. 1985. Random seas and design of maritime structure, Chapter 5. University of Tokyo press.

Jenson, O.J., and Juhl, J., 1987. Wave overtopping on breakwaters and sea dykes. Proc. International Conference on Coastal and port Engineering in Developing Countries.

Keillor, J.P., and Miller, A.H., 1987. Coastal Processes Manual, A Training Manual for Evaluating Coastal Property, University of Wisconsin Sea Grant Institute.

Losada, M.A. and Giménez-Curto, L.A. 1981. Flow characteristics on rough permeable slopes under wave action. Coastal Engineering, 4, Elsevier.

Mase, H. 1989. Random wave runup height on gentle slopes. Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 115, No. 5, September, pp.649-661.

MacLaren Plansearch, 1988. Wave Hindcast Database for Lake Ontario and Lake Superior. Report to the Ontario Ministry of Natural Resources, prepared by MacLaren Plansearch Inc., March.

Marshall Macklin Monaghan, 1981. Shoreline Flood Elevation Study, Lake Simcoe, Lake Couchiching. Report prepared for Ministry of Natural Resources.

Ministry of Natural Resources (MNR), 1989. Great Lakes system flood levels and water related hazards. Conservation Authorities and Water Management Branch, OMNR, February.

Owen, M.W. 1982. Overtopping of sea defences. International Conference on the Hydraulic Modelling of Civil Engineering Structures. Coventry England, September. pp.469-480

Philpott, 1988. Wave Hindcast Database for Ontario's Great Lakes, Lake Huron/Georgian Bay. Report prepared for Ontario Ministry of Natural Resources, prepared by Philpott Associates Coastal Engineers Limited.

Pilarczyk, K.W. 1990. Design of seawalls and dikes - Including overview of revetments. Coastal Protection, Proceeding of the Short Course on Coastal Protection, Delft University of Technology, A.A. Balkema, 500p.

St. Lawrence Seaway Authority Operations Branch, 1971. Report on Vessel Speed and Wave Study -St. Francis Section of the St. Lawrence Seaway.

Sandwell, 1988. Wave Hindcast Database for Lakes Erie and St. Clair. Report for Ontario Ministry of Natural Resources, prepared by Sandwell Swan Wooster Inc., March.

Seelig, W.N., 1979. Effect of breakwaters on waves: Laboratory tests of wave transmission by overtopping. Proc. Coastal Structures '79, ASCE, pp.941-961.

Stoa, P.N. 1978. Revised wave runup curves for smooth slopes. Coastal Engineering Research Center, CETA 78-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stoa, P.N. 1979. Wave runup on rough slopes. Coastal Engineering Research Center, CETA 79-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Army Corps of Engineers (USACE). 1990. Automated coastal engineering system. User's Guide. Technical Reference, Coastal Engineering Research Center, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Army Corps of Engineers (USACE), 1988. Revised report on Great Lakes open coast flood levels. Report prepared for Federal Emergency Management Agency by U.S. Army Corps of Engineers. Detroit, Michigan.

U.S. Army Corps of Engineers (USACE). 1984. Shore Protection Manual, Washington, D.C.

U.S. Army Corps of Engineers (USACE). 1977. Shore Protection Manual, Washington, D.C.

van der Meer, J.W., 1990. Data on wave transmission due to overtopping. Delft Hydraulics, H986, prepared for CURC 67, January.

van der Meer, J.W. and Stam, C.J.M., 1992. Wave runup on smooth and rock slopes of coastal structures. Journal of Waterway, Port, Coastal, and Ocean Engineering, Vol. 118, No. 5, September, pp.534-550.

Walton Jr., T.L. and Ahrens, J.P. 1989. Maximum periodic wave runup on smooth slopes. Journal of Waterway, Port, Coastal, and Ocean Engineering, Vol. 115, No. 5, September, pp.703-707.

Wuebben, J.L., 1983. Effect of vessel size on shoreline and shore structure damage along the Great Lakes connecting channels. Special Report 83-11. Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, Prepared for Detroit District, U.S. Army Corps of Engineers, May.

Section 5.0 Erosion Hazard

Geomatics International Inc., 1992. Great Lakes Shoreline Classification and Mapping Study: Canadian Side. Report submitted to Environment Canada, Water Planning and Management Branch.

Ministry of Natural Resources (MNR), 1988. Littoral cell definition and sediment budget for Ontario's Great Lakes. Report prepared for Ministry of Natural Resources Conservation Authorities and Water Management Branch by F.J. Reinders and Associates Canada Limited.

Penner, L.A., 1993. Shore Erosion and Slumping on Western Canadian Lakes and Reservoirs: A Methodology for Estimating Future Bank Recession Rates. Report prepared for Environment Canada, November.
Ministry of Natural Resources (MNR), 1996. Technical Guide for River and Stream Systems.

Terraprobe Limited, 1997. Geotechnical Principles for Stable Slopes. Report prepared for the Ontario Ministry of Natural Resources.

Section 8.0 Addressing the Hazards

ABCA, 1994. Shoreline Management Plan, Ausable Bayfield Conservation Authority.

Acqua, 1995. Cross-shore profile change models, Great Lakes - St. Lawrence River shorelines: Review and typical applications. Report prepared for Ontario Ministry of Natural Resources, Aquatic Ecosystems Branch by Acqua Engineering Inc. in association with National Research Council Coastal Engineering Program, July 1995.

Anglin, C.D., R.B. Nairn, W.F. Baird, P. Donnelly and D. Sawyer, 1993. Shoreline management along the cohesive shorelines of the Great Lakes. Coastlines of Canada, Coastal Zone '93, ASCE, pp73-87.

Armstrong, J.M. and R.B. Denuyl, 1977. An investment decision model for shoreland protection and management. Coastal Zone Management Journal 3(3): 237-53)

Atria, 1997. Wave uprush and overtopping: Methodologies and applications, Great Lakes - St. Lawrence River System. Report prepared for Ontario Ministry of Natural Resources, by Atria Engineering Inc.

Bishop, C., 1983. A shore protection alternative: Artificial headlands. Proceedings Canadian Coastal Conference, Vancouver, ACROSES, pp305-319.

Bishop, C., Skafel, M. and Nairn, R., 1992. Cohesive profile erosion by waves. Proceedings of the 23rd. International Conference on Coastal Engineering, Volume 3, Venice, Italy, ASCE, October, pp.2977-2989.

Boyd, G. 1981. Canada/ Ontario Great Lakes erosion monitoring programme 1973 - 1980. Final report. December, 1981. Unpublished manuscript.

Boyd, G., 1981b. The March 1978 lakeshore ice piling event on Lake St. Clair, Ontario. Proc. Workshop on Ice Action on Shores, ACROSES, National Research Council, May, p1-19.

Burcharth, H.F., 1992. Reliability evaluation of a structure at sea. Proc. Short Course on Design and Reliability of Coastal Structures, 23rd International Conf. Coastal Engineering, Venice, October, pp597-644.

Chapman, L.J., and Putnam, D.F., 1951. The physiography of southern Ontario: 2nd ed., 1966, University of Toronto Press, 385p.

Chasten, M.A., Rosati, J.D., McCormick, J.W., and Randall, R.E., 1993. Engineering design guidance for detached breakwaters as shoreline stabilization structures. Coastal Engineering Research Center, Tech. Report CERC-93-19, U.S. Army Corps of Engineers, December., 167p.

CIRIA/CUR, 1991. Manual on the use of rock in coastal and shoreline engineering. CIRIA special publication 83, CUR report 154.

Davidson-Arnott, R.G.D., 1986. Erosion of the nearshore profile in till: rates, controls and implications for shoreline protection. Proceedings Symposium on Cohesive Shores, Burlington, ACROSES, May, pp137-149.

Davison, A.T., 1993. The national flood insurance program and coastal hazards. Proceedings Coastal Zone '93, p1377-1391.

Dean, R.G., B.L. Edge, O.T. Magoon, T. Saville and R.L. Wiegel, 1991. Coastal Engineering Research Needs. Ad Hoc Committee on Coastal Engineering Research Needs, ASCE Coastal Engineering Research Council. Journal of the American Shore and Beach Preservation Association, Vol.59, No.4, pp4-7, October.

Dean Rosati, J., 1990. Functional design of breakwaters for shore protection: empirical methods. Technical Report CERC-90-15, Coastal Engineering Research Center, Vicksburg, Mississippi, U.S. Army Corps of Engineers, 43p.

de Waal, J.P., and J.W. van der Meer, 1992. Wave runup and overtopping on coastal structures. Proceedings of the 23rd. International Conference on Coastal Engineering, Volume 3, Venice, Italy, ASCE, October, pp1758-1771.

EC/MNR, 1976. Coastal Zone Atlas, Canada-Ontario Shore Damage Survey, Environment Canada and Ontario Ministry of Natural Resources.

FEMA, 1986a. Coastal construction manual. Federal Emergency Management Agency, February.

FEMA, 1986b. Floodproofing non-residential structures. Federal Emergency Management Agency, May.

FEMA, 1986c. Design manual for retrofitting flood-prone residential structures. Federal Emergency Management Agency, September.

FEMA, 1984. Elevated residential structures. Federal Emergency Management Agency, March.

Fleming, C.A., 1990. Guide on the use of groynes in coastal engineering, Construction Industry Research and Information Association (CIRIA), London, 114p.

Fulton-Bennett, K. and Griggs, G.B., 1986. Coastal protection structures and their effectiveness. Joint publication of the state of California, Department of Boating and Waterways and the Marine Sciences Institute of the University of California at Santa Cruz.

Garbisch, E.W., and Garbisch, J.L., 1994. Control of upland bank erosion through tidal marsh construction on restored shores: application in the Maryland portion of Chesapeake Bay. Environmental Management Vol. 18, No. 5, pp. 677-691.

Geomatics, 1992. Great Lakes shoreline classification and mapping study: Canadian side. Report submitted to Environment Canada, Water Planning and Management Branch, prepared by Geomatics International Inc. and Dr. Robin Davidson-Arnott, July.

Goda, Y., 1985. Random seas and design of maritime structures. University of Tokyo Press.

Griggs, G.B., 1986. Relocation or reconstruction - viable approaches for structures in areas of high coastal erosion. Shore and Beach, Journal of the American Shore and Beach Preservation Association, Berkeley, California, January, pp8-16.

Hall, K.R., and Silander, J., 1995. Incorporation of habitat enhancement into shore protection. Proc. Canadian Coastal Conference, Dartmouth, N.S., CC-SEA, pp. 413-427.

Kamphuis, J.W., 1988. What is coastal engineering. Short course notes, Coastal Engineering basics, Queen's University/ Ontario Ministry of Natural Resources, August.

Kamphuis, J.W., 1989. Shore protection design: where are we?. Second Regional Workshop on Atlantic Shorelines, Associate Committee on Shorelines, National Research Council of Canada, Ottawa, pp45-62.

Kamphuis, J.W., 1989b. Sediment transport modelling: Sensitivity to incident wave direction. Proc. Tech. Session C, Maritime Hydraulics, XXIII Congress International Association for Hydraulic Research, National Research Council, Ottawa, ppC285-C292

Kamphuis, J.W., 1990. Improving shore protection design. Can. J. Civ. Eng. 17, 142-147.

Kamphuis, J.W., 1991. Alongshore sediment transport rate. Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 117, No. 6, Nov/Dec., pp624-640

Kamphuis, J.W., 1992. Computation of coastal morphology. Proc. Short Course on Design and Reliability of Coastal Structures, 23rd International Conf. Coastal Engineering, Venice, October, pp21-257.

Kamphuis, J.W., 1993. Shore protection design - a necessary evil. Coastlines of Canada, proceedings Costal Zone '93, ASCE.

Kamphuis, J.W., Davies, M.H., Nairn, R.B., and Sayao, O.J., 1986. Calculation of littoral sand transport rate. Coastal Engineering Journal, 10, pp1-21.

Kamphuis, J.W., Rahka, K., and Jui, J., 1992. Hydraulic model experiments on seawalls. Proc. 23rd International Conf. Coastal Engineering, Venice, October, pp1272-1284.

Kamphuis, J.W., Rakha, K., and Badiei, P., 1993. Sediment transport near groins and seawalls; preliminary results., Proc. Canadian Coastal Conference, Canadian Coastal Science and Engineering Association, May, pp794-805.

Keizer, H.I., 1981. The history and durability of shore protection structures in the town of Stoney Creek. M.Sc. Thesis, University of Guelph.

Kolberg, M. and Sayao, O., 1991. Evaluating shoreline protection alternatives. Coastal Zone ‘91, ASCE.

Kraus, N.C., 1987. The effects of seawalls on the beach: A literature review. Proceedings of Coastal Sediments 1987, Volume I.

MacIntosh, K.J., Timco, G.W., and Willis, D.H., 1995. Canadian experience with ice and armour stone. Proc. Canadian Coastal Conference, Dartmouth, Canadian Coastal Science and Engineering Association, pp597-606.

McDougal, W.G., Sturtevant, M.A., and Komar, P.D., 1987. Laboratory and field investigations of the impact of shoreline stabilization on adjacent properties, Proc. of Coastal Sediments '87, ASCE, pp961-973.

McNinch, J.E., and Wells, J.T., 1993. Beach scraping in North Carolina: Short-term benefits and long-term prognosis. Proc. Hilton Head Island International Coastal Symposium, June.

Minns, C.K., Meisner, J.D., Moore, J.E., Greig, L.A., and Randall, R.G., 1995. Defensible methods for pre- and post-development assessment of fish habitat in the Great Lakes. I, A prototype methodology for headlands and offshore structures., Can. Manuscript Report of Fisheries and Aquatic Sciences 2328, Fisheries and Oceans Canada.

MNR, 1997. Technical Guide for River and Stream Systems, Ontario Ministry of Natural Resources

MNR, 1996. Beach and Dune Management Guide, Ministry of Natural Resources

MNR, 1987. How to protect your shore property. Ontario Ministry of Natural Resources, reprinted March, 1987.

MNR, 1983. Benefit-cost analysis guidelines for conservation authority flood and erosion control projects. Ontario Ministry of Natural Resources, November.

MNR, 1981. Great Lakes Shore Management Guide. Fisheries and Oceans Canada and Ministry of Natural Resources, October.

Nairn, R.B., 1992 Designing for cohesive shores. Presented at Coastal Engineering in Canada, Queen's University, Kingston, May.

Nicholls, R.J., Davison, A.T., and Gambel, J., 1993. Vertical erosion on beaches and the national flood insurance program., Proc. Coastal Zone '93, New Orleans, ASCE, pp1362-1376.

Ollerhead, J. and Davidson-Arnott, R., 1993. Vertical erosion of the beach and inner nearshore on a cohesive shoreline. Proc. Canadian Coastal Conference, Vancouver, CCSEA, May, pp715-727.

Penning-Rowsell, E.C., Coker, A., N'Jai, A., Parker, D.J. and Tunstall, 1989. Scheme worthwhileness. Coastal management. Proceedings of the conference organized by the Maritime Engineering Board of the Institution of Civil Engineers, May, pp.227-241.

Philpott, K.L., 1986. Ontario Ministry of Natural Resources, Guidelines for groyne installations in the Great Lakes. November, 1986.

Pilarczyk, K.W. (ed.), 1990. Coastal protection. Proceedings of the short course on coastal protection, Delft University of Technology. June 30 - July 1, 1990.

Pope, J., and Dean, J.L., 1986. Development of design criteria for segmented breakwaters. Proc. 20th International Coastal Engineering Conference, Taipei, ASCE, pp2144-2158.

Robbins, D.B., DenUyl, R.B., Armstrong, J.M., and Kureth, C.L., 1981. Deciding to buy lakeshore erosion protection. The Michigan Riparian, pp. 6-8

Seymour, R.J., Bockstael, N.E., Campbell, T.J., Dean, R.G., Komar, P.D., Pilkey, O.H., Pratt, A.P., Snow, M.R., Van Dolah, R.F., Weggel, J.R., and Wiegel, R.L., 1996. Beach nourishment and protection: executive summary. National Research Council, reproduced in Journal of the American Shore and Beach Preservation Association, Vol. 64, No.1, January, pp5-10.

Silander, J., and Hall, K.R., 1997. Modelling coastal wetland stability., Canadian Water Resources Journal, Vol. 22, No. 2, pp. 197-212.

Tait, J.F., and Griggs, G.B., 1990. Beach response to the presence of a seawall, a comparison of field observations. Journal of the American Shore and Beach Preservation Association, April, pp.11-28.

Terraprobe, 1997. Geotechnical principles for stable slopes. Report prepared for Ontario Ministry of Natural Resources by Terraprobe Limited.

USACE, 1992. Coastal groins and nearshore breakwaters, Engineer manual 1110-2-1617, Washington.

USACE, 1984. Shore Protection Manual. U.S. Army Corps of Engineers, Washington.

USACE, 1981. Low cost shore protection...a guide for engineers and contractors. U.S. Army Corps of Engineers, Washington.

USACE, 1980. Bank erosion control with smooth cordgrass and saltmeadow cordgrass on the Atlantic coast, TN-V-2, CERC, March.

Walton, T.L., Ahrens, J.P., Truitt, C.L. and Dean, R.J., 1989. Criteria for evaluating coastal flood-protection structures. Coastal Engineering Research Center, Technical Report CERC-89-15, December.

Walton, T.L., and Sensabaugh, W., 1983. Seawall design on the open coast, Florida Sea Grant College, Report No. 29, April, 24p.

Willis, D.H., 1991. Improving shore protection design: Discussion. Can. J. Civ. Eng. 18, 890-891.

Willis, D.H., Watson, D.A.W. and Davies, M., 1990. Experience with coastal evolution models. Proceedings of the Canadian Coastal Conference, NRCC, Kingston, Ontario, May, pp. 177-187.

Wortley, A., 1984. Great Lakes small-craft harbour and structure design for ice conditions: An engineering manual. University of Wisconsin Sea Grant Institute, October.

Section 9.0 Environmentally Sound Management Within Hazardous Lands

Adams, M.A. and I.W. Whyte, 1990. Fish Habitat Enhancement: A Manual For Freshwater, Estuarine and Marine Habitats. Department of Fisheries and Oceans.

Barton, D.R. and H.B.N. Hynes, 1978a. Seasonal Variations in Densities of Macrobenthic Populations in the Wave-Zone of North-Central Lake Erie, Journal of Great Lakes Research, pp. 50-56.

Barton, D.R. and H.B.N. Hynes, 1978b. Wave-Zone Macrobenthos of the Exposed Canadian Shores of the St. Lawrence Great Lakes, Journal of Great Lakes Research. pp. 27-45.

Bird, G, 1987. Managing Ontario's Streams: Impact of Sediment on River Systems", Paper prepared for the Canadian Water Resources.

Burger, J., 1981. Effects of Human Disturbance on Colonial Species, Particularly Gulls. Colonial Waterbirds: Journal of the Colonial Waterbird Group, Vol. 4, pp. 28-36.

Dennis, D.G. and R.E. Chandler, 1974. Waterfowl Use of the Ontario Shoreline of the Southern Great Lakes During Migration. H. Boyd (ed.), Canadian Wildlife Service Rep. Serv. No. 29., pp. 58-65.

Dennis, D.G., G.B. McCullough, N.R. North and R.K. Ross, 1982. An Updated Assessment of Migrant Waterfowl Use of the Ontario Shorelines of Southern Great Lakes. Waterfowl Studies in Ontario 1973-81, Occasional Paper No. 54, Canadian Wildlife Service, pp. 37-42.

Eagles, P.F.J. and J.D. McCauley, 1982. The Rare Breeding Birds of Ontario, Department of Recreation and Department of Man-Environment Studies, University of Waterloo.

Glooschenko, B., 1987. Provincially and Regionally Significant Wetlands in Southern Ontario, Interim Report. Wildlife Branch, Ontario Ministry of Natural Resources.

Hickie, J., 1985. Habitat Management Guidelines for Waterfowl in Ontario (for use in Timber Management). Wildlife Branch, Ontario Ministry of Natural Resources.

James, R.D., 1985. Habitat Management Guidelines for Birds of Ontario Wetlands, Including Marshes, Swamps and Fens or Bogs of Various Types. Nongame Program, Wildlife Branch, Ontario Ministry of Natural Resources.

Kevern, N.R., W.E. Benierm, S.R. VanDerlaan and S.D. Cornelius, 1985. Preliminary Evaluation of an Artificial Reef as a Fishery Management Strategy in Lake Michigan. D'itri, F.M. (ed.), Artificial Reefs Marine and Freshwater Applications, Lewis Publishers Inc., Michigan, pp. 443-458.

LaRoe, E.T., 1986. Instream Impacts of Soil Erosion in Fish & Wildlife. T.E. Waddell (ed.) The Off-Site Costs of Soil Erosion, Washington, D.C., The Conservation Foundation.

Marine Board Commission on Engineering and Technical Systems, 1985. Dredging Coastal Ports, National Research Council, Washington, National Academy Press.

Ontario Ministry of Natural Resources, n.d. Community Wildlife Involvement Program: Field Manual.

Ontario Ministry of Natural Resources, 1991. Interim Fisheries Guidelines for Shoreline Alterations.

Samsel, Jr., G.L., 1973. Effects of Sedimentation on the Algae Flora of a Small Recreational Impoundment. Water Resources Bulletin, Vol. 9, No. 6, pp. 1145-1152.

Scott, A.D. and E.J. Crossman, 1973. Freshwater Fishes of Canada, Ottawa, Environment Canada, Fisheries Research Board of Canada, Bulletin No. 184.