TECHNICAL GUIDE FOR GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

PART 7

ADDRESSING THE HAZARDS

ADDRESSING THE HAZARDS

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7.1 INTRODUCTION

Human responses to shoreline flooding, erosion and dynamic beach concerns have primarily involved the construction of various forms of shoreline protection works. Unfortunately, these responses have often included works which were incompatible with neighbouring installations, works which were installed in an ad hoc fashion or works which largely ignored coastal processes and environmental impacts. In a significant number of cases, rather than protecting against flood or erosion damages, the failure or improper selection, design or installation of the selected protection work has often resulted in marked increases in property damages, losses of land, social disruption and environmental degradation.

For certain *development* and *site alteration* to be permitted within *hazardous lands* adjacent to the shorelines of the *Great Lakes - St. Lawrence River System*, 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)).

For the purposes of this Technical Guide, where *development* and/or *site alteration* is being considered within the *hazardous lands* adjacent to the *Great Lakes - St. Lawrence River System*, use of the term *hazards* shall refer to *flooding, erosion* and *dynamic beach hazards* that must be addressed. As *development* and *site alteration* are not permitted within the *defined portion of the dynamic beach* and/or *defined portion of the 100 year flood level along connecting channels* (i.e., Policy 3.1.2 (a) and (b)), discussions respecting "addressing the *hazards"* (i.e., Part 7) will only focus on those being experienced within the least hazardous portions of the *hazardous lands* and not those impacting the lands covered under Policy 3.1.2 (a) and (b).

In ensuring that these requirements are met, the intent of Part 7 of this Technical Guide is to provide direction on how to "address the *hazards*". This includes assessing whether or not protection works for *development* and *site alteration* within the *hazardous lands* interest appropriately address the *hazards* on-site. In addition, Part 7 outlines considerations that help determine the ultimate success of protection works including, but not limited to, *hazards* typically associated with the various shoreline types, design criteria such as water levels, waves, sediment transport processes and structure stability, construction and maintenance. In doing so, Part 7 also provides guidance in assessing if proposed protection works create and/or aggravate *hazards* at other sites. This is accomplished by identifying the potential impacts of protection works on the physical coastal processes. The physical impacts identified in Part 7 are then used in Part 8, to provide guidance in assessing 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.

For the purposes of clarification, Part 7 will examine the topics outlined above in the following manner:

- **Section 7.2** presents an overview of the policies contained in the Provincial Policy Statement (1996) governing Public Health and Safety, 3.1: Natural Hazards relating to the shorelines of the *Great Lakes - St. Lawrence River System*.

- **Section 7.3** provides an overview of the various shoreline management approaches that can be considered for addressing shoreline *hazards*. 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.

- **Section 7.4** provides guidance in assessing whether or not a proposed shoreline management approach safely and appropriately addresses the *hazards* on-site. Addressing the *flooding, erosion and dynamic beach 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 to address *flooding, erosion and dynamic beach hazards*. Table 7.1 summarizes the appropriate shoreline management approaches that may be given preliminary consideration to address the *hazards* for development based on the different types of shoreline as defined by the recommended shoreline classification scheme. Improvements and maintenance to existing protection works and artificial shorelines are discussed.

- **Section 7.5** provides guidance in assessing the potential influences and impacts of shoreline management approaches on the general physical shoreline processes and characteristics. The 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 7.2. Part 8 of this Technical Guide uses the influences and impacts identified in Section 7.5 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 7.3.

- **Section 7.6** summarizes the process of addressing the *hazards* in the context of the physical shoreline processes and characteristics and directs the reader to Part 8: Environmentally Sound Hazard Management within the *hazardous lands*, to examine the potential impacts on the terrestrial and aquatic habitat.

- **References**

- **Appendix A7.1** provides an overview of a recommended design approach for proposed protection works that stresses the need to identify, evaluate and document the proposed activity, the shoreline processes, the proposed shoreline treatment, the extent of the *flooding, erosion and dynamic beach hazards*, and the potential impacts. The typical project phases are outlined. Suggested levels of investigation are identified based on an initial screening of the level of concern regarding the proposed shoreline protection works. Guidelines for reporting are provided.

  Appendix A7.1 identifies the coastal engineering design considerations including the shoreline processes and characteristics and the shoreline protection design criteria.

- **Appendix A7.2** presents suggested considerations for preparing local guidelines for existing development.

7.2 ADDRESSING SHORELINE HAZARDS: PROVINCIAL POLICY

Shoreline flooding, erosion and dynamic beaches are natural phenomena evident on most shoreline reaches of the *Great Lakes - St. Lawrence River System*. These phenomena, or natural shoreline processes, only become problems, or shoreline *hazards*, when development is located in close proximity to the shoreline. Parts 1 through 6 of this Technical Guide have discussed the characteristics of these shoreline processes and the delineation and mapping of *hazardous lands* adjacent to the shorelines of the *Great Lakes - St. Lawrence River System* which are impacted by *flooding, erosion*, and/or *dynamic beach hazards*. Part 7 builds on this information and examines the shoreline management approaches that may enable the *hazards* to be safely and appropriately addressed in an environmentally sound manner.

7.2.1 Shoreline Policies

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 (non-structural or structural) and emergency response. Prevention is essentially the orderly planning of land use and the regulation of *development* and *site alteration* along shorelines subject to *hazards* (i.e., generally directing *development* and *site alteration* to areas outside of *hazardous lands* as stated in Policy 3.1.1(a)).

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, 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, 1996)

Prevention approaches are the preferred approach for management of the *Great Lakes - St. Lawrence River System* shoreline *hazards* as they reduce or minimize losses by modifying the loss potential (e.g., hazard allowances and property acquisition).

Protection, as an alternative to prevention, involves non-structural and structural protection works which are essentially engineered methods for protecting *development* and *site alteration* located within *hazard* susceptible shoreline areas. Protection approaches (e.g., relocation, floodproofing, bluff measures, dune enhancement, filling and dyking, revetments, seawalls, groynes, artificial headlands and detached breakwaters) reduce hazard losses by modifying the *hazards* at the shoreline.

While prevention is clearly the preferred choice for management of shorelines along the *Great Lakes - St. Lawrence River System*, protection works are not to be considered as inherently negative. In a number of locations and situations, protection works are necessary and may be the only realistic option. For example, protection works may be necessary at hazard prone shorelines where a large investment has already been made in the existing development, at waterfront parks in highly urbanized areas where recreational space is very limited, or in areas of very significant historical or social importance. In cases like these, it may be appropriate to proceed with protection works if the impacts that result from the works can be identified and mitigated or compensated.

Proper protection works, in combination with the appropriate allowances to address the stable slope and *hazards* (i.e., *established standards and procedures*, Policy 3.1.3(a)), may provide sufficient "protection" to warrant consideration of *development* and *site alteration* within the limit of the *hazardous lands*. Excluding those areas where development is not permitted (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 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)).

The inclusion of these requirements 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*. 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* is to be directed to areas outside the *hazardous lands*.

The intent of these conditions (i.e., Policy 3.1.3 (a) to (e)) is 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.

There are areas where protection works may be inappropriate and unacceptable as they would not meet all of the requirements of Policy 3.1.3. These areas may include, but are not limited to: locations where the active erosion of the site provides an essential sediment source for downdrift beaches; sites where the proposed protection works would result in unacceptable environmental impacts (i.e., adjacent wetland or fish habitat is significantly impacted); areas where the protection works create or aggravate *hazards* at updrift/downdrift properties (i.e., groynes trapping or deflecting alongshore sediment transport resulting in a significantly reduced quantity of sediment on beaches at adjacent properties thus increasing *hazards*).

Although the policies governing natural *hazards* do provide the flexibility for municipalities and planning boards to consider *development* and *site alteration* within the least hazardous portions of the *hazardous lands*, care must be taken to ensure that *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)).

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. Appendix A7.2 of this Technical Guide provides considerations for preparing local guidelines for 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, consultation with the local Conservation Authority and the Ministry of Natural Resources may assist municipalities and planning boards in determining 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.

7.2.2 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. *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 and/or dynamic beach hazards* to reduce the damages caused by *flooding, erosion* and/or *other water related hazards*, and to allow access for their maintenance and repair."

- "**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*."

Floodproofing will not eliminate the risk of flood damage, it merely reduces the risk. In addition, it must be recognized that there are no guarantees that protection works will offer protection for the 100 year planning horizon. In fact, protection works installed to address *erosion hazards* typically have a design life of only 25 to 50 years. This is due to limitations in current knowledge of coastal processes and their interaction with structures, the limited durability of structures and materials in the harsh coastal environment, the irreversible downcutting of the nearshore along cohesive shorelines, possible inadequate quality control during design and construction, and insufficient maintenance. Access to the development in times of flooding and erosion emergencies is necessary for safety. Access to the protection works is required for maintenance and repairs. Further discussion and details regarding the floodproofing, protection works and access standards are provided in Sections 7.4.3 (a), (b) and (c) respectively.

7.3 SHORELINE MANAGEMENT APPROACHES FOR ADDRESSING THE HAZARDS

Ensuring that the *hazards* can safely be addressed, as required by Policy 3.1.3(a), essentially means that any measures or actions intended to minimize or reduce the *flooding, erosion* and *dynamic beach hazards* must not place the safety of people or property and developments at risk. This section provides an overview of the various shoreline management approaches that may be considered to address shoreline *flooding, erosion* and/or *dynamic beach hazards*.

7.3.1 Classification of Shoreline Management Approaches

There are a wide variety of shoreline management approaches and they can be classified or grouped in many ways according to different criteria. For the purpose of this Technical Guide, shoreline management approaches have been classified as being either a **prevention** or a **protection** approach.

Prevention is the orderly planning of land use and the regulation of development in *hazard* susceptible shorelines. Prevention approaches reduce hazard losses by modifying the loss potential (i.e., hazard allowances and property acquisition) and are further discussed in Section 7.3.2

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, bluff measures and dune enhancement. These are discussed in further detail in Section 7.3.3(a). **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. The eight types are described in Section 7.3.3(b). Figure 7.1 presents a schematic view of the primary types of structural protection works. Protection approaches must include an appropriate *hazard* allowance along with the actual non-structural or structural works. *Hazard* allowances are discussed in Section 7.4.3(b)(ii).

The predominant location of each of the shoreline management approaches has also been identified. The location of an approach provides a good first indication of the potential impact of the structure on the physical coastal processes as well as the terrestrial and aquatic habitat. In Part 2: Recommended Shoreline Classification Scheme to Determine Shoreline Reaches, the shore zone was divided into four distinct units (see Figure 2.1):

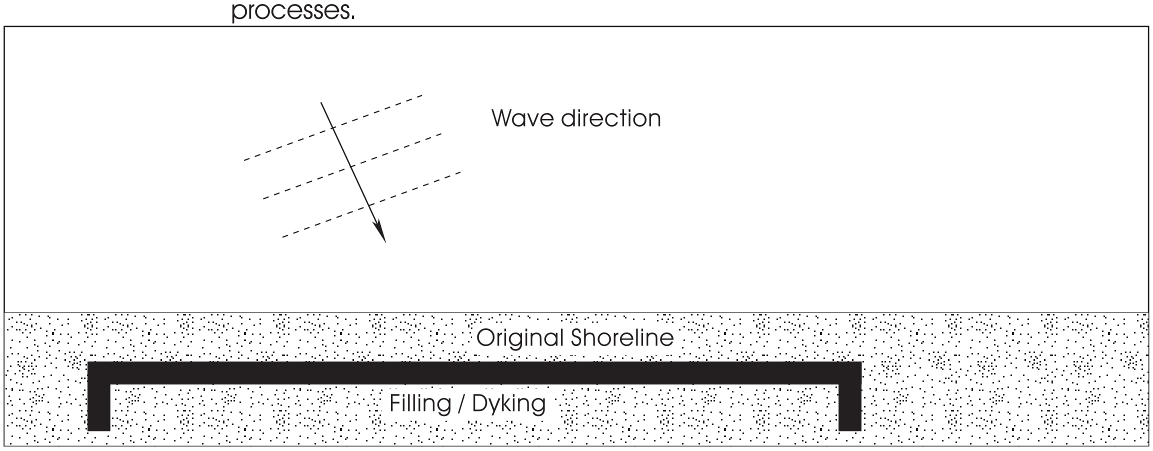
- onshore;
- backshore;
- nearshore; and
- offshore.

The **onshore** zone is the area landward and generally beyond the limit of wave action and is only subject to occasional inundation. Management approaches in the onshore zone include prevention, relocation, floodproofing, bluff measures, dune enhancement, filling and dyking. Typically, these measures are not exposed to direct wave action.

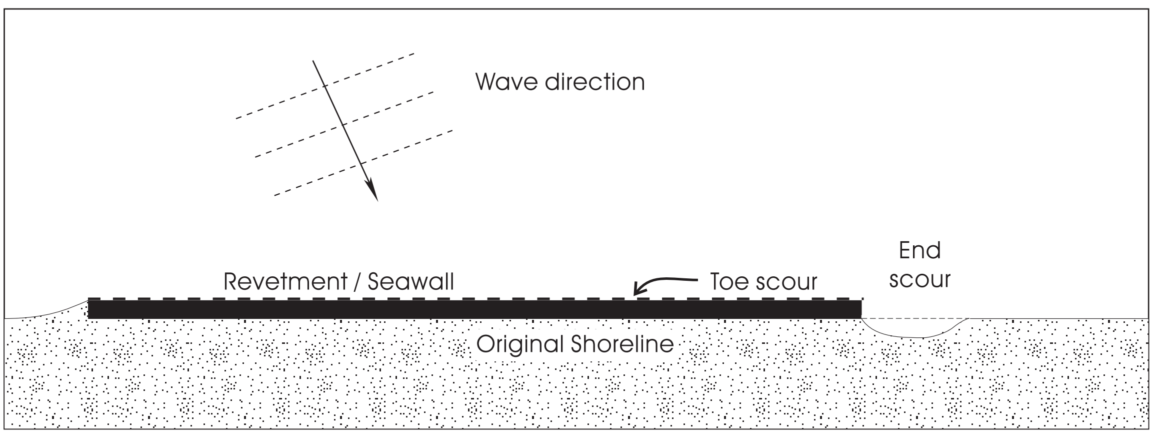
The **backshore** zone is typically only affected during severe storms particularly at exceptionally high water. Management approaches in the backshore zone include revetments and seawalls which are placed parallel to the shoreline. The base of the seawall or revetment may extend into the shallow nearshore. Revetments and seawalls are intended to control the erosion of the shoreline near the water's edge.

Figure 7.1: Primary Types of Structural Shoreline Protection Works

a) Filling / Dyking: Located in onshore (parallel to shoreline) - minimal interaction with shore processes.



b) Revetments / Seawalls: Located in backshore (parallel to shoreline) - attempts to directly oppose shoreline processes.



c) Beach Nourishment: "Soft" structural protection located in nearshore and backshore (parallel and perpendicular to shoreline) - replicates shoreline processes.

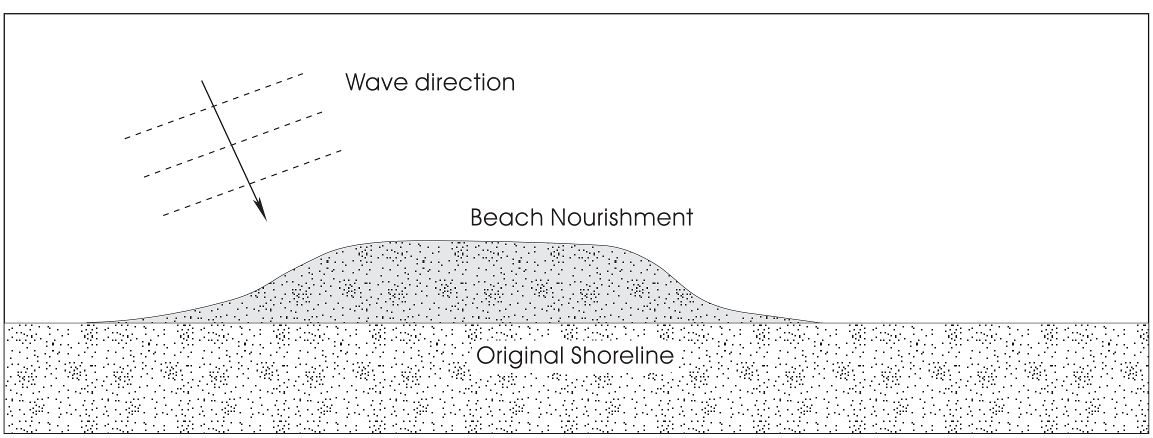
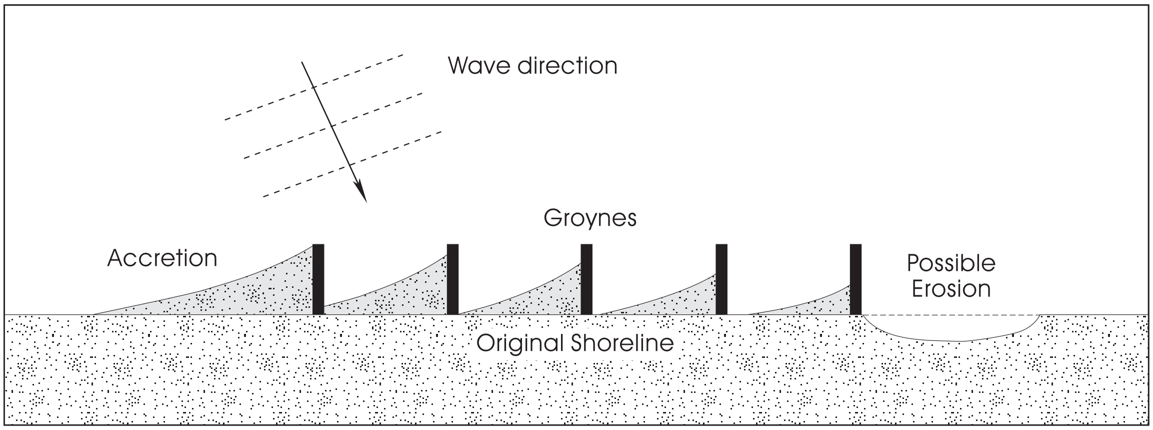
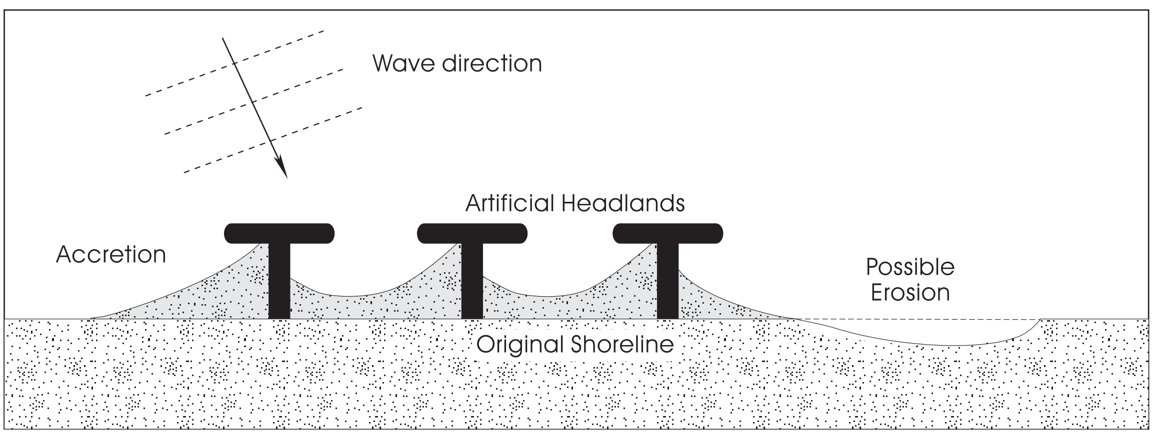


Figure 7.1 (cont'd): Primary Types of Structural Shoreline Protection Works

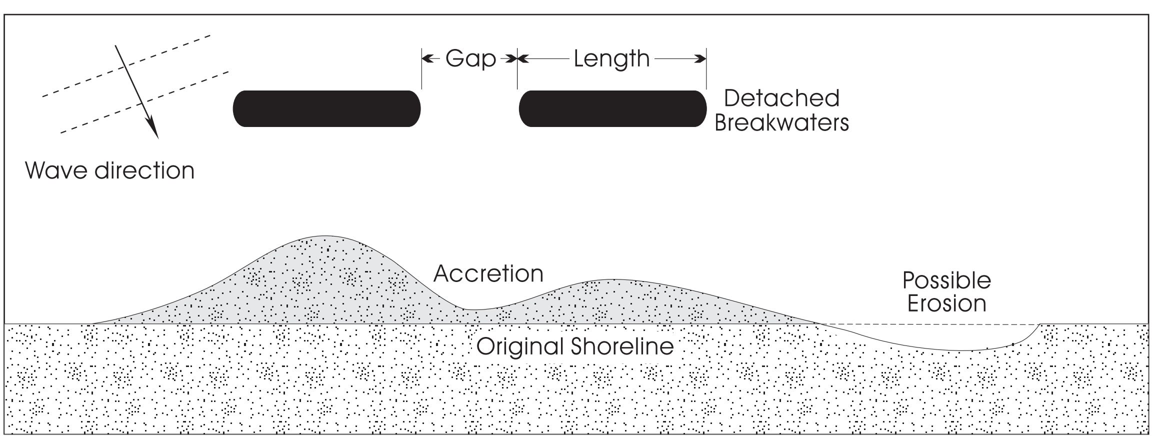
d) roynes: Located in nearshore (perpendicular to shoreline) - attempts to work with shoreline processes.



e) rtificial eadlands: Located in nearshore (perpendicular and parallel to shoreline) - attempts to work with shoreline processes.



f) Detached Breakwaters: Located in nearshore/offshore (parallel to shoreline) - attempts to work with shoreline processes.



The **nearshore zone** is an indefinite zone extending from just beyond the breakers zone to the landward limit of the swash zone and includes the foreshore (which is often nearly synonymous with the beach face). Groynes, headland breakwaters and detached breakwaters are considered to be nearshore zone structures. Some are placed perpendicular to the shoreline (i.e., groynes, headland breakwaters) while the others are placed parallel to the shore (i.e., perched beaches, detached breakwaters). Groynes will extend into the backshore zone. Beach nourishment is commonly placed from the backshore into the nearshore. Detached breakwaters for shoreline protection purposes are generally located in the nearshore, as defined by this Technical Guide. Nearshore protection schemes are typically more elaborate, costly and larger scale than the backshore methods.

Detached breakwaters can in some instances be located in the **offshore zone**, but for most shore protection applications they are located in the nearshore (i.e., in depths less than 5 m).

When classifying a shoreline management approach, it is worthwhile to consider its location and how it interacts with the natural shoreline processes. Onshore structures generally have minimal or no impact on the physical coastal process. Nearshore structures will typically result in the most significant impacts on the physical coastal processes. Some potential impacts on the physical processes are often evident with backshore structures but the impacts can be more readily mitigated.

The prevention and non-structural protection approaches are intended to function by allowing the natural processes to continue taking place unaltered. Structural protection works for stabilizing an eroding shoreline can achieve their objectives either directly, by forming a physical barrier or line of defence, or indirectly by providing protection to (or encouraging creation of) natural features such as beaches or dunes. CIRIA/CUR (1991) describes direct structural defences as normally having "to be designed to function in spite of the beach behaviour (while) an indirect coastal defence scheme generally functions because of the beach behaviour (as controlled by the structures provided)". Backshore works (revetments and seawalls) are typically shore parallel and are of the direct 'in-spite-of-' kind and tend to work directly against the shore processes. Nearshore works are generally indirect 'because-of-beach' defences and can be either shore perpendicular (i.e., groynes), shore parallel (i.e., detached breakwaters) or both (i.e., beach nourishment and artificial headlands). The purpose of these nearshore works is to work with or replicate the natural shore processes.

Different types of structure materials should not be confused with the type of structure. Quarried armour stone, field stone, rip rap, poured-in place concrete, steel sheet pile, gabion baskets and mats, timber and precast concrete units and shapes (including proprietary modules) are examples of materials commonly used in shoreline protection works. For the purposes of clarification, a distinction must be made between "structure materials" and "structure types". Stone, timber, gabions and concrete are examples of "structure materials", while revetments, seawalls, groynes and detached breakwaters are examples of "types of structures". For instance, a revetment (i.e., a type of structure) can be constructed of armour stone, concrete or gabion mats (i.e., structure materials).

The main types of shoreline management approaches have been classified as prevention, non-structural protection or structural protection and have been identified by location. This is a simplified approach. In practice protection works may extend across two or more shoreline zones or they may be used in combination with each other. Although the classification into which a particular approach has been placed is somewhat subjective and overlapping it is useful in order to provide a summarized guide for evaluating the appropriate response to safely address the *hazards* and the potential impacts.

7.3.2 Prevention Approaches

As stated earlier, **prevention** of hazard damages along the shorelines of the *Great Lakes - St. Lawrence River System* is normally achieved through the orderly planning of land use and the regulation of development in *hazard* susceptible shorelines. Land use planning and the regulation of shorelines involve the use of regulations, restrictions or by-laws which are enacted to control or modify shoreline uses and development in a manner that will minimize the potential conflict between the development and the natural shoreline processes and water level fluctuations. Prevention approaches reduce hazard losses by modifying the loss potential.

For *hazard* susceptible shorelines of the *Great Lakes - St. Lawrence River System*, the prevention approaches considered to be best management approaches include:

- **hazard allowances and minimum elevation requirements**; and
- **property acquisition**.

Prevention approaches are generally the most environmentally sound and cost-effective means of ensuring that buildings and structures are not susceptible to *hazards (*i.e., *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.

a) Hazard Allowances and Minimum Elevation Requirements

In general, hazard allowances are mechanisms requiring that *development* and *site alterations* be set back to the outer limit of the "area of provincial interest" (e.g., outside the *hazardous lands*). In addition to hazard allowances, there may also be elevation requirements that specify that buildings or structures must be elevated above the predetermined flood limit (e.g., floodproofing standard). Hazard allowances are normally supported by hazard mapping (e.g., Flood Damage Reduction Program, 1:2000 scale mapping).

The hazard allowances defined by the *hazardous lands* should be considered to be <u>minimum standards</u>. The mere identification of a standard does not preclude an event of a greater magnitude from happening (e.g., flood levels with return periods of greater than 100 years). Also, due to ongoing erosion, use of the minimum erosion allowances will require relocation, abandonment or protection of the development in about 70 to 100 years. Although often difficult to promote, shore property owners should be encouraged to use greater standards where possible. This is normally considered where there is sufficient area to site the building further from the *hazards* as an added insurance against the uncertainties of the site-specific *hazards*. For instance, in a highly erosive area, a greater erosion allowance could be used (i.e., greater than 100 times the average annual recession rate). Options that concentrate development in clusters should be considered over linear development parallel to the shoreline. Along undeveloped portions of the shoreline, land use planning could consider directing development towards natural erosion-resistant headlands or siting development based on considerations of the very long-term (much greater than 100 years) evolution of the shoreline (possibly based on such concepts as headland-bay development).

By keeping development out of the "area of provincial interest" (i.e., *hazardous lands*), the shoreline ecosystem is maintained which in itself may have significant long-term physical and environmental benefits along the shoreline. For example, eroding bluffs are a significant natural source of sand and gravel for downdrift shoreline beaches. Although beaches along cohesive shores generally do not provide adequate hazard protection, they do provide recreational and aesthetic benefits and increase shoreline diversity which in turn may enhance and promote wildlife habitat. In addition, sand and gravel in the nearshore zone plays an integral role in the downcutting process. Reducing the amount of sand and gravel in the nearshore may accelerate the downcutting by more frequently exposing the underlying controlling substrate.

In conclusion, maintaining the *hazardous lands* adjacent to the *Great Lakes - St. Lawrence River System* in a natural state, by directing *development* and *site alterations* to areas outside of the *hazardous lands* essentially provides a buffer along the shoreline for environmental and social considerations such as terrestrial habitat, control of sediment and surface runoff and access to and along the water's edge.

b) Property Acquisition

One prevention approach is the public acquisition of shorelines in certain situations. Acquisition, however, is usually considered only if other resource management goals, such as habitat protection or recreation, are to be achieved. Shore habitats can include wetlands, barrier beaches and dunes.

Public acquisition of shoreline properties should be considered as an option to publicly funded structural shoreline protection works for private properties.

7.3.3 Protection Approaches

Protection approaches involve engineered methods for protecting development located within *hazard* susceptible shoreline areas. Where protection works are installed they are always to be combined with an appropriate allowance for stable slope and an appropriate *hazard* allowance (i.e., addressing flooding, erosion and/or dynamic beach hazards). Protection approaches reduce hazard losses by modifying the *flooding, erosion* and/or *dynamic beach hazards*. For the purpose of this Technical Guide, protection approaches or methods have been classified as non-structural or structural works. A brief outline of the various protection approaches is provided in the following sections.

a) Non-Structural Protection Works

Non-structural protection works are activities that do not involve the construction or placement of significant additional structures or material and include:

- relocation;
- floodproofing;
- bluff measures; and
- dune enhancement.

In comparison with structural protection works, non-structural methods tend to have minimal or no impacts on the physical coastal processes.

i) Relocation

Relocation is the moving of a 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 7.2). A Michigan study during the high water period of the 1970's concluded that relocation of endangered shoreline houses was the most economical option in cases where relocation was feasible (Armstrong and Denuyl 1977).

Relocation, as a form of prevention, is an effective practice to mitigating *flooding, erosion* and *dynamic beach hazards* for existing buildings. Prevention through relocation often proves to be less costly than protection, especially in areas of high to severe erosion. Many owners invest such large amounts in protection (including materials, construction, and future maintenance) that they essentially "rebuy" their house and land every 20 years, and in most cases their land continues to erode (Robbins et. al 1981). In many instances a benefit-cost analysis may suggest that acquisition and/or removal/relocation of a building from *hazard* susceptible shorelines is a more appropriate response than structural protection works.

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. Even when moving a structure is impossible, complete rebuilding may be less expensive than long-term coastal protection (Griggs 1986). When a building or service is relocated it should be placed landward of the *hazardous lands*.

Figure 7.2: Relocation of Residence from Hazardous Lands

ii) Floodproofing

In the context of the *Great Lakes - St. Lawrence River System*, floodproofing is defined in the *Provincial Policy Statement (1996)* 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 7.3 and 7.4), watertight closures for doors and windows and location of electrical equipment and utilities above the expected flood levels (see Figure 7.5). 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 damage 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 (See Section 7.4.3(a)).

Wet floodproofing is considered to be 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 the *Great Lakes - St. Lawrence River System*.

iii) Bluff Measures

Bluff measures consist of planting stabilizing vegetation on the bluff slope, controlling drainage of the surface runoff and/or the groundwater flow, and/or the regrading of the slope. When applying bluff measures, 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 possibly septic systems.

On their own, bluff measures are insufficient to address an *erosion hazard* on a shoreline that is eroding due to wave action except possibly in very low wave energy environments (i.e., sheltereed embayments). In situations of bluff instability a professional engineer qualified in geotechnical engineering should be consulted. Part 4: Erosion Hazards (of this Technical Guide) provides guidance for reviewing slope stability concerns.

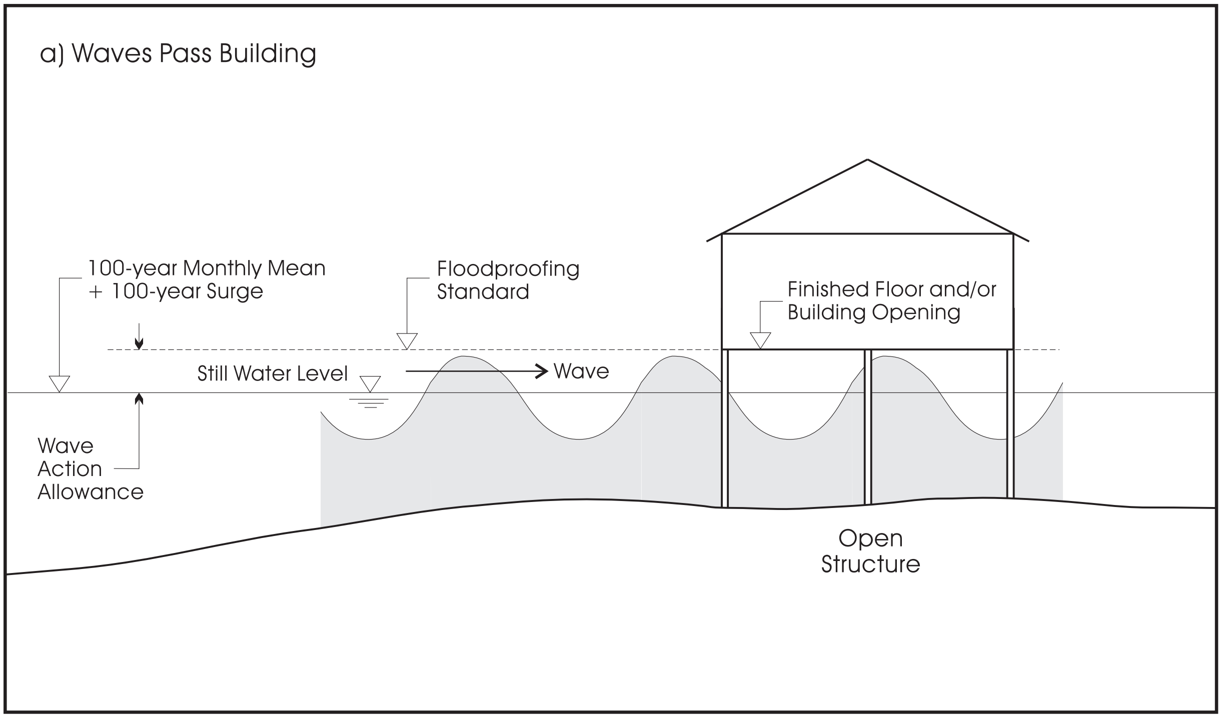
A brief outline of some of the various bluff measures include:

- **Vegetation and bioengineering**. 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 7.6). It can improve the visual quality of a shoreline area and provide wildlife habitat. Bioengineering combines structural measures (e.g., timber cribbing) with live plant materials in order to stabilize the slope face (see Figure 7.7). Native plant species which are compatible with the local flora should be used.

- **Surface drainage**. The erosive effects of surface drainage on a slope can be reduced by directing water away from the slope (see Figure 7.8a) or by providing an erosion resistant swale or channel which conveys the water down the slope face in a controlled manner (see Figure 7.8b).

- **Internal drainage improvements**. 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 7.8c).

Figure 7.3: Elevation of Flood Prone Residence (Dry Passive Floodproofing)



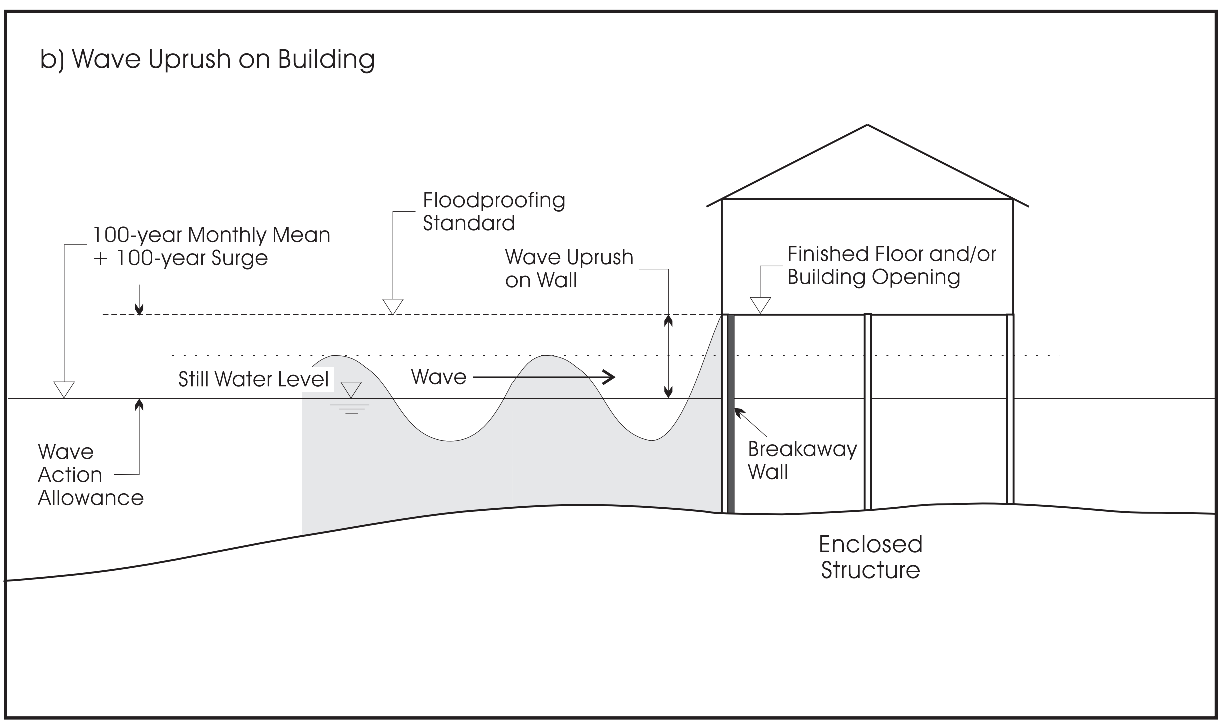


Figure 7.4: Structure Elevated as Floodproofing Measure

Figure 7.5: Utilities Relocated Above Floodproofing Standard (Wet Floodproofing Measure)

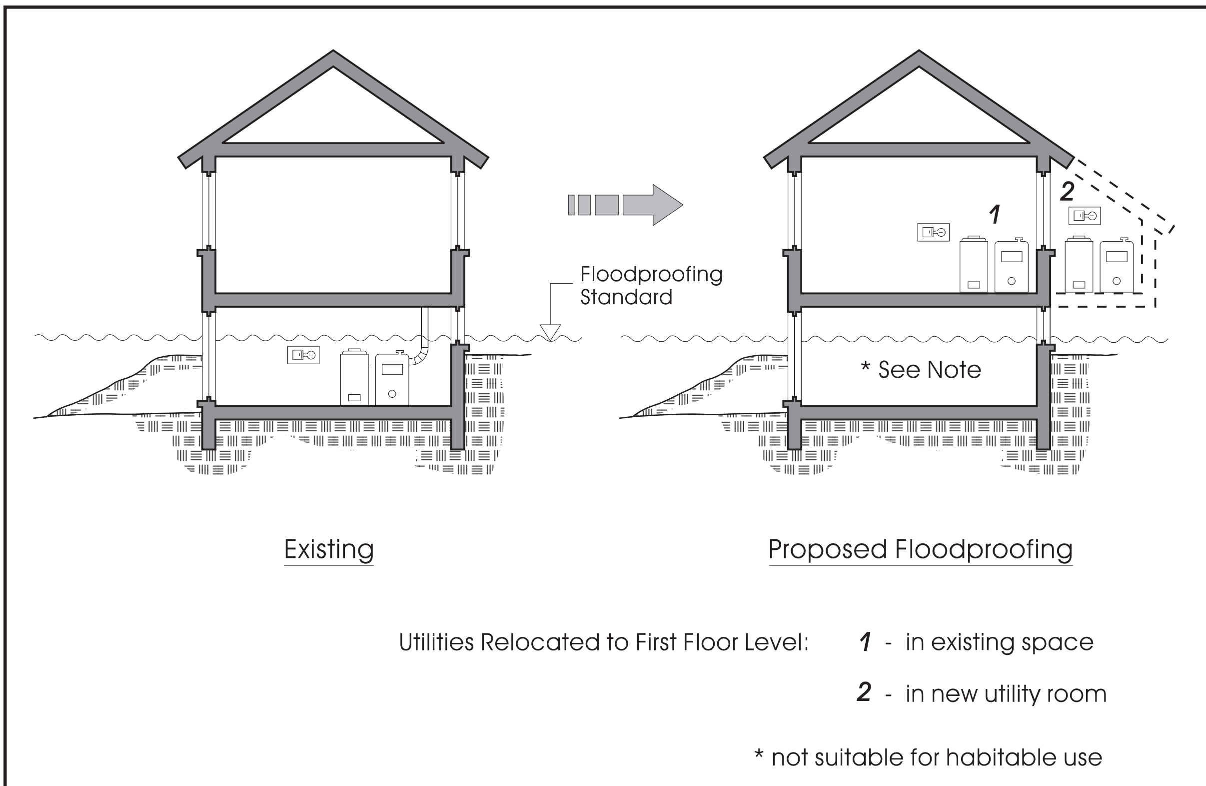


Figure 7.6: Effects of Vegetation

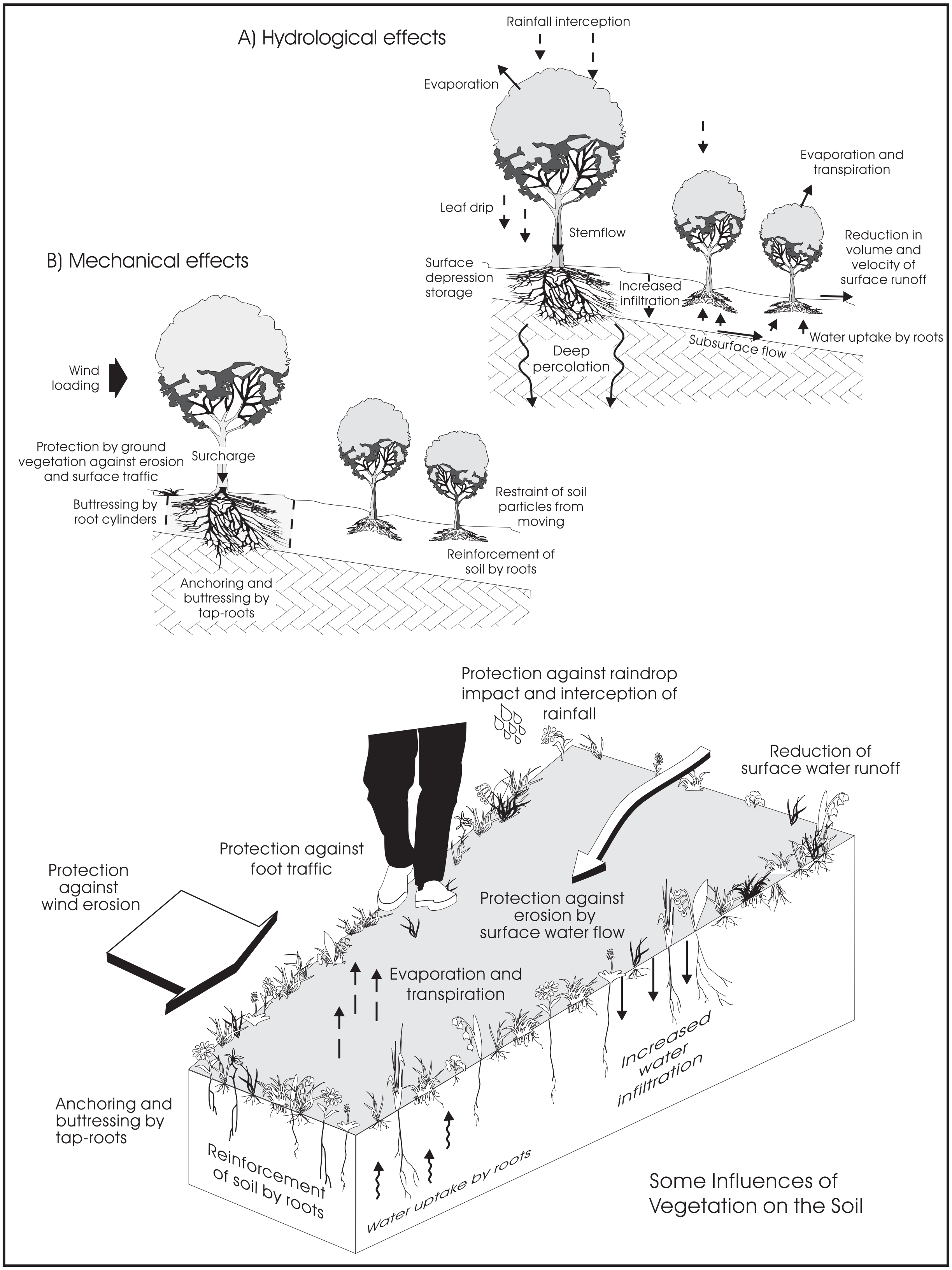
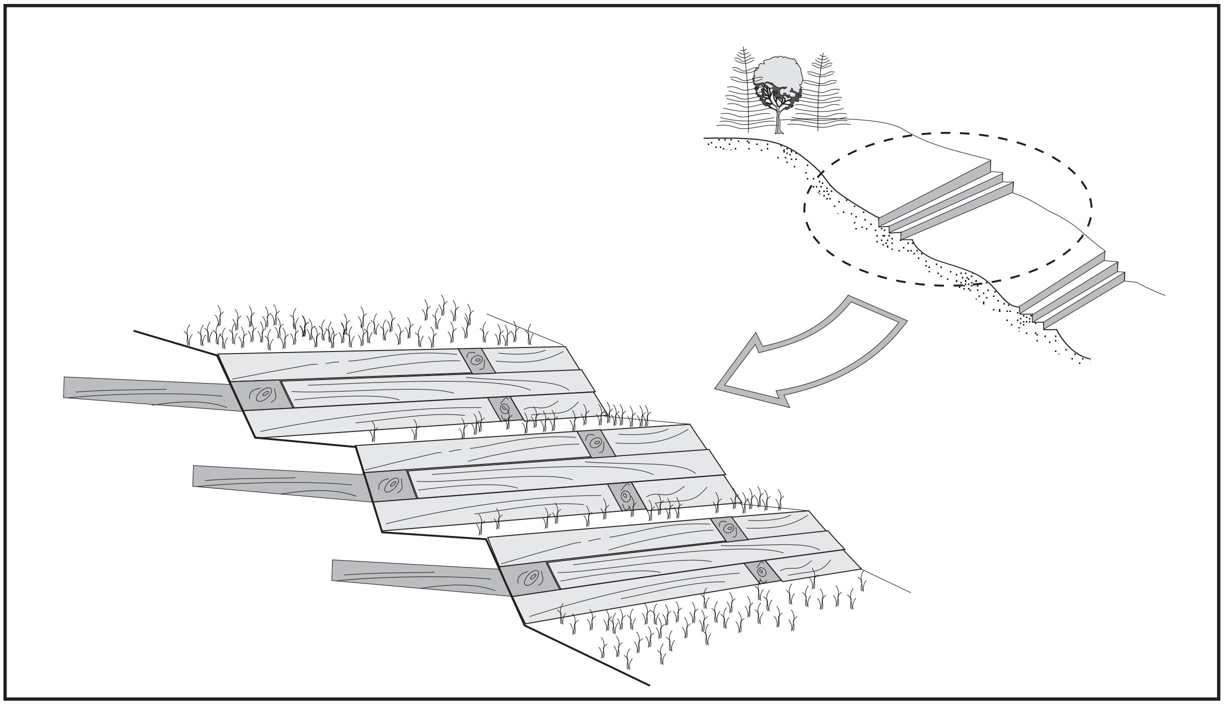


Figure 7.7: Bluff Measures - Bio-Engineering Techniques

a) Slope Terracing with Railroad Ties



b) Contour Wattling Used to Slow Runoff and Provide a Base for Vegetation

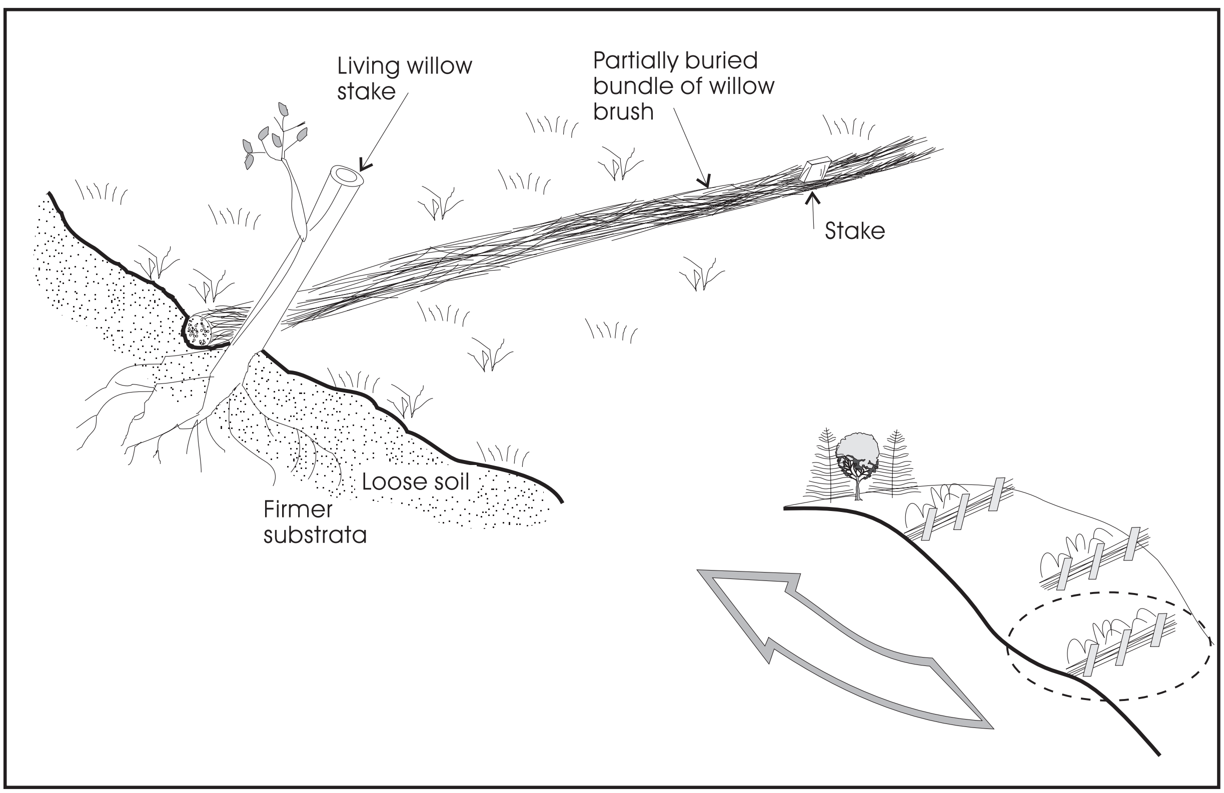


Figure 7.8: Bluff Measures - Drainage

Figure 7.8a: Diverting Surface Runoff

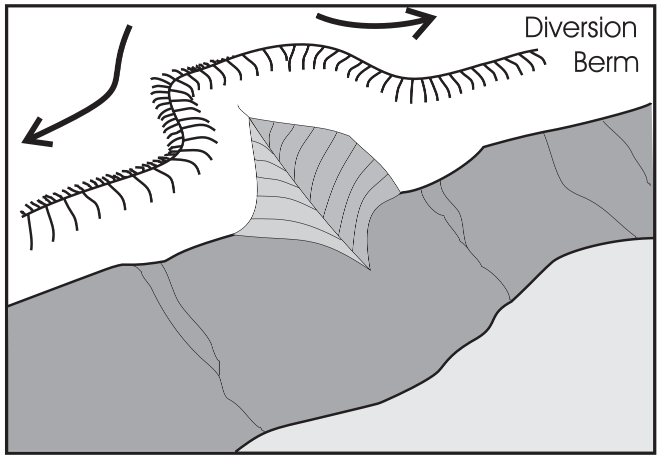


Figure 7.8b: Controlling Surface Runoff

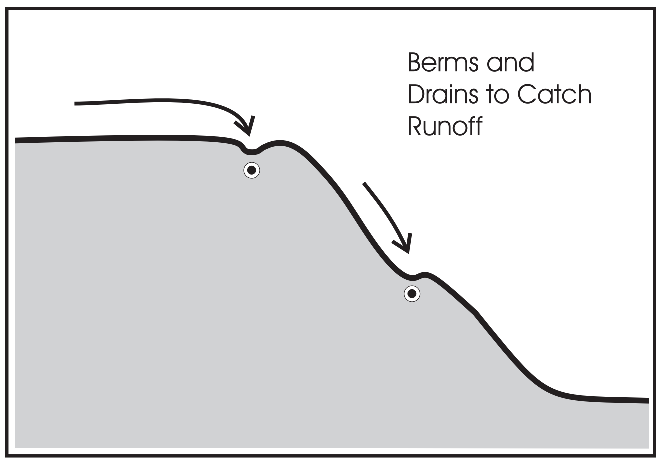
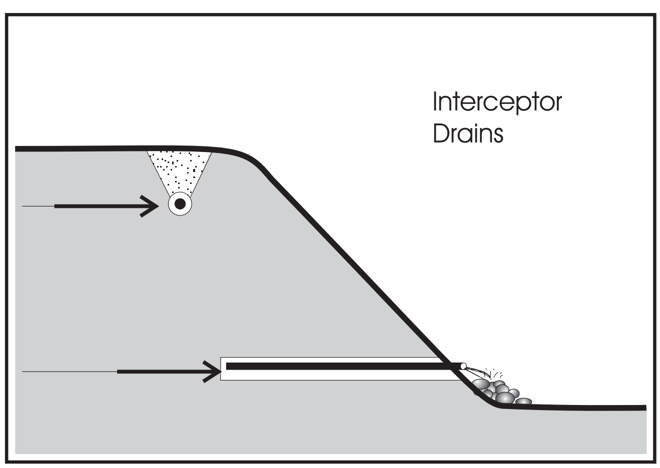


Figure 7.8c: Internal Drainage Measures



- **Regrading slope**. Where the existing bluff is oversteep and unstable, the bluff can be regraded to a flatter slope (see Figure 7.9). Regrading is often accompanied by drainage improvements and revegetation.

Further details on bluff measures (e.g., vegetation, bio-engineering and drainage) can be found in Part 4: Erosion Hazards (of this Technical Guide), Terraprobe (1997) and the Technical Guide for Large Inland Lakes (1996).

iv) 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 (see Figure 7.10) and the re-establishment of dune vegetation. Driftwood and fallen trees help protect dunes and should not be removed. The Beach and Dune Management Guide (MNR 1996) provides additional information on the importance of dunes and measures for dune enhancement.

b) Structural Protection Works

For the purpose of this Technical Guide, 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. As discussed in Section 7.3.1, most structural protection works can be discussed within the context of the following eight basic types:

- filling;
- dyking;
- flexible revetments and seawalls;
- rigid revetments and seawalls;
- beach nourishment;
- groynes;
- artificial headlands; and
- detached breakwaters.

These structure types are briefly discussed in the following sub-sections followed by an overview of other shoreline structures such as combination structures, nearshore armouring, docks, piers and boat launches, and proprietary systems.

i) 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 7.11). Dykes are artificial banks or mounds built around the perimeter of subject area to prevent the entry of flood waters (see Figure 7.12). As with dykes, floodwalls are designed to keep the water away from the house (see Figure 7.13), 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.

For the purposes of this Technical Guide, filling and dykes are, by definition, located in the onshore area which is subject to only occasional inundation and beyond the limit of normal storm wave action. Fill placed lakeward of the onshore area is classified as lakefilling. Lakefill exposed to wave action must be accompanied by suitable erosion protection structures.

Figure 7.9: Regrading Slope

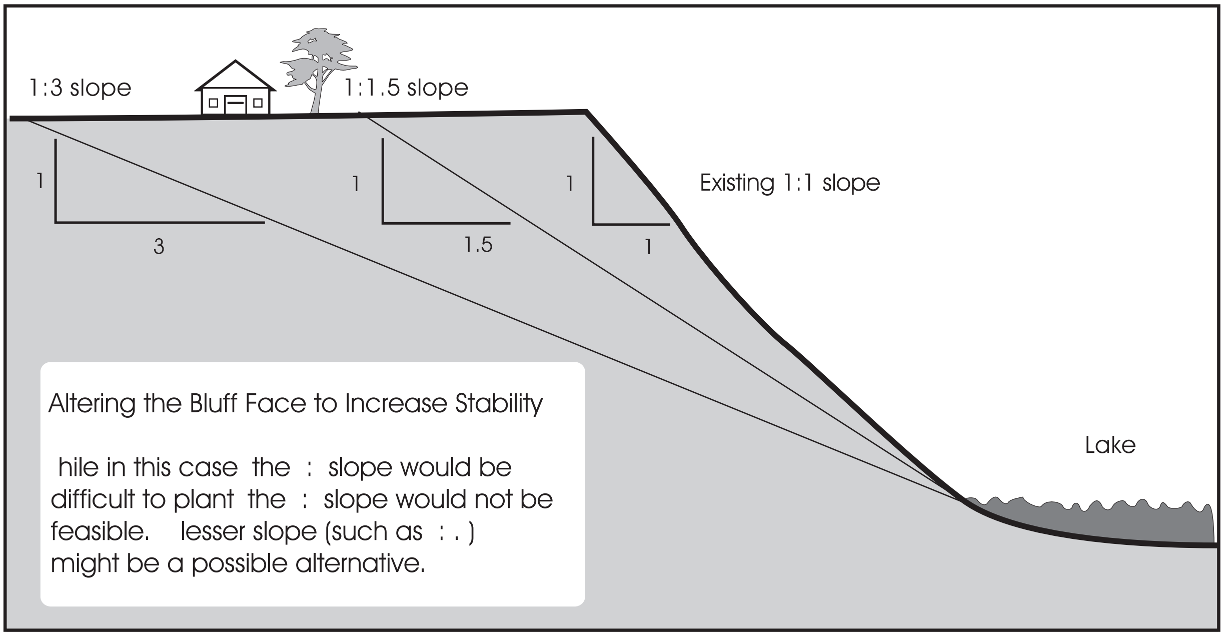


Figure 7.10: Controlled Dune Access

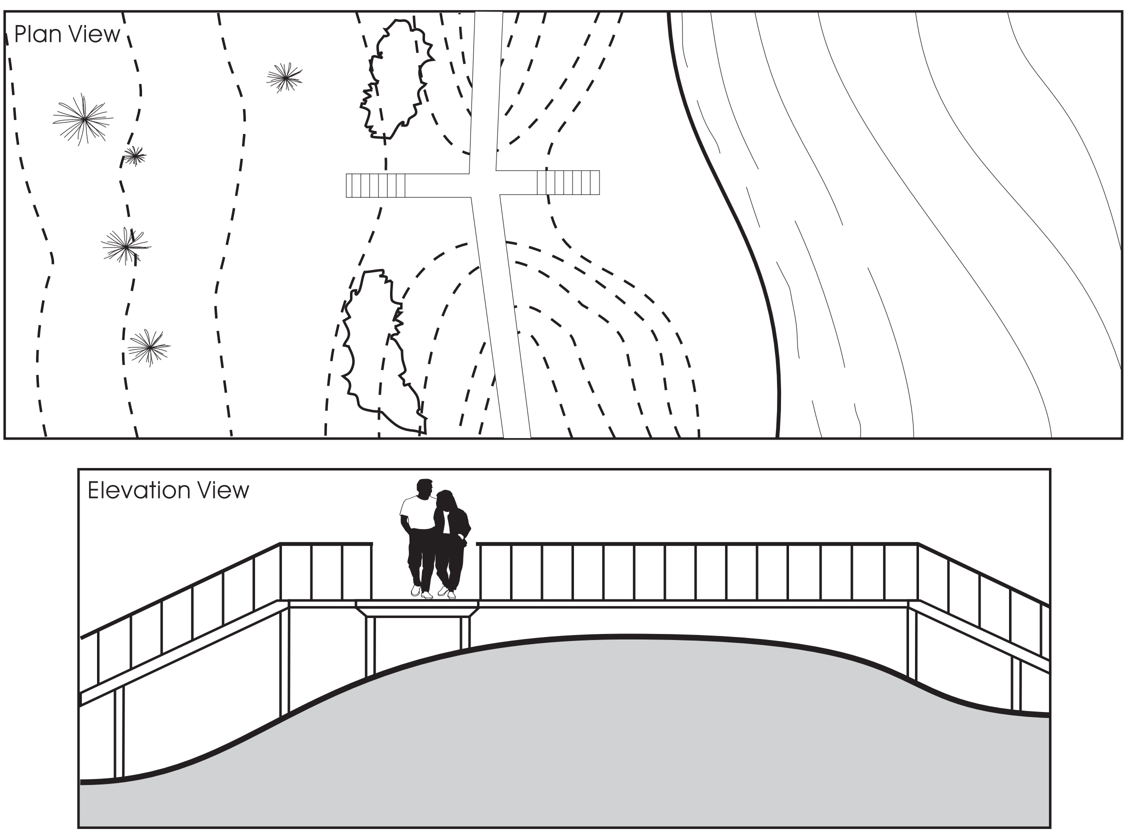


Figure 7.11: Filling (Above 100-Year Flood Level)

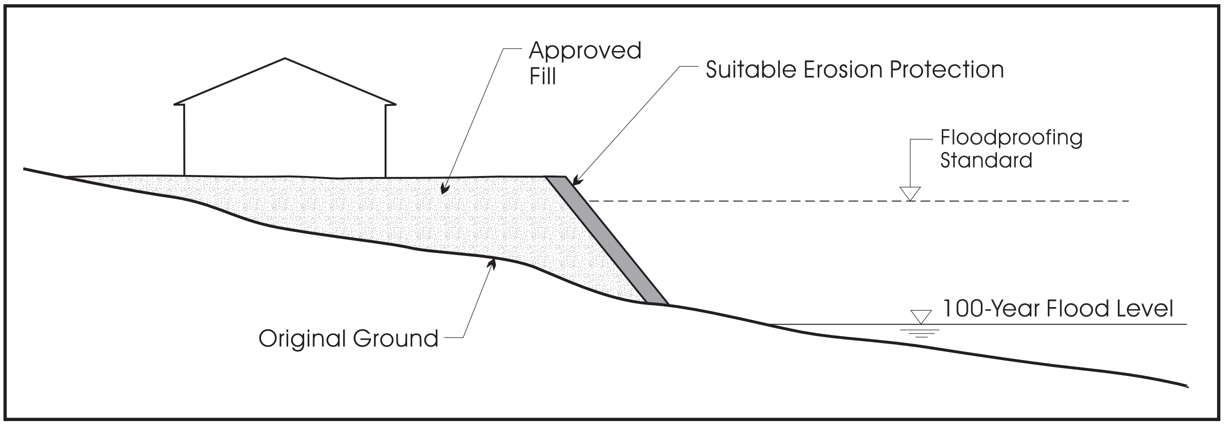


Figure 7.12: Dyke

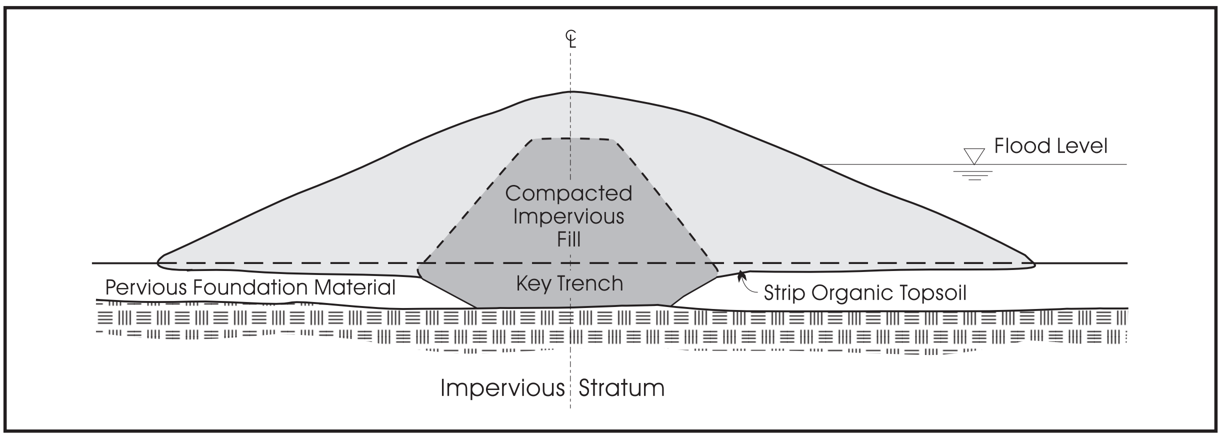
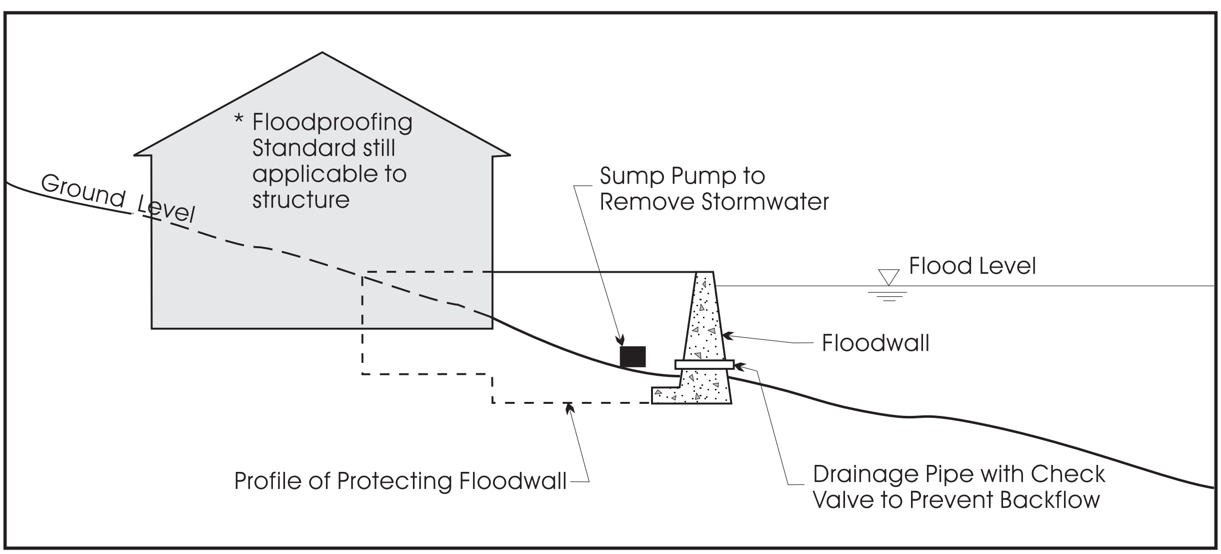


Figure 7.13: Floodwall



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. Auxiliary measures that may be needed (e.g., pumps, backflow gates and valves) must be subject to periodic inspections and regular maintenance.

Fill material used in fill areas and dykes must meet the Ministry of Environment and Energy requirements as outlined in *Fill Quality Guidelines for Lakefilling in Ontario: Application of Sediment and Water Quality Guidelines to Lakefilling and Policy for Management of Excess Soil, Rock and Like Materials*. The *Fill Quality Guidelines* apply to all new or on-going lakefill projects including:

- shoreline stabilization projects;
- construction of piers, groynes, docks and causeways;
- construction of breakwaters and Confined Disposal Facility (CDF) perimeter walls/structures;
- large-scale projects for recreational purposes;
- beach creation; and
- enclosure dykes or dams for mine tailings ponds.

Lakefill *Fill Quality Guidelines* do not apply to:

- material placed within a CDF structure;
- material placed on shorelines above the high water mark and adequately stabilized or protected; and
- filling behind impermeable barriers such as concrete or sheetpile revetment walls (subject to appropriate treatment of decant water).

For further information and specific details and application procedures regarding fill quality (for large-scale and small-scale projects), the MOEE Guidelines should be consulted.

One final approach often identified as a filling and dyking approach is beach scraping. In simple terms, beach scraping is the process of removing sediment from the foreshore or lower berm and constructing a protective dyke or fill in the backshore for the purpose of mitigating erosion and damage to the backshore features. Although the practice has been conducted, it has received little scientific attention and remains controversial as to whether a measurable benefit is provided (McNinch and Wells 1993).

ii) Flexible and Rigid Revetments and Seawalls

A revetment is a sloped 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 can endure some settlement or other movement without failing. Armour stone (i.e., individual quarried stone blocks; see Figure 7.14a), rip-rap, and interlocking concrete block mats are examples of materials used in flexible revetments. An armour stone or rip-rap revetment can tolerate more settlement than an interlocking concrete block revetment. A poured-in-place concrete slab revetment is an example of a rigid structure (see Figure 7.14b). A rigid concrete revetment requires a sound foundation which will not settle over time. Settlement or movement of a rigid structure will usually result in cracking and possibly structural failure.

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 7.15a). Dynamic revetments have smaller armouring material which is designed to shift and reshape in response to the wave action (see Figure 7.15b). Figure 7.16 shows a photograph of a typical static armour stone revetment.

Figure 7.14: Flexible and Rigid Revetments and Seawalls

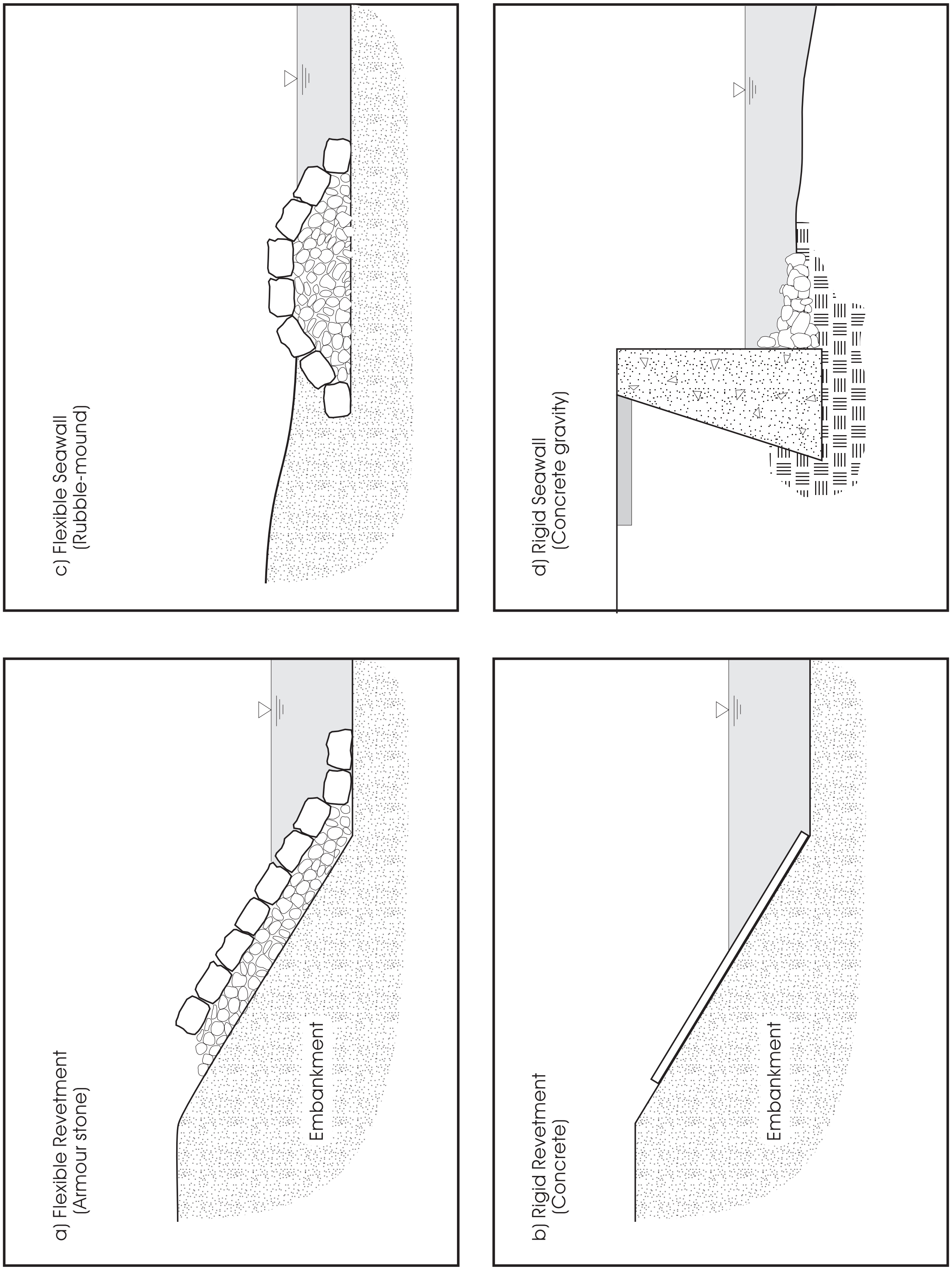
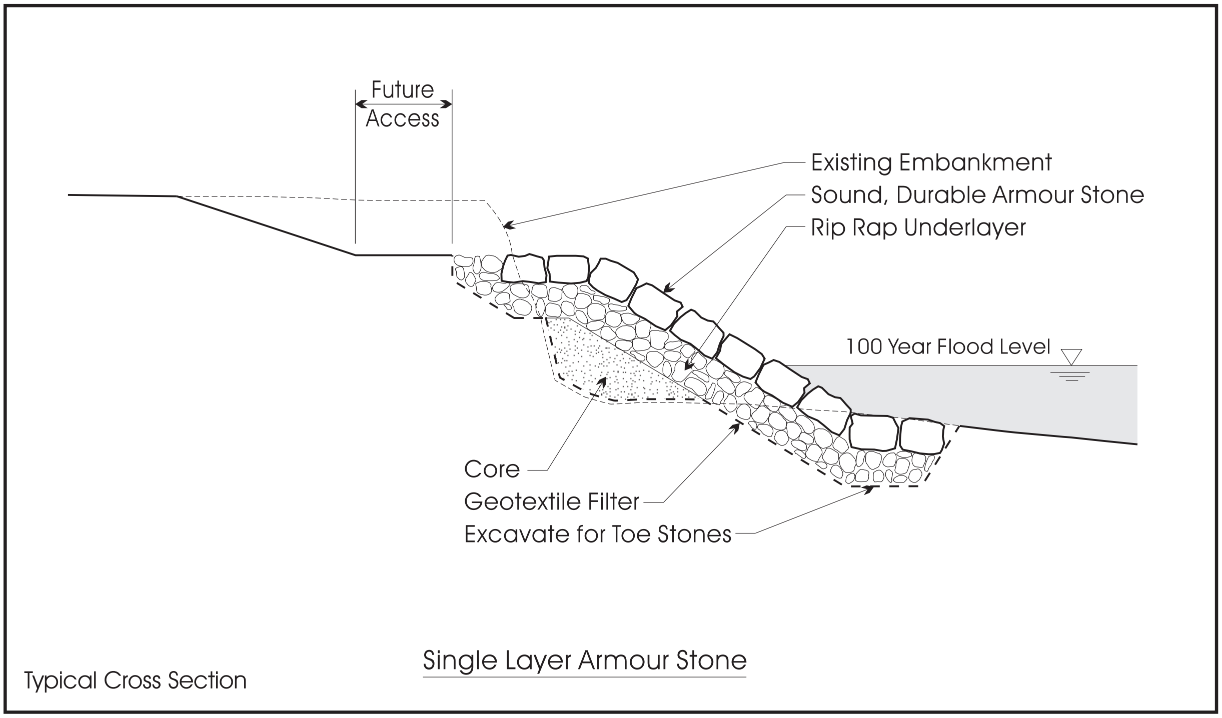


Figure 7.15: Revetment Armouring

a) Static Armouring



b) Dynamic Armouring

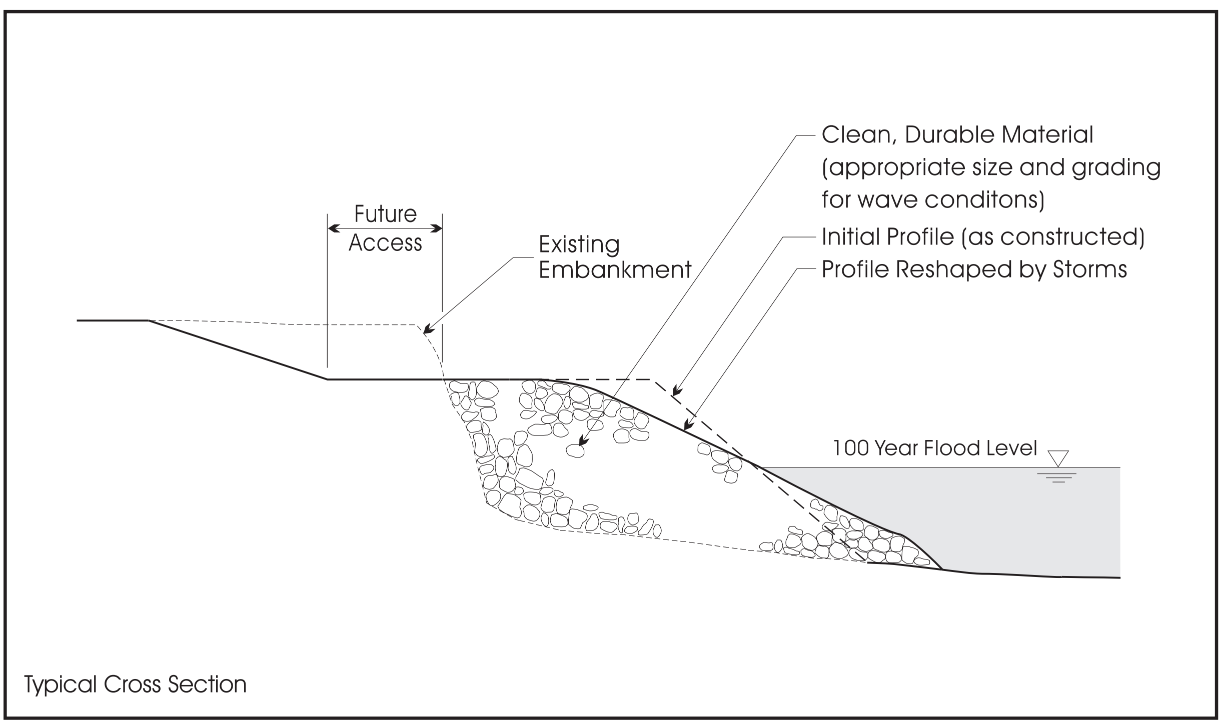


Figure 7.16: Photograph of Armour Stone Revetment

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 7.17). The wave action is recognized in the design process as being 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 7.14d) or flexible rubble-mound seawalls (see Figure 7.14(c)).

Rubble-mound seawalls are similar to armour stone revetments in terms of the outer cover armouring layer and the underlayer but differ in the overall size of the core (see Figure 7.14). A revetment primarily consists of a facing of stone and depends, to a large extent, on the underlying embankment for support. A rubble-mound structure is simply a mound of stones with a cover layer of large selected stones or concrete units. A rubble-mound structure can "stand alone" and does not rely to any large extent on the backshore for support. 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 but both 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 7.18) or timber. Bulkhead structures, such as anchored steel sheet piles, can be designed to resist wave action, effectively acting as seawalls. However, bulkheads are mostly constructed with little consideration of the wave forces and as such are generally not recommended for use along exposed shorelines.

Smooth, vertical, impermeable seawalls (such as concrete 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. As nearshore downcutting progresses, the increased depth in front of the revetment or seawall will permit larger waves to attack the structure, thereby possibly putting the stability of the structure at risk. 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 for support, such as bedrock, 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.

At the alongshore ends of a revetment or seawall, the adjacent shoreline may be subject to some localized scour or erosion (in addition to any ongoing erosion of the shoreline). Revetments and seawalls located in the backshore area tend not to have a significant effect on the alongshore transport rate because littoral material can bypass the site.

Figure 7.17: Seawalls

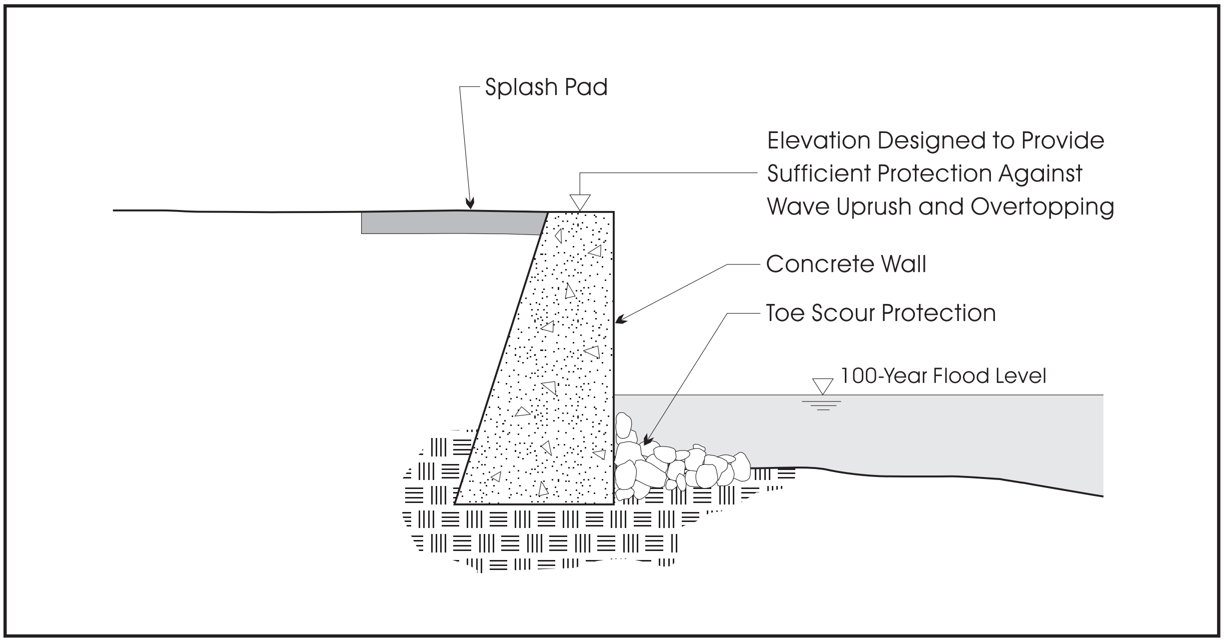
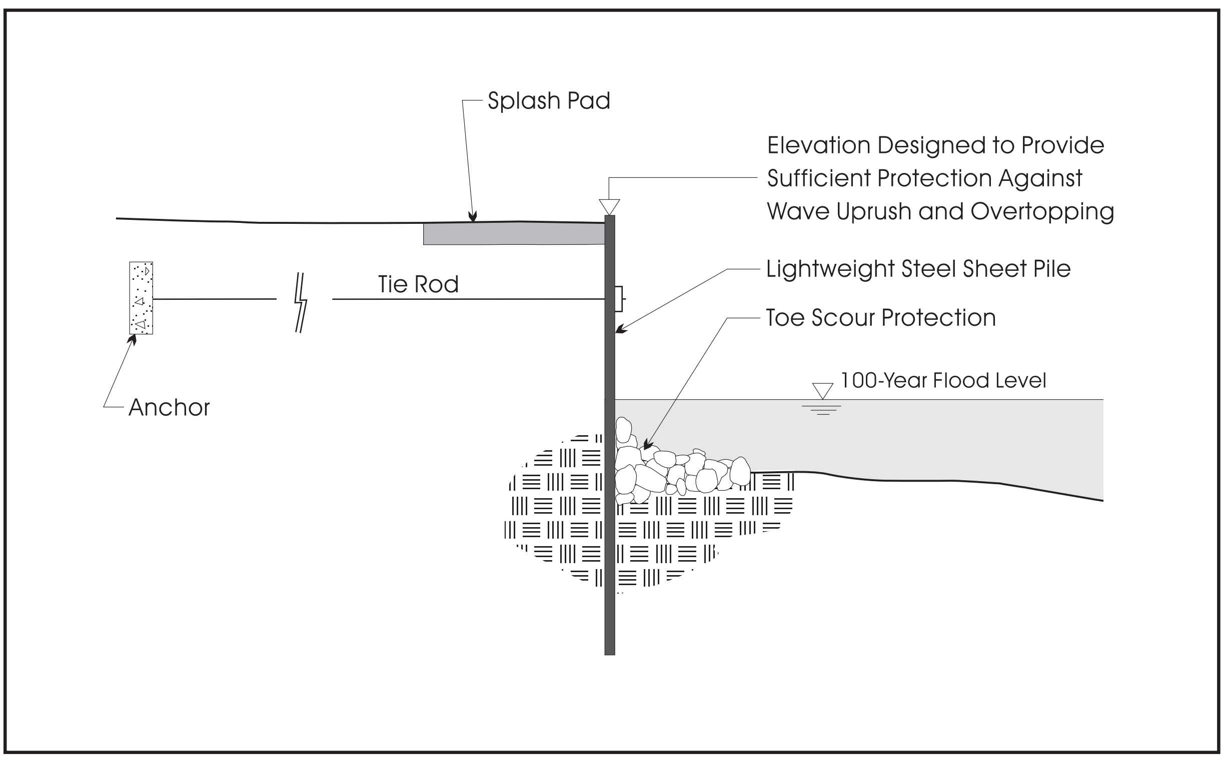


Figure 7.18: Steel Sheet Pile Bulkhead



iii) 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. It is considered a structural approach because it is an engineered method that involves the placement of significant quantities of additional material at the shoreline. However, beach nourishment is considered a "soft" structural protection method because it attempts to replicate the natural processes. This additional distinction is noted because no other structural protection work creates sand in the surf zone. Any accumulation of sand produced by a structure, other than beach nourishment, is at the expense of an adjacent section of the shore.

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. Beach nourishment typically extends from the backshore area into the nearshore. Depending on the beach width and slope, the added beach material protects the backshore and the nearshore profile from erosion and storm wave damage (see Figure 7.19). The increased beach width can also provide recreational benefits. The beach material can be imported from an inland source or obtained by offshore dredging. Beach fill material used should meet the MOEE requirements as outlined in the *Fill Quality Guidelines for Lakefilling in Ontario: Application of Sediment and Water Quality Guidelines to Lakefilling and Policy for Management of Excess Soil, Rock and Like Materials*.

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 re-nourishment) 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.**

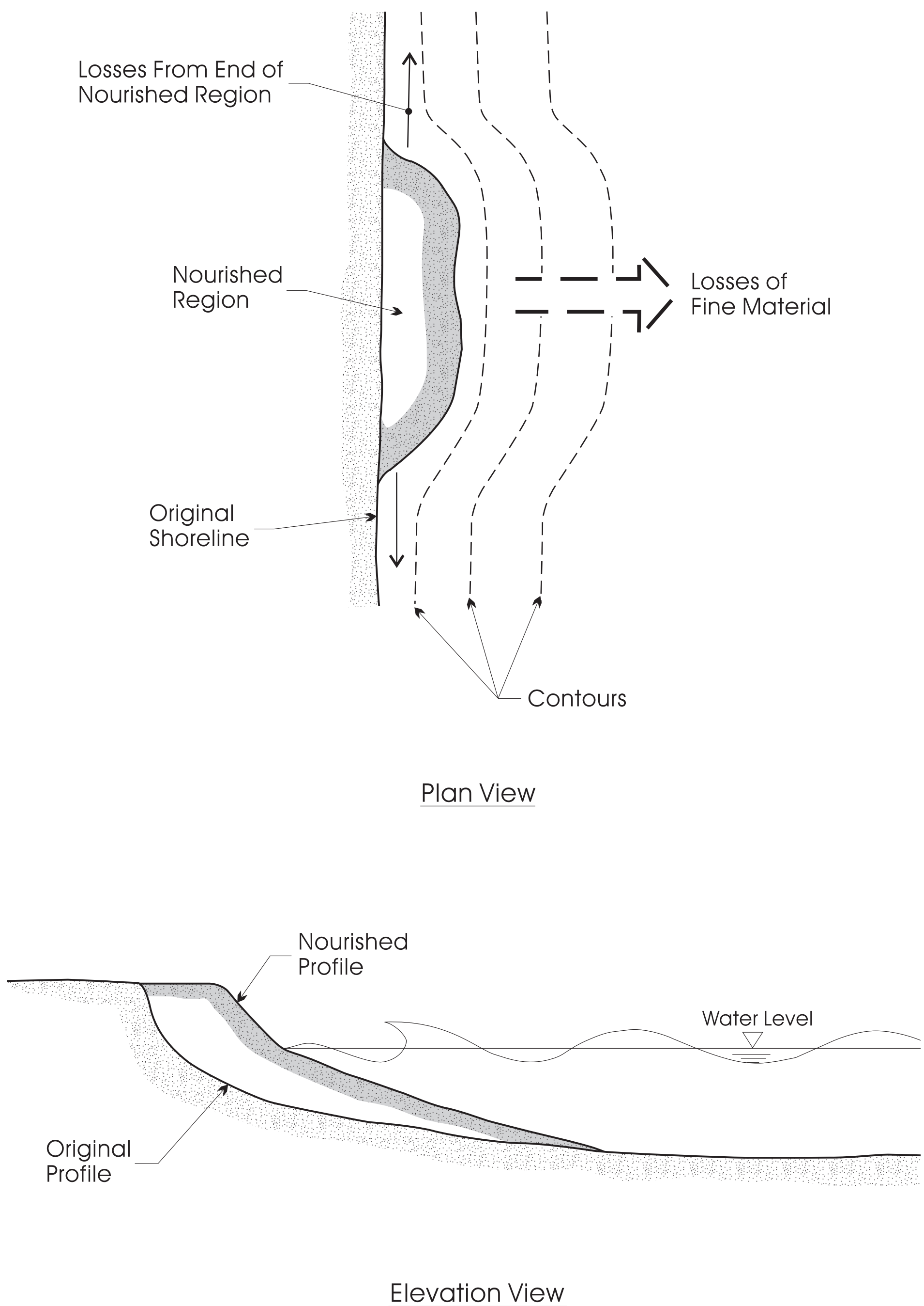
As a result of the "loss" of the placed material from the site, the sediment supply to the littoral zone is increased. In the context of the physical coastal processes, this will usually benefit rather than endanger downdrift areas. A concern that must be evaluated is the effect of the "loss" of the 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 is 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. Losses to the offshore are an important consideration for shorelines where cross-shore transport is dominant. 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., fine-grained cohesive shores) or where no previous beach existed (i.e., bedrock shores).

Beach nourishment or beach fill can be used in conjunction with other types of shoreline protection works to provide toe scour protection or recreational benefits.

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. Beach nourishment is not a simple task of just dumping sand on the beach. Like any engineering work in a harsh environment, beach nourishment is a comprehensive undertaking. 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. Numerical modelling of shoreline processes requires a great deal of experience and expertise to be properly utilized. Further information on modelling can be found in *Cross-Shore Profile Change Models: Great Lakes - St. Lawrence River Shorelines Review and Typical Applications* (Acqua Engineering 1995).

Figure 7.19: Beach Nourishment



Characteristics of Nourishment Region and Sediment Loss Pathways

Perched beaches are a form of stepped beach created by placing beach fill behind a beach sill (see Figure 7.20). 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 or to reduce the rate of offshore sediment movement from a beach by acting as a barrier to cross-shore transport, particularly for artificially nourished beaches. Beach sills are sometimes used between adjacent groynes, artificial headlands, or detached breakwaters to help to retain the placed beach fill from being moved by waves towards the offshore. The abrupt change in depth at the beach sill may pose a safety concern for swimmers and boaters. Material that is carried offshore of the sill will have difficulty being returned to the shore due to the barrier imposed by the sill. The design of the sill structure will involve many of the aspects discussed for detached breakwaters later in this section. In essence, a beach sill is a very submerged detached breakwater but the effect of the sill on waves is relatively small due to the low crest elevation. 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 the Great Lakes and hence it is difficult to evaluate their effectiveness.

iv) 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 (typically 15 m to 60 m apart on the Great Lakes, see Figures 7.21 and 7.22). Groynes come in various shapes (i.e., straight, L-shaped, T-shaped) and sizes, though on the Great Lakes they are commonly constructed with a straight body in plan and have, in the past, typically varied in length from 10 to 30 m. It should be noted that the spacing and lengths typically used in the past, along the Great Lakes shorelines, have proven to be inappropriate. Groynes are constructed of various materials such as 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. The groyne structure itself does little to alter the incoming waves. It is the trapped material that helps to protect the nearshore and the backshore from wave attack and erosion.

As noted, by definition, groynes are intended to trap alongshore beach material. This trapping 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 slowly returned to shore further downdrift. The impacts of the groynes will generally depend on the nature of the littoral system and the length, height and permeability of the groynes. High, long and impermeable groynes will typically have the greatest impacts while short, low and permeable groynes will have the least impacts. It should be noted that least impacts does not necessarily mean negligible impacts. The net result of these impacts on the downdrift shore will vary according to the shoreline type (i.e., bedrock, cohesive or dynamic beach).

Although groynes have been successfully used in some locations to widen beaches on the Great Lakes, there are also many locations where they have either failed or have caused damage to other properties. The following key points should be noted:

- On the Great Lakes, groynes, including prefilled groynes, are easily emptied of the protective beach material at times of rising water levels (Kamphuis, 1990);
- To effectively protect the nearshore profile of cohesive shorelines from downcutting, groynes would typically have to extend beyond a depth of 2 m below datum (generally more than 100 m offshore). Groynes of such length are not likely, thus groynes would generally not be considered along cohesive shores except those areas which exhibit stable to low recession rates (i.e, cohesive cobble/boulder till);
- Groynes will not work, if there is minimal or no natural alongshore transport of suitable beach material now or in the future (i.e., along many cohesive shorelines). Groynes do not "attract" beach material that does not exist. This can be a substantial concern in areas where increasing shoreline protection further decreases an already limited sediment supply; and
- Short groynes have a problem trapping sand particularly if the beach is backed by a reflective structure.

Figure 7.20: Perched Beach

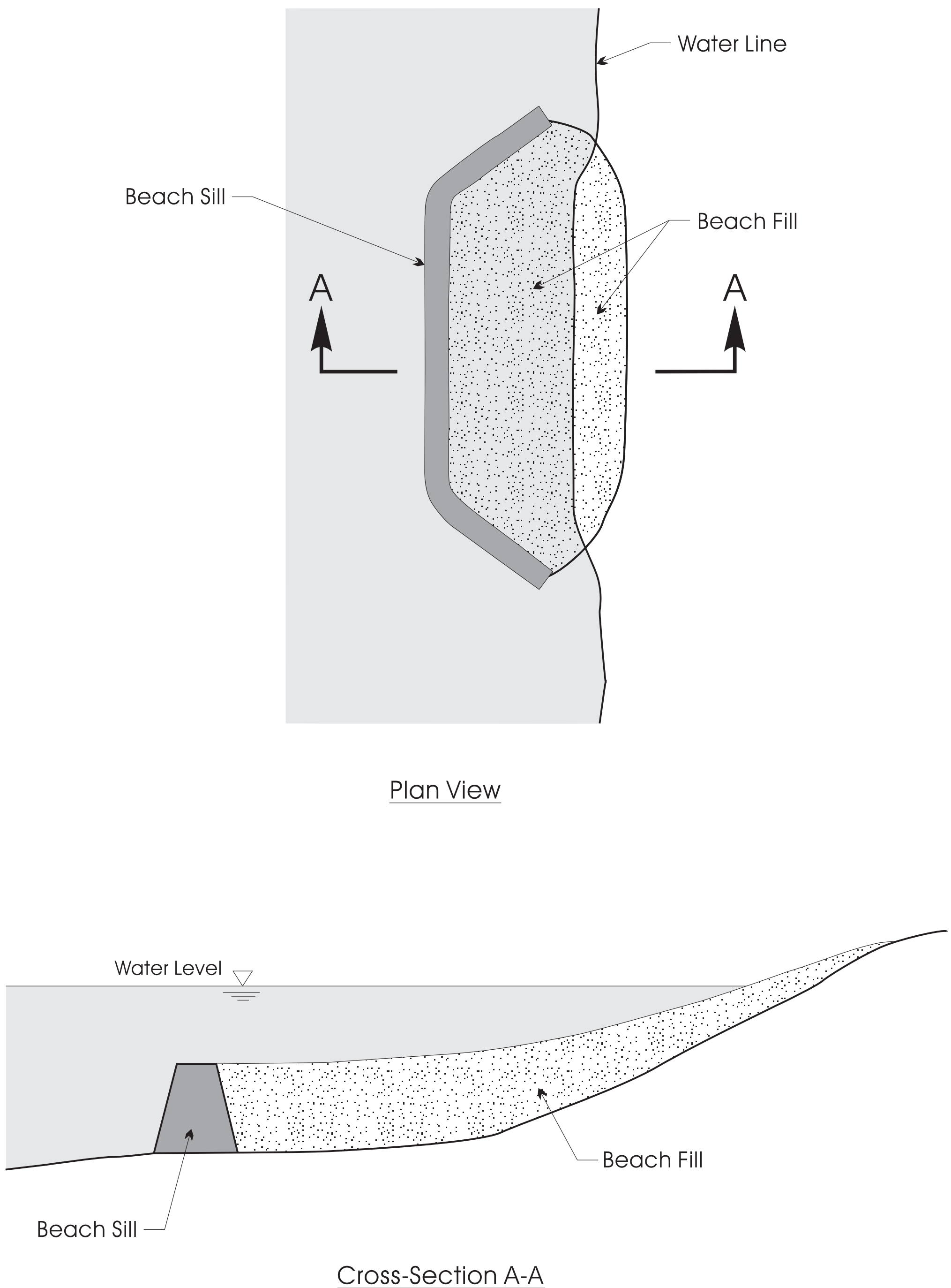


Figure 7.21: Groyne Field

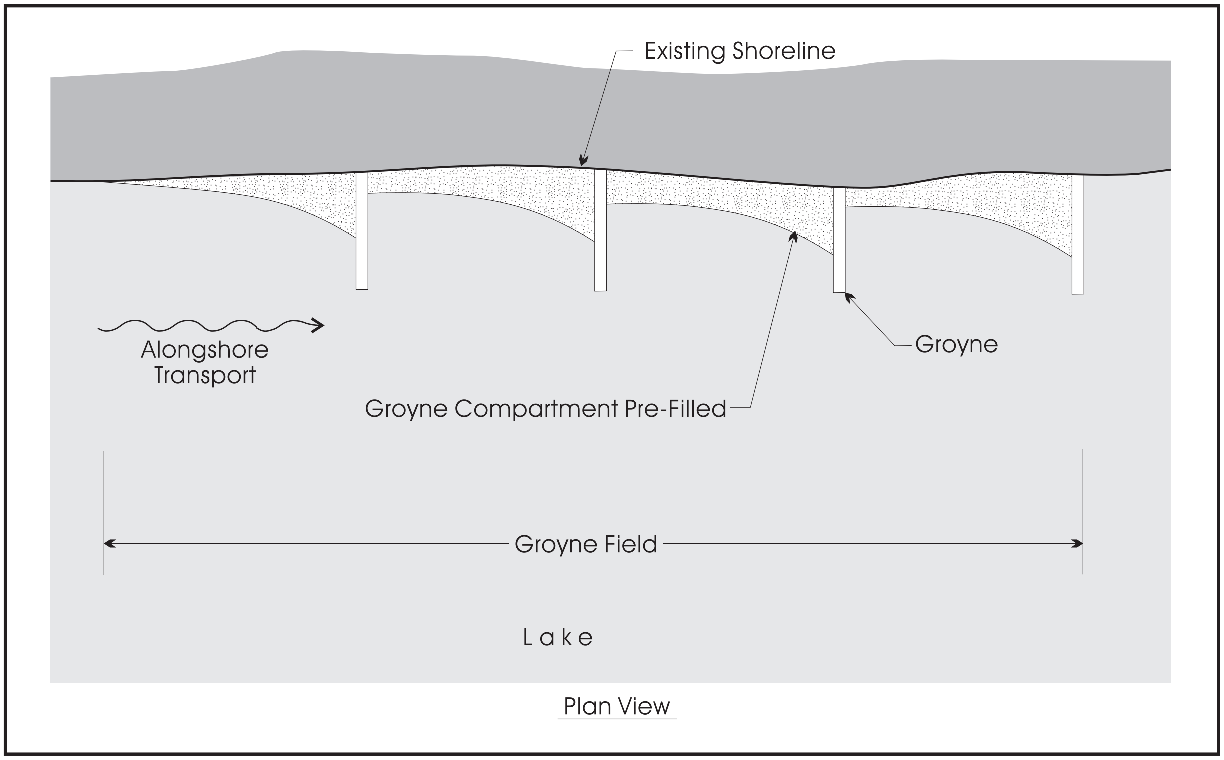


Figure 7.22: Photograph of Groyne Field

The use of groynes involves the cooperation of many adjacent shoreline property owners. There are no generally accepted design rules specifically for groynes on the Great Lakes (Philpott 1986). 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.

Guidelines for groyne design would have to be prepared on a regional basis and would depend on the shoreline classification, sediment size and littoral conditions.

v) Artificial Headlands

Artificial headlands (see Figure 7.23) 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 (i.e., the alongshore length of the headlands is significant relative to the spacing of the headlands, or the gaps between the headlands). Groyne structures typically have a minimal alongshore dimension (i.e., the width of an individual groyne is usually not very significant compared to the distance between adjacent groynes).

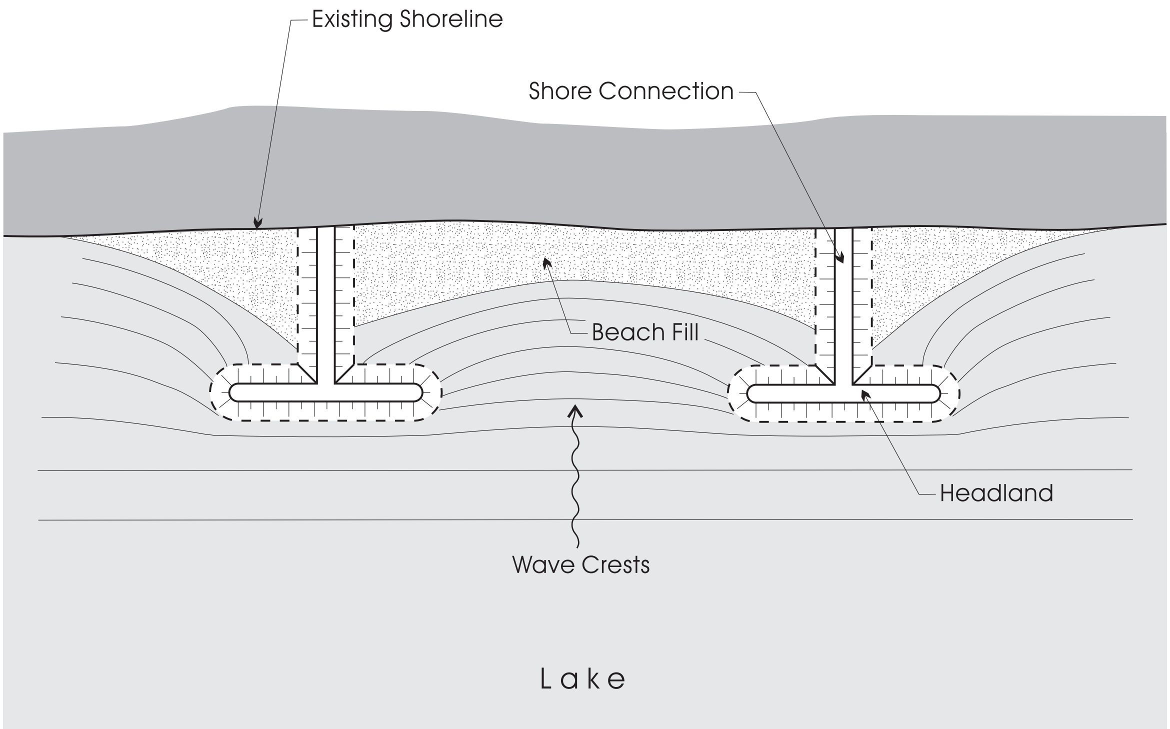
Artificial headlands differ from detached breakwaters in that artificial headlands are generally constructed closer to the original shoreline and tend to have a fixed connection to the shore. Detached breakwaters are generally located further offshore and remain "detached" from the shore but this is not always the case. In some instances, it may be difficult to decide whether the structures are artificial headlands or detached breakwaters and the final classification should then be based on the predominant characteristics. With artificial headlands, the fixed connection to the shore may be constructed as part of the original scheme or the artificial headlands may be designed to promote beach growth out to the headlands forming a tombolo or a periodic tombolo. The tombolo types of connection to the shoreline tend to act as transmissible groynes.

Artificial headlands are often used to protect and retain placed beach fill material particularly in areas where there is a sediment deficit and/or the littoral processes are dominated by cross-shore transport. In some cases, the artificial headlands are linked by a beach sill with the retained beach fill forming a perched beach. Artificial headlands, like groynes, 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**.

As structural shoreline protection, artificial headlands should be differentiated from the shoreline management concept of headland-bays. Headland-bays are a common natural feature on shorelines formed in unconsolidated deposits where crenulate or log spiral shaped bays form between natural headlands (i.e., rock outcrops) or hardpoints (i.e., till with high boulder content). The spacing of natural headland-bays on the Great Lakes is typically in the order of a few kilometres or more (Bishop 1983). Section A1.2.5(b) of Appendix A1.2, Lake/Land Interaction, provides a further description of headland-bays. Artificial headlands, as shoreline protection, can be considered to be about an order of magnitude smaller than headland-bays.

Figure 7.23: Artificial Headlands



Plan View

vi) Detached Breakwaters

Detached breakwaters (see Figure 7.24) 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). Located roughly at the beginning of the breaker zone, detached breakwaters will typically be at least three inshore wavelengths from the shore (i.e., in the order of 75 m to 150 m offshore). 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 7.24). 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 7.24). 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. The reduced wave energy results in slower alongshore currents, which reduces the current's sediment carrying capacity in the vicinity of the structure. Beach response is therefore a direct result of the amount of wave energy reaching the lee of the breakwaters. Projects where high wave energy continues to reach the shore tend to have little or no sinuosity in the beach planform. If the wave energy is reduced, sediment will tend to deposit along the shore forming a crescentic beach. This will typically appear as a bulge in the beach planform. The newly formed beach is called a salient if it does not extend all the way to the offshore detached breakwater. If the leeside wave energy is reduced low 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.

The extent of the deposition behind the breakwater will depend on the site and the details of the structure (i.e., wave climate, net and gross alongshore transport rates, cross-shore sediment movement, structure length, gaps between structures, distance offshore, wave transmission over and through the structure). Detached breakwaters have an advantage over groynes in situations where the dominant sediment transport mechanism is cross-shore. However, with segmented detached offshore breakwaters, a net lakeward flow of water through the gaps can be created if the crest elevations are sufficiently low to permit significant overtopping. The lakeward return flow can cause offshore sediment losses, scour around the structure and create a hazard to swimmers.

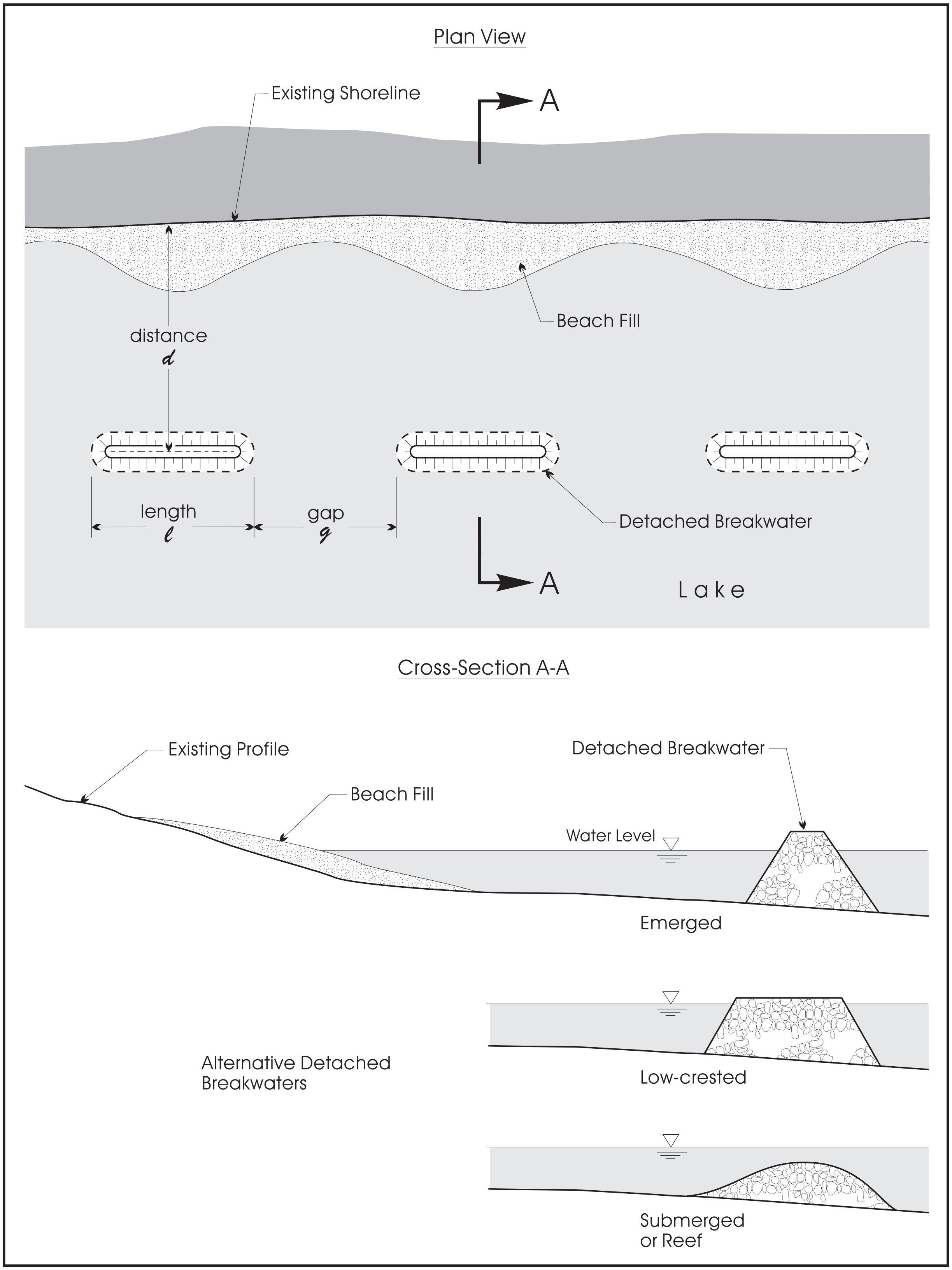
It is recommended that beach fill be included as part of detached breakwater projects to mitigate downdrift effects especially in sediment starved areas. A properly designed detached breakwater, that addresses the potential impacts on the coastal processes, would require a significant design effort. **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**.

vii) Other Shoreline Structures

. Combination Structures

Most structural protection works can be classified as being one of the eight primary types (see Figure 7.1) or acting in a similar manner as one of the eight. Structures which combine elements of two or more of the eight primary types could be grouped according to the predominant element. The use of structures such as terminal groynes, artificial headlands or detached breakwaters can enhance the performance of beach nourishment projects when properly placed and designed. In instances where a shoreline revetment structure may have short, widely spaced "groynes" extending out from the revetment, the structure type would more accurately be classified as a revetment, not groyne field. The groynes likely only provide for some minor accumulations of beach material during average water level conditions. However, during storms and also at times of high water levels, the beach material is unlikely to remain thereby providing little hazard protection.

Figure 7.24: Detached Breakwaters



. Proprietary Systems

There are a number of proprietary, non-traditional shore protection devices that are being marketed as unique beach erosion control systems. Many of these devices are called "breakwater" systems consisting of precast concrete units of unique geometry or construction and ranging in size from a few tonnes to in excess of 20 tonnes per unit and from about 1 m to 2 m in height. Typically, the units are individually placed, side-by-side, to form a continuous structure parallel to the shoreline. For most applications in the Great Lakes, the smaller units have been placed in relatively shallow water in the nearshore area. The proponents claim that the systems perform in a manner similar to detached breakwaters, or "sand traps" or beach sills. In some instances, the placement is in such shallow water that essentially the system acts as nothing more than a shoreline revetment. In other applications, primarily in the Atlantic Ocean, the larger units have been used more as beach sills and submerged reef breakwaters and are often promoted in conjunction with artificial beach nourishment.

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 (e.g., revetments, groynes, headlands, etc.).

. Nearshore Armouring

Conceptually, nearshore armouring involves protecting the nearshore profile against further downcutting. This would be accomplished by dumping a layer of coarse material (i.e., say cobble to boulder size) to blanket the lake bottom. The nearshore armouring would have to carried out on a large scale, covering an area at least many 100's of metres alongshore by 100's of metres offshore. The objective would be to protect that portion of the nearshore where downcutting is most severe (i.e., from the water's edge to a depth greater than 2 m (say 3 to 5 m). Essentially, one would try to create a "convex" or "shelf-type" nearshore profile (Part 1, Appendix A1.2, Figure A1.2.3) which typically develops in erosion resistant cohesive material (i.e., cobble/boulder till).

Nearshore armouring likely would only be part of a long-term strategy for shoreline management. Unless, the nearshore armouring was accompanied by backshore protection works to hold the shoreline position over the short-term, the shoreline position would continue to retreat for some period of time until it reached an equilibrium with the new nearshore condition. At that time, the shoreline recession would be greatly diminished. To date, experience with nearshore armouring on a large scale on the Great Lakes is almost non-existent and its cost-effectiveness has yet to be established.

. Docks, Piers and Boat Launch Ramps

Structures that are not primarily intended to address *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. Another example is a jetty. On an exposed shoreline, a jetty is a structure that extends into the lake and is designed to prevent shoaling of a navigation channel by littoral materials. For the purpose of this Technical Guide, the jetty could be considered as a single, long, high, impermeable groyne. The impacts could then be assessed accordingly. A simple boat launch ramp (i.e, with no alongside piers or docks) could likely be considered as a single, low, short groyne.

7.4 ADDRESSING THE HAZARDS ON-SITE

Earlier sections of this Technical Guide have confirmed that the preferred approach to addressing the *hazards* is prevention by locating *development* and *site alterations* outside the *hazardous lands*. However, as previously identified in Section 7.2.1, Policy 3.1.3 provides the flexibility to permit *development* and *site alteration* within the least hazardous portions of the *hazardous lands* adjacent to the shoreline of the *Great Lakes - St. Lawrence River System* provided the conditions, as set out by policies 3.1.3(a) to (e) inclusive, are all fulfilled. This section provides guidance in assessing what constitutes fulfilment of Policy 3.1.3(a), namely:

- the *hazards* can be safely addressed, and the *development* and *site alteration* is carried out in accordance with *established standards and procedures.*

Established standards and procedures, as originally presented in Section 7.2.2, include:

- the *floodproofing standard*;
- the *protection works standard*; and
- the *access standard*.

These standards are discussed in Sections 7.4.3(a), 7.4.3(b) and 7.4.3(c) respectively.

In addition, Section 7.4.1 outlines some general considerations that should be reviewed prior to selecting an approach to address the *flooding*, *erosion* and/or *dynamic beach hazards*. The characteristics of the *hazards* are identified in Section 7.4.2. A summary table is presented in Section 7.4.4 to aid in the initial evaluation of appropriate shoreline management approaches which have the potential to address the *hazards* at a site, for a given shoreline type and nearshore substrate. Section 7.4 also deals with the provision of safe ingress and egress during times of flooding, erosion and other emergencies (Policy 3.1.3(d)), improvements to or maintenance of existing protection works, and artificial shorelines.

Using this Section 7.4 to determine 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 7.5. Biological impacts to the environment are outlined in Part 8: Environmentally Sound Hazard Management.

7.4.1 General Considerations

Prior to determining which shoreline management practice, particularly which structural works, will safely address the *flooding*, *erosion* and/or *dynamic beach hazards* at a particular site, it is appropriate to examine some general considerations. These considerations include: type of development activity; alternatives to structural protection works; understanding the purpose of the works; potential impacts; total costs over the long-term; and a coordinated approach with adjacent properties. In evaluating structural protection options, it is always necessary to consider if there are alternative approaches that are more suitable, if the structure will fulfil its intended purpose, if it will have any adverse impacts on neighbouring properties and the environment, what it will cost, and if it is viable considering what exists at the adjacent properties.

a) Type of Development Activity

Development and *site alteration* were defined in Section 7.2.1. The characteristics of a proposed development activity, or the resulting land use, can influence the type of floodproofing and/or hazard protection measures to be applied. For example, high density residential development will obviously require a greater degree of protection from *hazards* than non-habitable buildings. Development can generally be grouped into three major categories:

- multi-lot, large lot and large scale development, involving:
  - . creation of multiple lots, or large lot, medium to high density residential development, or other large-scale developments;

- residential or habitable infilling, redevelopment, replacement, major additions/alterations, minor additions/alterations, where:
  - . infilling — involves development on a previously undeveloped lot, or the 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 — involves an 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 — involves the removal of an existing structure and a new residential or habitable unit for same use and of same size or smaller erected;
  - . major additions/ alterations — involves construction which is equal to or exceeds 30% for *erosion hazards* and/or 50% for *flooding hazards*, of the foundation area or market value of the existing structure or work; and
  - . minor additions/ alterations — involves construction that is less than 30% for *erosion hazards* and/or 50% for *flooding hazards*, of the foundation area or market value of the existing structure or work.

- non-habitable buildings and structures, where:
  - . major structures — involve non-habitable buildings or structures that do not qualify as minor structures; and
  - . minor structures — involve non-habitable, moveable structures with no utilities and maximum size of 14 square metres.

Further discussion dealing with existing development within the *hazardous lands* is presented in Appendix A7.2, Existing Development Within the *Hazardous Lands*.

Institutional uses or *essential emergency services* or the disposal, manufacture, treatment or storage of *hazardous substances* are not permitted in *hazardous lands* (Policy 3.1.3(e)). In addition, as first presented in Section 7.2, *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)).

Defined portions of the dynamic beach is defined and discussed in Section 5.3 of this Technical Guide. The *defined portions of the one hundred year flood level along connecting channels* is further discussed in Section 3.4.3.

b) Prevention and Relocation Versus Shoreline Protection

The preferred and often the most appropriate means of addressing the *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 *flooding*, *erosion* and *dynamic beach hazards* for the planning horizon In areas of existing development, relocation should be given serious consideration. The advantages of prevention and relocation over structural protection works are:

- the *hazards* are addressed within a defined acceptable level of risk;
- 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 within the limits of the *flooding hazard*, *erosion hazard* and/or the *dynamic beach hazard*, excluding areas defined under Policy 3.1.2, 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 *hazards* require a shoreline management response and that prevention and nonstructural (i.e., relocation, floodproofing, bluff measures and dune enhancement) are not feasible alternatives, structural protection may be considered.

Given an existing development threatened by erosion and where nonstructural measures are not feasible, there are essentially three choices for protection:

- armour the shoreline (e.g., seawalls and revetments at the toe of the bluff);
- build up the beach, (e.g., beach nourishment, groynes, artificial headlands and detached breakwaters) if appropriate shoreline type and conditions exist; or
- reduce the incoming wave energy (e.g., artificial headlands and detached breakwaters).

These may be accompanied by other measures such as bluff measures and dune enhancement. Floodproofing would be required to address *flooding hazards.*

c) Understanding the Purpose of Shoreline Protection Works

The primary purpose of shoreline works to address the *hazards* can be: flood protection, which includes protection from high lake levels, wave uprush (i.e., storm wave damage) and other water related *hazards;* erosion protection;, dynamic beach protection; or a combination of 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*, *erosion* and/or *dynamic beach 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 which protection works can effectively satisfy multiple purposes. In the example provided above, both effective protection and access could possibly be provided by stepping the armour stone, by using a flatter, more permeable structure, or by incorporating a berm into the slope.

Proposed shoreline works intended primarily for purposes other than addressing the *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 the *hazards*. However, 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.

d) Impacts

Structural protection works are most commonly associated with effects on the physical shoreline environment (i.e., reducing sediment supply by stopping bluff erosion, trapping and/or deflecting alongshore sediment transport). These effects are discussed in more detail in Section 7.5. 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 Part 8: Environmentally Sound Hazard Management.

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. For example, it may not be appropriate to place protection works in areas where the continued, active erosion of the site provides an essential sediment source for downdrift beach environments considered of value to the public interest or other resource management programs. These areas would normally be identified through the completion of a comprehensive Shoreline Management Plan.

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 only minor environmental impacts, the works may be permitted subject to proper mitigation and/or compensation measures.

While there are certainly many instances where protection works have caused detrimental impacts, it cannot be generalized that all protection works cause additional erosion or have adverse environmental impacts. Shore protection works are generally found where the shoreline is already eroding. It is not always clear what are the effects of protection works on adjacent shorelines and the magnitude of those effects. Additional research and quantitative study continues to further our understanding of the effects of armouring the shoreline (Kraus 1987; Pilarczyk 1990; Dean et al. 1991; Kamphuis 1993).

e) Total Costs

Proponents should be encouraged to critically evaluate the total costs and benefits of proposed protection works. In the past, 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). As indicated in Section 7.3.3, many owners invest such large amounts in protection, including materials, construction, and future maintenance, that they essentially "rebuy" their house and land every 20 years and in most cases their land continues to erode (Robbins et. al 1981). The direct cost of shore protection is often not justified by the direct benefit of the value of shoreline property protected from erosion (Armstrong and Denuyl 1977; Griggs 1986; Penning-Rowsell et al. 1989; Kolberg and Sayao 1991; Kamphuis 1993). Generally only in areas of high property values, in the larger urban areas, would protection works be a feasible option based on an evaluation of direct benefits and costs.

In many existing shoreline situations, the impacts of protection works on the environment and on flood and erosion *hazards* off-site, were not adequately considered. These impacts, or indirect costs, to the environment and to updrift/downdrift shorelines were 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). Many current benefit-cost evaluations only use narrowly defined criteria of value of property damage prevented versus construction cost of protection works. As such, a broader 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.

Many of the methods described as "low cost" (e.g., in “Low Cost Shore Protection” (USACE 1981), and repeated in “How to Protect Your Shore Property” (MNR 1987)), including but not limited to, timber or steel drum bulkheads, sandbag revetments and gabion basket groynes, are not intended for fully exposed open lake sites. These "lighter" structures are usually more appropriate for use only in sheltered waters.

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 *flooding*, *erosion* and/or *dynamic beach hazard* 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 25). 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 26). 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.

7.4.2 Characteristics of Shoreline Hazards to be Addressed

a) Flooding Hazard

Flood damages along the shorelines of the *Great Lakes - St. Lawrence River System* 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 3: Flooding Hazards (see also Figure 3.2), are as follows:

- higher, lakewide, static water levels or water levels in connecting channels;
- wind setup; and
- wave uprush and overtopping and other water related hazards (e.g., ice and boat and ship 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 and other water related hazards 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 7.27a). Hydrostatic forces increase with increases in the water depth.

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 7.27b). These are more common in flash floods, shoreline floods, and when flood water is wind-driven.

Figure 7.25: Insufficient Adjacent Flood Protection

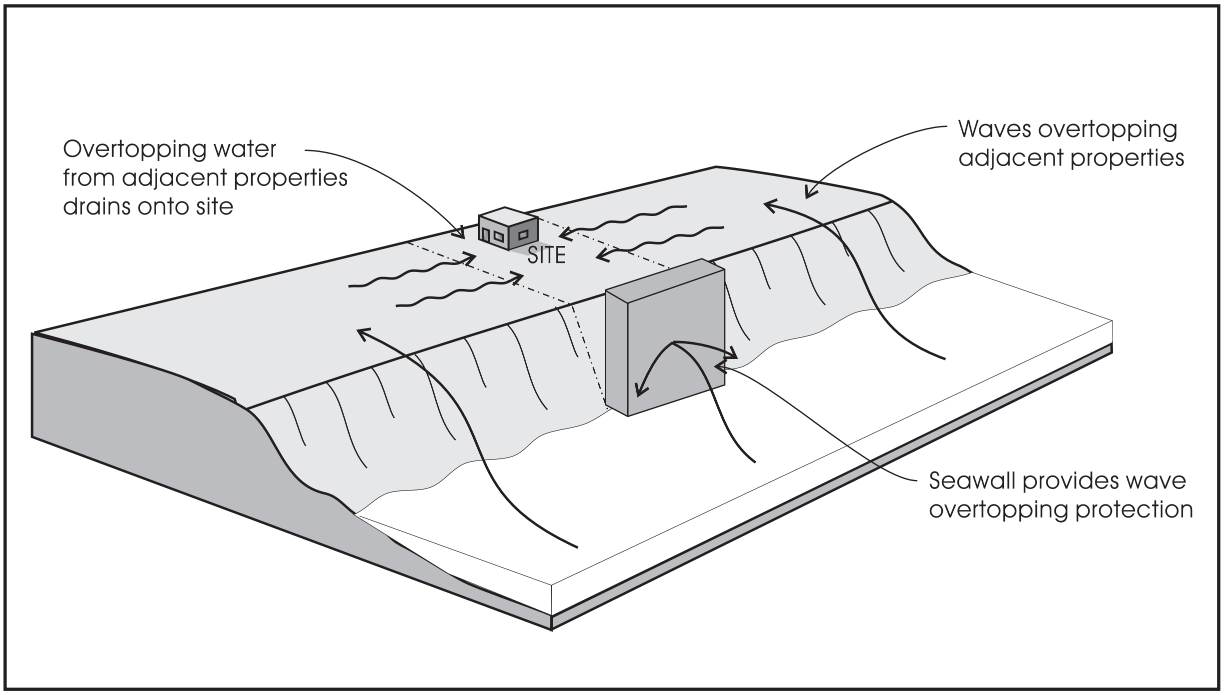


Figure 7.26: Insufficient Flank Erosion Allowance

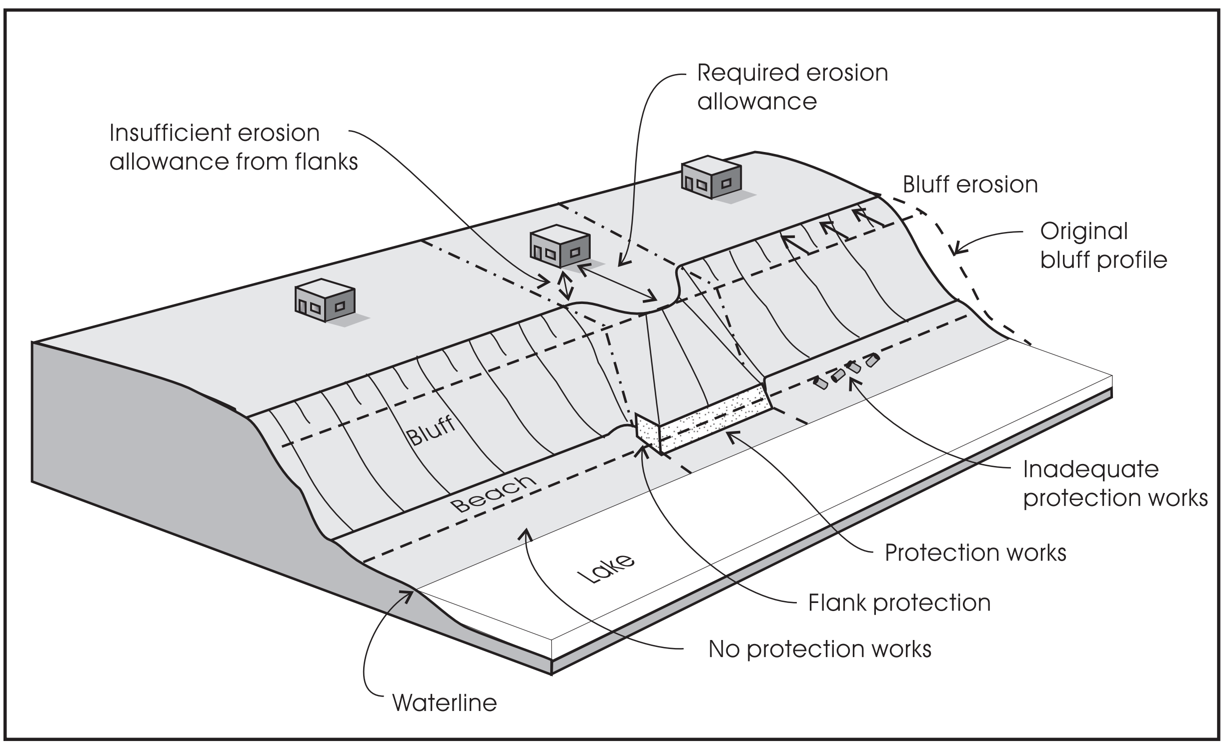
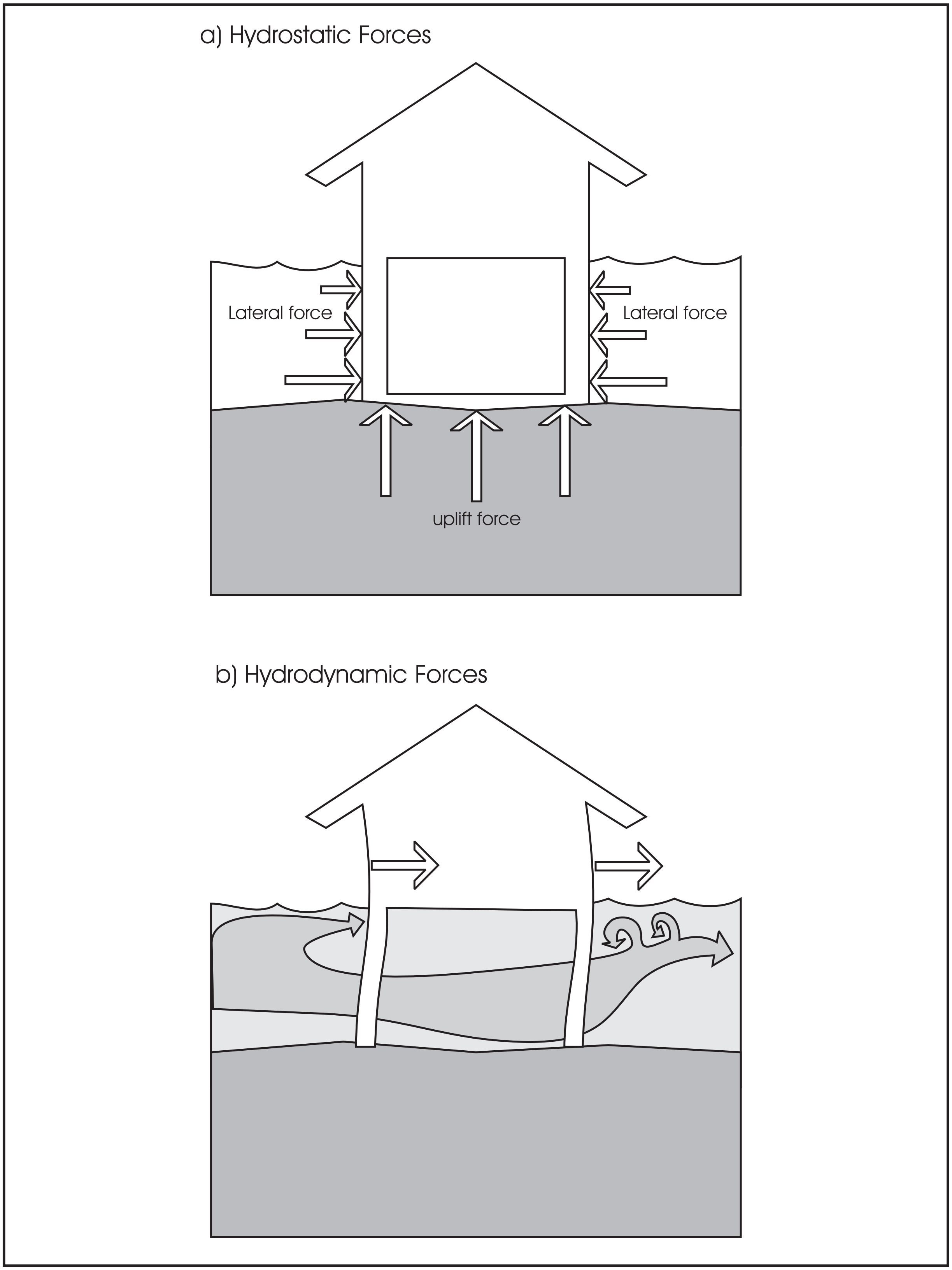


Figure 7.27: Flooding Forces



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. There is little that can be done to avoid these phenomena short of avoiding sites where they are more likely to occur.

For further information regarding the characteristics of flooding, Part 3: Flooding Hazard, 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 (see Figure 7.4) and elevating services (see Figure 7.5)). 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; see Figures 7.11, 7.12 and 7.13).

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.

Flooding hazards can be safely addressed in accordance with the following *established standards and procedures* which are presented in Section 7.4.3: floodproofing standard; protection works standard; and access standard.

b) Erosion Hazard

As discussed in Part 1: The Great Lakes - St. Lawrence River System: Physical Features and Processes, 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. In general, shoreline property losses are therefore, the result of naturally occurring erosion processes associated with wave action, unstable slopes and the continuous landward recession or retreat of the shoreline. Part 4: 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, dynamic beaches, or artificial). More detailed information on the controlling nearshore substrates and general shoreline types is outlined in Part 2 (Section 2.2.2) 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). Part 4: Erosion Hazard (Section 4.5) presents a recommended classification scheme to aid in identifying and describing shoreline areas having similar erosion characteristics.

Assessments of *erosion hazards* in this Technical Guide will be described in terms of whether one is dealing with bedrock or cohesive shores (see sub-sections below), dynamic beaches (section 7.4.2(c)), or artificial shorelines (section 7.4.5).

Where addressing the *erosion hazards* involves the installation of protection works, the protection works must be combined with an allowance for stable slope plus a *hazard* allowance. It must be recognized that there are no guarantees that any protection works will offer long term protection

As stated earlier, proper shoreline management should involve a reach-by-reach assessment of hazard management alternatives. In all situations, the preferred approach is one of prevention (maintaining the area in its natural state and development out of the erosion susceptible area) rather than protection. Where protection approaches are considered, assessments on a reach-by-reach basis (areas of similar shoreline types) are more likely to lead to an overall protection strategy that recognizes and is consistent with the local physical erosion processes. It must be noted that shoreline processes do not recognize property boundaries, and as such, protection works should be coordinated with the adjacent properties.

i) Bedrock Shorelines

As outlined in Part 2: 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. The nearshore profiles are generally devoid of sand and tend to be relatively shallow. 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. If the backshore/onshore material is erosion resistant bedrock, then erosion protection is unlikely to be necessary.

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. For example, beach nourishment and groyne options could be used together. This would involve the use of imported cobble, shingle or gravel beach fill and terminal anchor groynes. The most appropriate method will depend on cost, and impacts to the environment and the adjacent properties.

ii) Cohesive Shorelines

As explained in Appendix A1.2: Lake/Land Interaction, of this Technical Guide, 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 Part 2: Recommended Shoreline Classification Scheme to Determine Shoreline Reaches), characterized by moderate to severe recession rates, often 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.

Cohesive shorelines with exposed bedrock, cobbles and boulders, or sufficient volumes of sand and gravel over the nearshore substrate often, but not always, are characterized by recession rates that are moderate, or even possibly low. "Cobble/boulder till" cohesive shorelines (see Part 2) tend to exhibit shelf-type nearshore profiles.

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. The role and action of the sand cover, and its importance to the overall erosion of a cohesive shoreline is not very well understood and is the subject of ongoing research. With no sand and gravel cover, erosion of the cohesive profile is essentially a function of the wave action and the strength of the cohesive material. It is now thought that sand and gravel can act either as an erosive or a protective agent, depending on the quantity present. Sand, in small quantities, first acts as an abrasive agent and helps to erode the profile (refer to Figure A1.2.4 in Appendix A1.2: Lake/Land Interaction). However, as the volume of sand in the nearshore increases, it reaches a point where it fully covers the bottom in sufficient quantities to protect the profile. The protective characteristics of the sand cover is thought to then increase as the volume and stability of the sand increases. The stability of the sand refers to the amount of movement of the sand bars (i.e., less movement results in more protection to the underlying cohesive profile). Therefore it is possible, for cohesive shorelines, with a sufficient existing volume of sand and gravel sediment present in the nearshore zone, to be impacted by alterations in the supply and transport of littoral materials.

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. To do so, the profile must be protected to a depth greater than about 2 m below datum. In areas of high to severe erosion, the depth of protection may extend to beyond 4 m below datum. Such a requirement can only be accomplished by "regional" or "macro" type protection works such as:

- large, extensive lakefill structures or protective beaches (i.e., beach nourishment (see Section 7.3) generally accompanied by detached breakwaters or large artificial headlands (see Section 7.3)) to protect the cohesive profile; and
- detached breakwaters which reduce wave action across the nearshore profile (see Section 7.3).

These macro-scale projects are very costly and require the coordinated response of many property owners over several hundreds of metres or more 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 (especially fisheries habitat and the alongshore transport of sand). Given the coordinated effort required, the generally limited finances of individual shore property owners, and the potential for adverse environmental impacts, it is unlikely that any of the macro-scale projects (i.e., detached breakwaters, large artificial headlands, beach nourishment) would be contemplated by individual shoreline property owners.

On cobble/boulder till cohesive shorelines, nearshore structures such as beach nourishment used in conjunction with groynes, artificial headlands and detached breakwaters, may be viable options to consider. However it should be noted that these structures also require extensive design efforts. For fine-grained cohesive shores, groyne lengths have typically been too short, in the past, to provide sufficient protection to the nearshore profile. Where a fine-grained cohesive nearshore has a significant volume of sand and gravel cover, artificial headlands may be feasible if they are large enough to provide protection to the nearshore profile.

Backshore, shore parallel structures, such as revetments and seawalls (see Section 7.3) 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 (see Figure 7.28). 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.

Where structural erosion protection works are deemed necessary and appropriate, backshore works such as revetments and seawalls may be feasible in areas with low to moderate recession rates. The ultimate long term success of a revetment, or any other backshore protection structure, is in large part linked to the rate of nearshore downcutting which is indicated by the recession rate of the bluff (i.e., the greater the downcutting, the higher the bluff recession rate). 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.

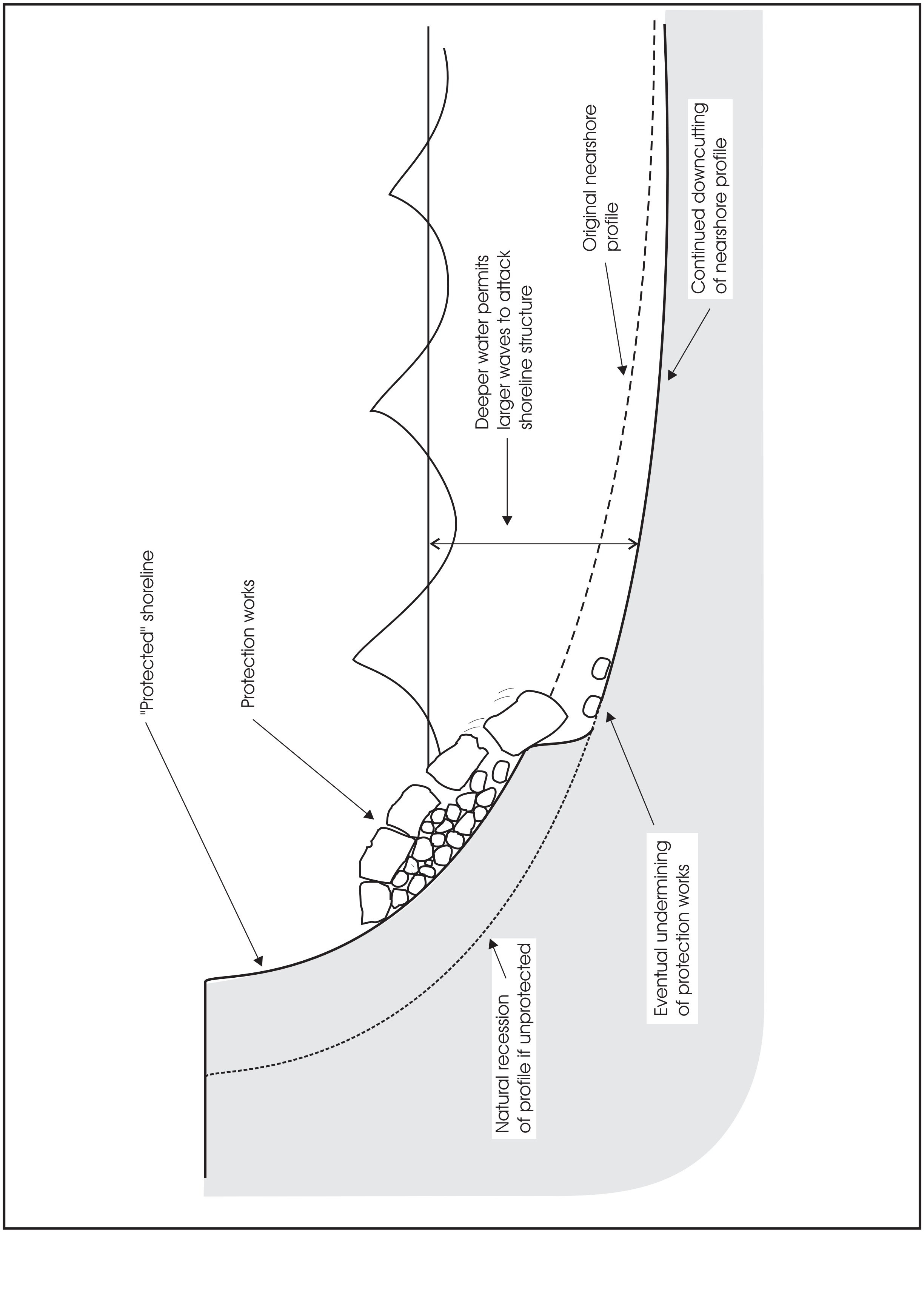
At sites with low recession rates (≤0.3 m/yr), addressing the *erosion hazard* over the long-term may be viable by implementing suitable backshore protection works accompanied by a stable slope allowance <u>plus</u> a *hazard* allowance. In areas of low recession rates, special attention should be given to landside erosion considerations as these may be a significant factor in the shoreline recession. The protection works must be properly engineered taking into consideration all the appropriate design factors as discussed in Appendix A7.1. When selecting protection works, proponents should be encouraged to review and to take into consideration the environmental implications and the true costs of construction, maintenance and replacement over the life of the structure.

In areas of moderate recession rates (0.3 to 0.7 m/yr), protection works become less viable both in terms functional performance and with respect to a cost/benefit consideration. Downcutting of the cohesive shore becomes an increasingly important factor in the lifespan of the structure. Rigid revetments/seawalls require a sound foundation in order to remain intact. Therefore they can be problematic (i.e., very limited life span) in areas of moderate to high recession rates. Flexible revetments/seawalls can sustain more undermining prior to collapse and may be suitable for these areas. Practical construction approaches (e.g., depth of water, slumping of the sides of excavated toe trenches, and construction access at the water's edge) limit the depth to which the toe of a structure can be excavated to provide a sufficient base elevation for protection against long term downcutting.

Along cohesive shorelines with high (0.7 to 1.2 m/yr) to severe (>1.2 m/yr) recession rates, structural protection works that appropriately address the erosion hazard will be relatively large and costly (i.e., large artificial headlands and detached breakwaters) and may not be feasible for most shore properties over the long term. Rigid revetments/seawalls are not recommended for fine-grained cohesive shorelines with high to severe recession rates. Flexible revetments/seawalls, even though they can sustain more undermining prior to collapse, will still have very limited life spans in areas of high to severe recession. The life span of the structure should be individually evaluated by a qualified coastal engineer.

Bluff measures will most likely be insufficient on their own to address erosion *hazards* along cohesive shorelines except in relatively sheltered areas where recession rates are low. Bluff measures could be used in conjunction with structural protection works.

Figure 7.28: Schematic of Continued Downcutting of Nearshore Profile



To safely address the *erosion hazard*, *development* and *site alteration* must be carried out in accordance with the following *established standards and procedures*: protection works standard (refer to Section 7.4.3(b)); and the access standard (refer to Section 7.4.3(c)). The protection works standard requires that all proposed protection works must be used in conjunction with a stable slope allowance and a *hazard* allowance addressing erosion. In addition, particular attention must be given to the condition, effectiveness and residual lifespan of adjacent protection works. The access standard requires proper ingress and egress during times of flooding and erosion emergencies and access for maintenance of the protection works.

c) Dynamic Beach Hazard

i) Definition of 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 (see Figure 7.29). 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 7.4.3(a) on floodproofing, provided they do not interfere with the normal adjustment of the dynamic beach profile. In this section, attention will be focussed on addressing the *hazards* associated with wave action.

It is important to distinguish between: 1) situations where the shoreline is stable (i.e. shoreline position shows zero or negative recession rate); and 2) situations where the recession rate is positive and thus the shoreline is migrating landward. In the first situation the problem is to be address the hazard of wave action that is associated with some combination of lake levels, storm intensity and adjustment of the dynamic beach over some normal range. In the second situation the problem is to address first the hazard of shoreline recession and then to address any problem related to dynamic beach adjustment.

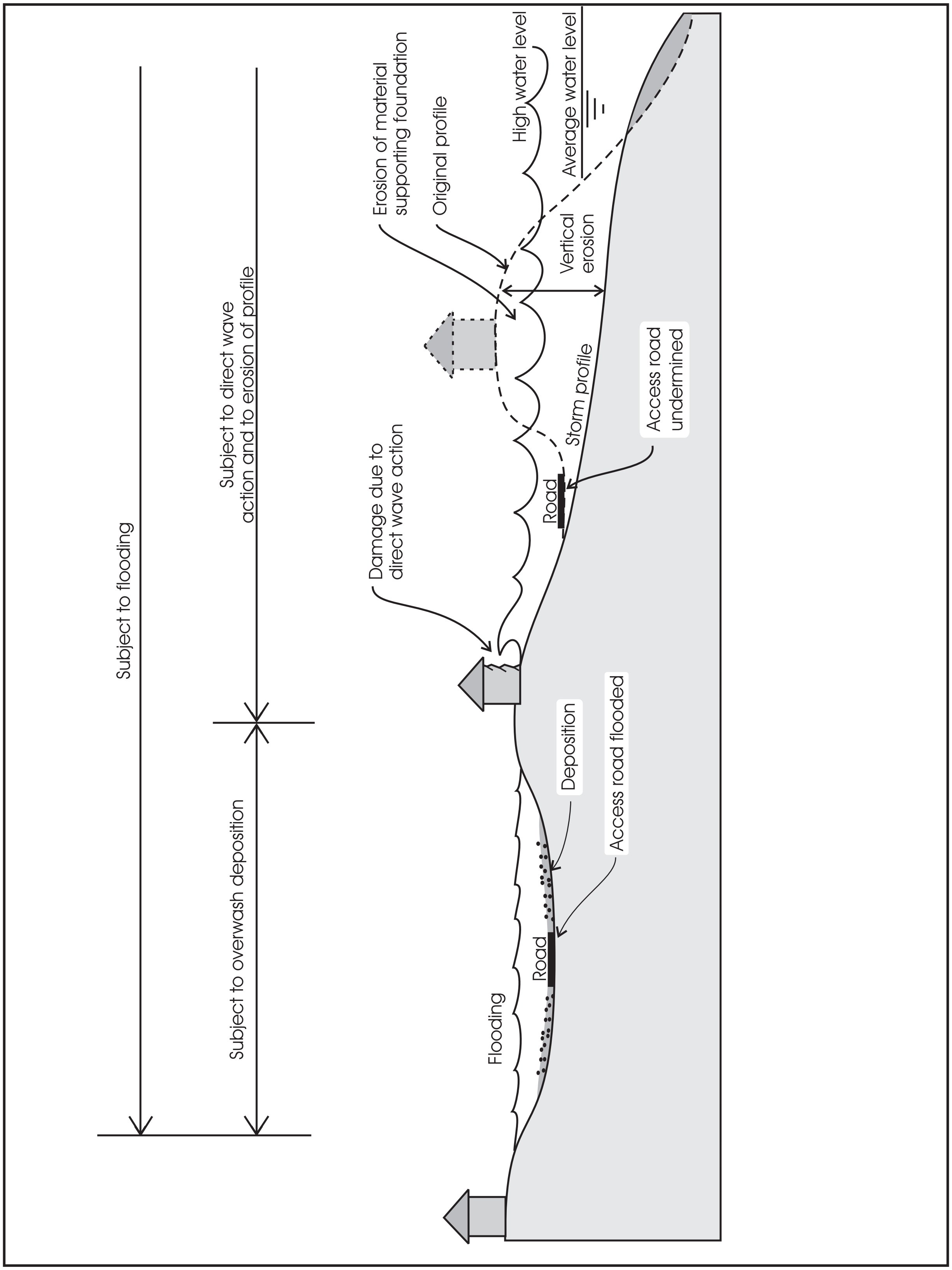
ii) Addressing the Hazard on a Non-Erosional Dynamic Beach Shoreline

A "non-erosional" shoreline is defined as one where there is no measurable recession rate and no evidence of long-term shoreline recession. It also includes shorelines where there is progradation (lakeward movement of the shoreline due to sediment accumulation) or regression (lakeward movement of the shoreline due to falling lake level or to isostatic rebound of the land). A "non-erosional" dynamic beach shoreline will exhibit movement in the beach profile, in response to water level variations and wave action, but the overall, long-term position of the shoreline will remain constant.

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 removal of 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* (1996) that *development* and *site alteration* will not be permitted within *defined portions of the dynamic beach*.

Figure 7.29: Schematic Representation of Dynamic Beach Hazards



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 revetment, 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 impact on normal beach processes. Seawalls, revetments and other protection works positioned for the protection of non-essential structures and features, including but not limited to ancillary structures (e.g., gazebos, sheds etc.), lawns and/or other landscaping features, and which extend into the *dynamic beach hazard,* should not be permitted.

4. Where existing buildings, road and other facilities are located so close to the beach that they are subject to wave action more than once every ten years, then a greater degree of protection than set out in 3 above will be required. This should be permitted only in exceptional cases where it is essential for the operation of the facility that it 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. However, it should be recognized that it is impossible to build a structure within this zone without having a significant impact on the beach environment. Alternative approaches that involve either building out of the beach, through trapping of sand in groynes, or behind detached breakwaters, are likely to have an even greater impact on downdrift areas and are therefore even less desirable.

Where one of the first three approaches is taken, the protection afforded by the beach and associated dunes on a sandy beach can be enhanced by promotion of dune development through protection of the natural dune vegetation and through measures designed to 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.

iii) Addressing the Hazard on an Erosional Dynamic Beach Shoreline

An "erosional" dynamic beach shoreline is defined as one where there is a measurable recession rate or evidence of long-term shoreline recession. As was the case with non-erosional dynamic beaches described in the previous sub-section, no *development* or *site alteration* should be permitted within the *defined portion of the dynamic beach* on an erosional shoreline, which in this case will include an additional setback of 100 times the average annual recession rate.

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

Thus, on an erosional dynamic beach shoreline, if location or relocation outside the *dynamic beach hazard* limit is not possible, hazard protection should focus first on the rate of recession and on whether it is possible or desirable to stabilize the shoreline position. If the recession rate is relatively slow, then it may be feasible to use one of measures 2-4, perhaps with relocation of the structure from time to time.

If the recession rate is high, then it is likely that stabilization of the shoreline will need to be accomplished before any measures to reduce wave hazards are undertaken. Shoreline stabilization on a dynamic beach shoreline can be accomplished either a) by altering the local sediment budget so as to increase the sediment supply and/or reduce sediment losses; or b) fixing the shoreline position through the use of large seawalls, revetments and other protective structures. These alternatives all have the potential for major impact on the physical processes operating in the beach and nearshore area as well as for significant impact on wetlands, fisheries habitat and other aspects of the biological environment (see Part 8: Environmentally Sound Hazard Management). In most cases these approaches require design and evaluation by professional engineers qualified in coastal engineering and environmental scientists. Because of their potential impact on the adjacent coastline, most of the measures should be carried out only as part of a co-ordinated plan considering one or more shoreline reaches, rather than by an individual property owner over a small segment of a reach.

7.4.3 Established Standards and Procedures

a) Floodproofing

i) 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 lakes Superior, Huron, St. Clair, Erie or Ontario, *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 7.30);

- **along the connecting channels, *development* and *site alteration* is to be protected from flooding, as a minimum, to the *flooding hazard*** (i.e., 100 year flood level plus a flood allowance for wave uprush and other water-related hazards; see Figure 7.30).

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 evidence exists to suggest otherwise.

On lakes Superior, Huron, St. Clair, Erie and Ontario, development located within the *flooding hazard* limit must be protected to a higher level than on the connecting channels since development located on the Great Lakes is exposed to a greater risk of damage due to greater and more destructive wave action, wind setup, ice forces and storm surge, particularly during high lake levels. In comparison, a lesser level of risk exists along the shorelines of the connecting channels, where wind and wave action are not usually significant factors given their relatively narrow width.

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.

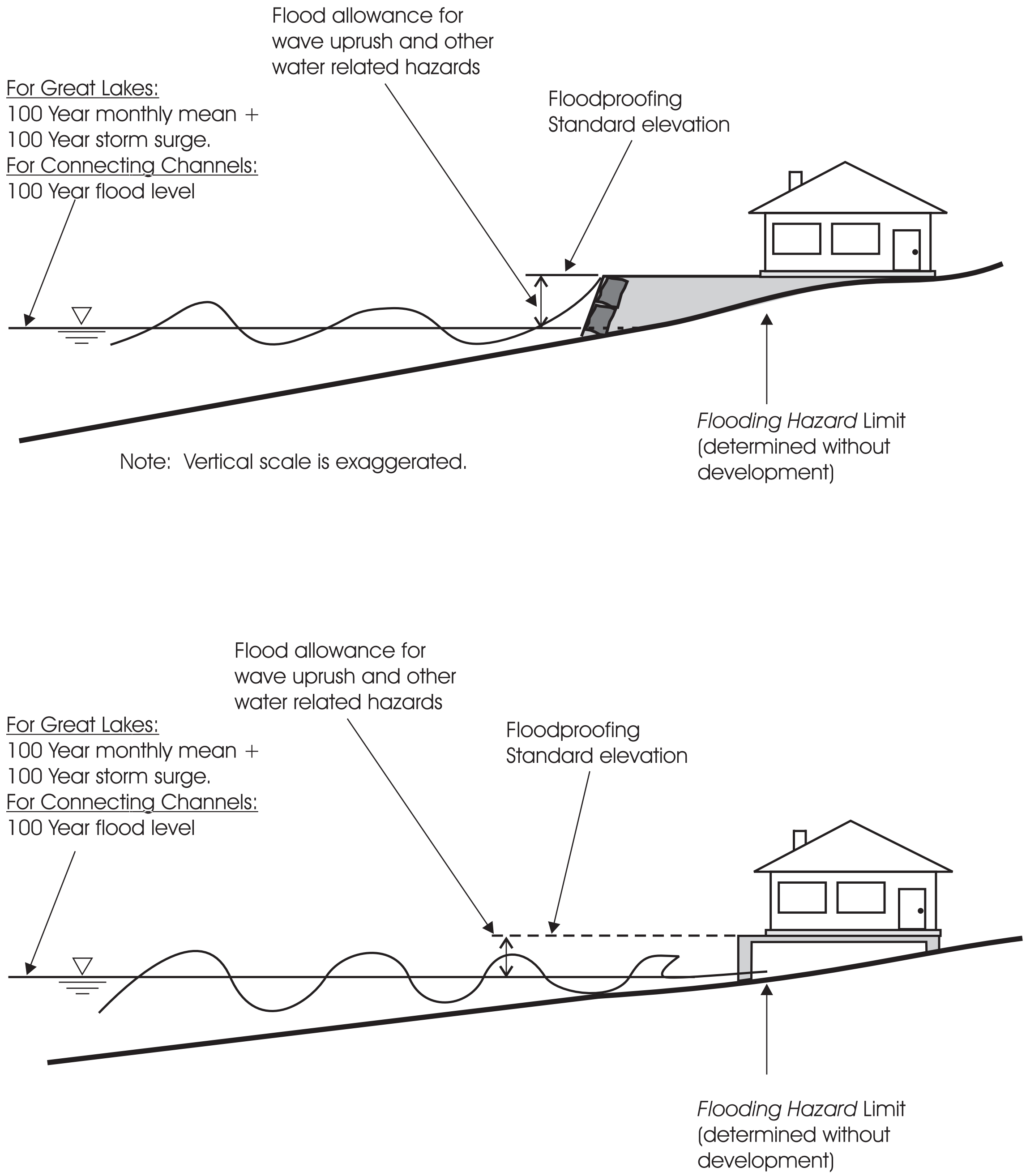
ii) General Approach to Floodproofing

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 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 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 7.30: Floodproofing Standard



Note: Development not permitted within *defined portions of the 100 Year flood level along connecting channels*. Development must also meet other Policy requirements, including safe access.

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, as discussed in Section 7.4.1(a), 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 <u>overnight accommodation</u> 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 (i.e., Policy specifies two floodproofing standards: one specific to lake environments and one specific to connecting channel locations);

- 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 to 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, <u>it is recommended that a professional engineer or architect skilled in floodproofing measures</u> 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. A summary of floodproofing and access design criteria is provided in Appendix A7.1.

b) Protection Works

i) 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 *alteration* could possibly 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.

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 30 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 subsequent sub-sections.

Where the established standard and procedure for stable slope (i.e., 3:1) or the hazard allowance (i.e., 30 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 <u>plus</u> 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.

Care in 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.

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 7.5.

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 Part 8: Environmentally Sound Hazard Management).

ii) Stable Slope Allowance

The stable slope allowance is addressed in Part 4: Erosion Hazard of this Technical Guide and forms an integral component of the overall approach to addressing the *hazard.*

iii) 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 30 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 processes (see Appendix A1.2: Lake/Land Interaction, and Part 4: Erosion Hazard);
- limited design life of protection works (see Appendix A7.1);
- wave uprush, overtopping and spray (see Part 3: Flooding Hazard);
- inability to enforce long-term maintenance requirements;
- some uncertainty with respect to structure performance (i.e., armour stability, wave overtopping, toe scour; see Appendix A7.1);
- condition and effectiveness of any adjoining protection works (see Section 7.4.1(f);
- provision of an environmental buffer strip along the shoreline (see Part 8);
- provision for maintenance access (see Appendix A7.1); and
- provision for ingress/egress during emergencies (see Section 7.4.3(c)).

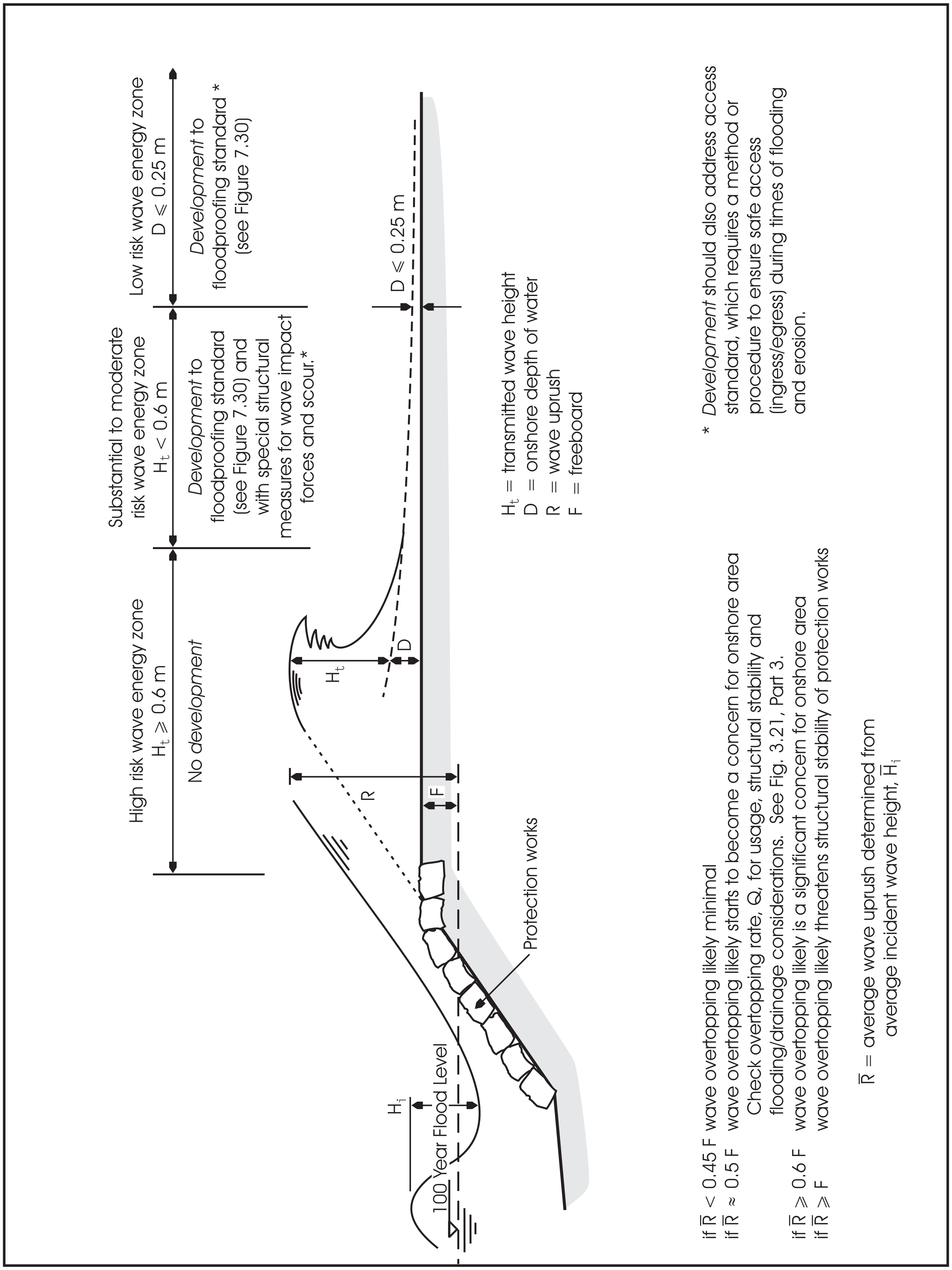
Development located outside the *flooding hazard* and without shoreline protection works is generally considered safe from *flooding hazards*. Where development is being considered within the *flooding hazard* limit, one must first meet the requirements of the floodproofing standard, as described in Section 7.4.3(a). 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 7.31). The lower the freeboard and the higher the uprush, the greater the required distance for a safe setback.

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 7.32a) <u>or</u> 30 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> 30 metres <u>or</u> 30 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, 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.

Figure 7.31: Protection Works Standard - Flood Allowance



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 30 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).

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 (30 metres (Figure 7.32b(i)) or as determined by a study (Figure 7.32b(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].**

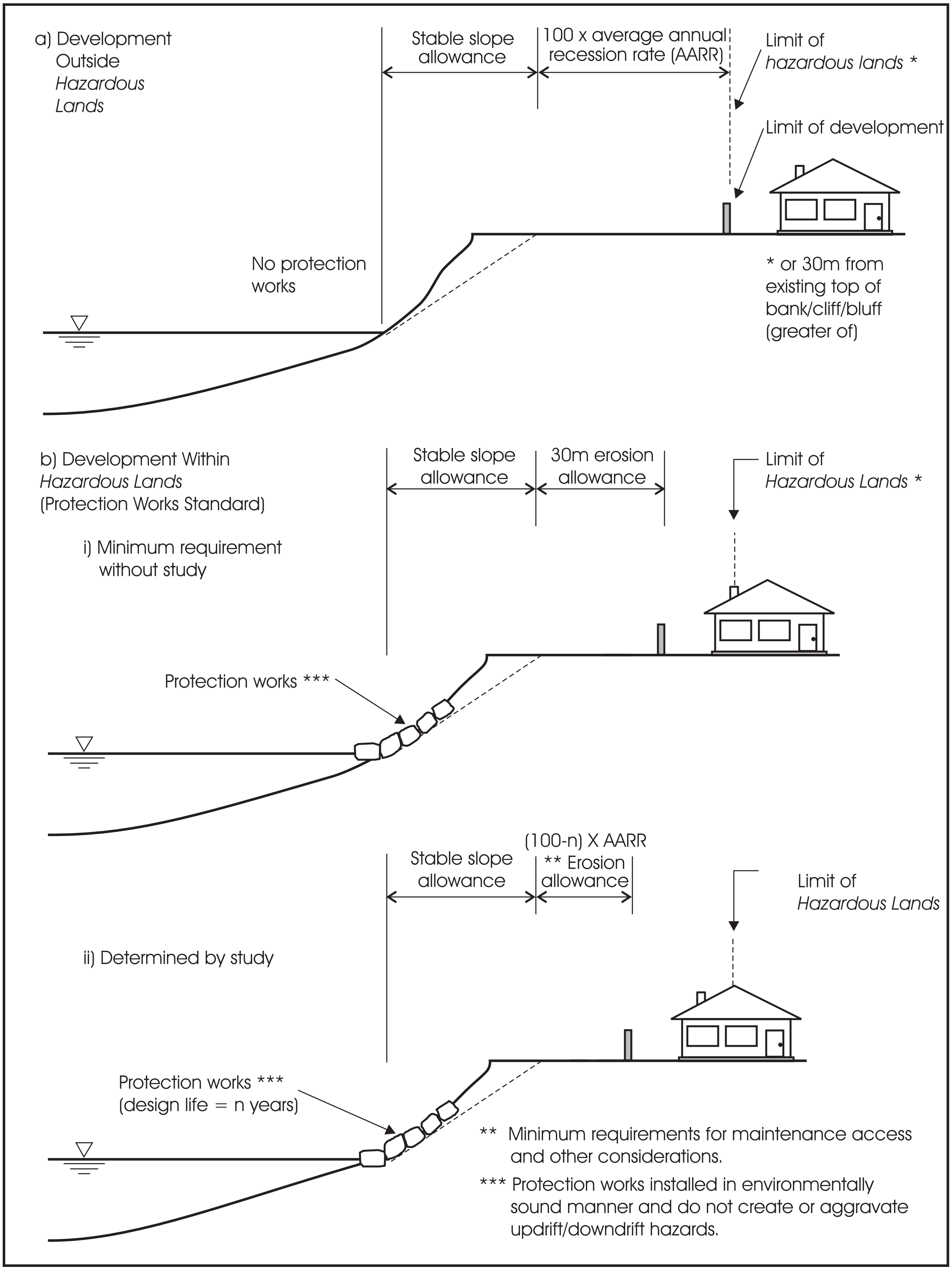
This approach (see Figure 7.32b)(ii)) recognizes that most protection works have a design life that is significantly less than the planning horizon of 100 years and that there is no mechanism to ensure that the present owner or subsequent buyers of the property will be able to rebuild or replace the protection works. Design life is discussed in Appendix A7.1.

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 8: 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 (see Section 7.4.3(c); includes fire department standards);
- allowances (i.e., setbacks) for wave overtopping and spray (see Part 3: Flooding Hazard, including ice buildup during winter);
- volume of overtopping water (drainage provisions, see Part 3);
- 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*.

Figure 7.32: Protection Works Standard - Erosion Allowance



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 Part 4: Erosion Hazard (see section 4.6, Adjustments to the Erosion Allowance).

iv) Hazard Allowance at the Alongshore Limits of a Property

As discussed in Section 7.4.1(f), 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 plus a 5 metre allowance (Figure 7.33). 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.

c) Access

i) 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.

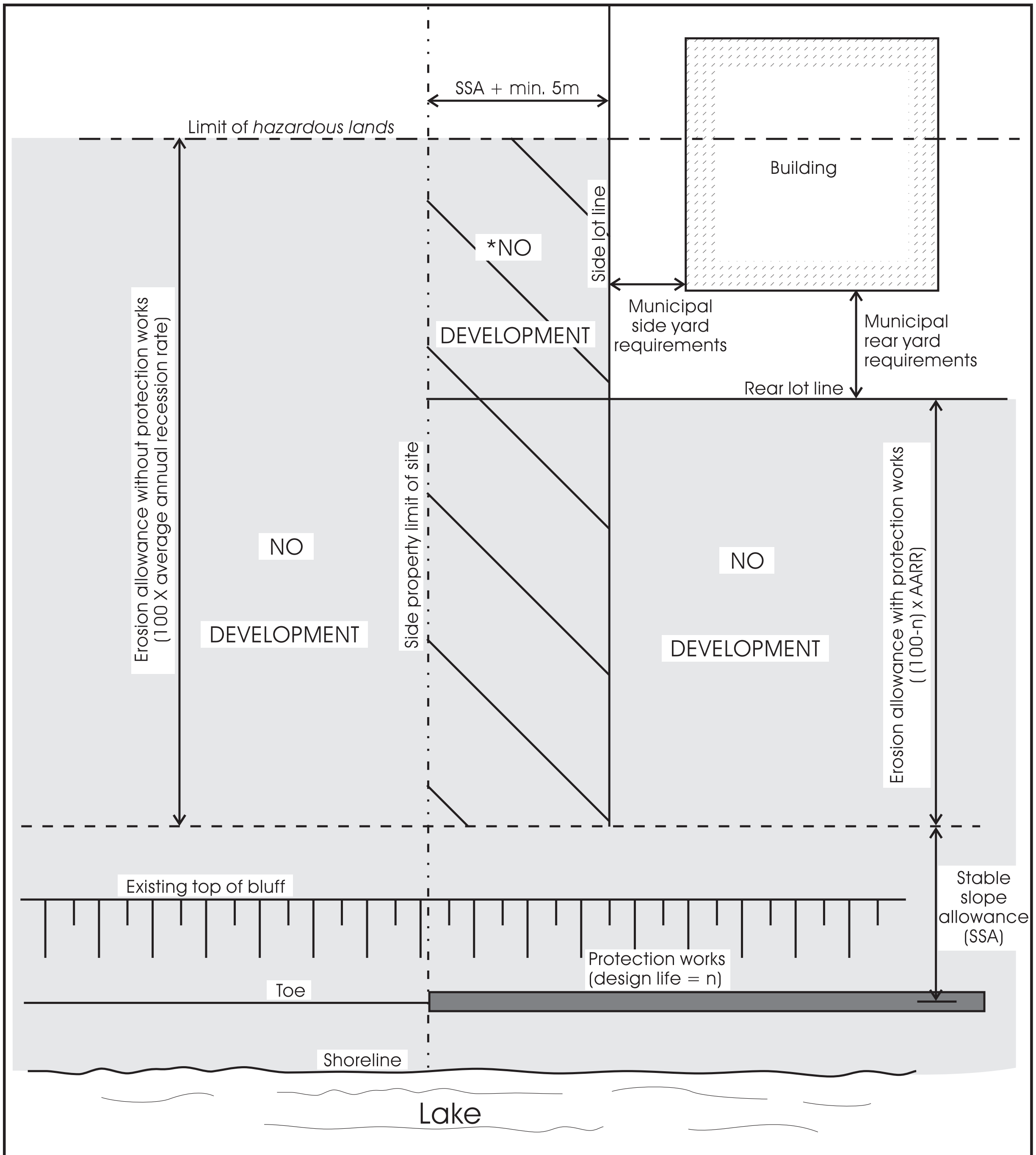
In keeping with Policy 3.1.3(d), the **access standard** for development located within the *hazardous lands* is as follows:

> **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.

Figure 7.33: 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.

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.

ii) 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. Further details regarding maintenance access are provided in Appendix A7.1.

7.4.4 Initial Evaluation of Shoreline Management Approaches

The various shoreline classes, based on general shoreline type, controlling substrate and surficial substrate were discussed in Part 2: Recommended Shoreline Classification Scheme to Determine Shoreline Reaches. The different types of shoreline management approaches were presented in Section 7.3. Section 7.4, addressing the *flooding*, *erosion* and *dynamic beach hazards* was examined. 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 7.1 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 7.1 does <u>not</u> include the potential impacts of these approaches and therefore it must be read in conjunction with Section 7.5.

In Table 7.1, 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 Part 2). 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 7.1: Addressing the Hazards for Development: Initial Evaluation of Shoreline Management Approaches by Shoreline Class

Shoreline Class			Typical[1] Hazard(s)	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 7.1 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													
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]	Prevention		Non-structural Protection				Structural Protection (plus stable slope and flood/erosion allowances)							
				Onshore		Onshore				Onshore		Backshore		Nearshore[10]			
				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 7.1 legend and notes.

Table 7.1: 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 but 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 - bluff 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 not 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 7.2**, to assess the potential influences and impacts of shoreline management approaches on the physical shoreline processes and characteristics.

Refer to **Table 7.3**, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood, erosion and dynamic beach hazards.

Refer to **Table 8.2, 8.3 and 8.4, Part 8**, to assess the biological impacts related to shoreline management approaches.

Tables must be read in conjunction with Technical Guide text.

Table 7.1 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 7.1 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 7.1 notes that all structural options must be accompanied by a stable slope allowance and a hazard allowance (see Section 7.4.3(b)).

Table 7.1 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 7.1 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 7.1 must be followed by an identification of the potential impacts of the selected approach on the physical shoreline processes and characteristics (see Section 7.5, Table 7.2). The impacts identified in Table 7.2 are then evaluated with respect to their potential for creating or aggravating any updrift/downdrift *hazards* away from the site (see Section 7.5, Table 7.3). As well, the impacts identified in Table 7.2 must be examined to ensure that the selected approach is environmentally sound (see Part 8). It is possible that a review of Tables 7.2 and 7.3 and Part 8 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)).

If a proposed shoreline management approach is not identified in Table 7.1 as appropriate for the shoreline class in question, then a further detailed study must be provided to show that the proposed practice is appropriate for the local site conditions. 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.

7.4.5 Existing Protection Works

a) Improvements and Maintenance

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 7.34):

- 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.

It warrants repeating (see Section 7.4.1(e)) that approaches that can be classified as "low cost" are not appropriate for application on open, exposed shorelines of the Great Lakes.

b) Artificial Shorelines

The characteristics common to shorelines classified as "artificial" are outlined in Part 2: Recommended Shoreline Classification Scheme to Determine Shoreline Reaches, of this Technical Guide. Often, due to their very longevity, size and nature, artificial shorelines are initially assumed to sufficiently address the *hazards*. This assumption, however, can prove to be incorrect. To ensure the continued integrity and performance of artificial shorelines over the development planning horizon (100 years), there are several factors that must be critically evaluated and confirmed. These include, but are not limited to:

- In general, much of the existing artificial shoreline has been in service for decades. As such, these structures will require detailed inspections, both above and below water, by qualified engineers experienced in coastal and marine structures, to assess their integrity and residual design life.

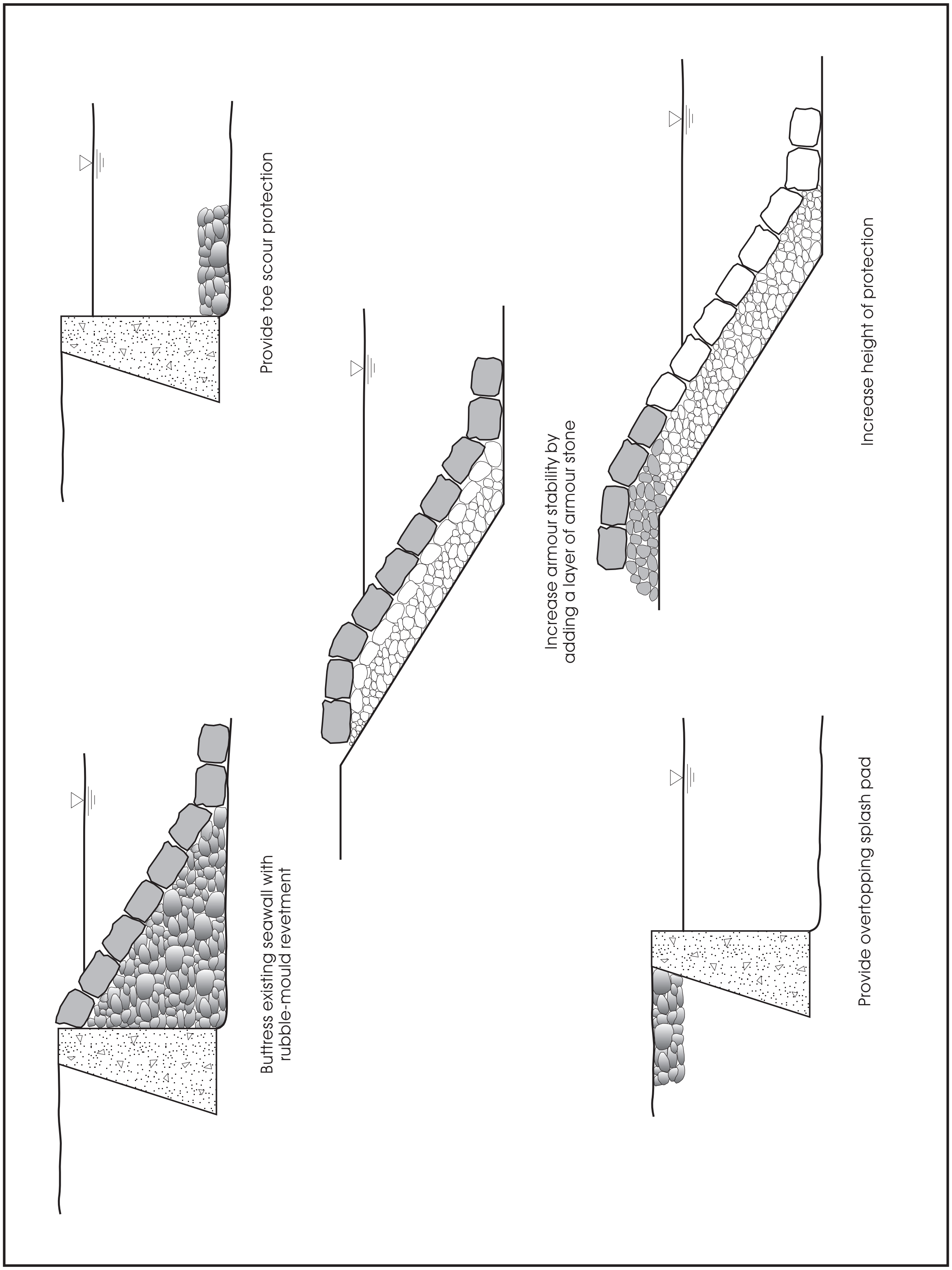
- Recent improvements in our understanding of the downcutting of cohesive shores demonstrates that certain existing structures may be threatened by undermining that is not visible to a cursory above-water inspection. A review of the controlling substrate and the recession rates is necessary.

- The potential for diminishing sediment supplies from updrift and nearshore sources may affect the existing shorelines through reduced beach widths (resulting in an increasing risk due to wave uprush) or decreased volumes of sediment over a cohesive nearshore profile (resulting in a possible increase in the rate of downcutting).

- Present 100 year flood levels may be higher than the design water level used initially for existing structures. Protection against flooding *hazards* may be insufficient and may require remedial works.

Due to the unique nature of artificial shorelines, they should be evaluated by means of a comprehensive study using accepted engineering principles.

Figure 7.34: Typical Improvements to Existing Protection Works



7.5 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 *Great Lakes - St. Lawrence River System* 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 this section. 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 7.5.4. 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 Part 8 of this Technical Guide.

7.5.1 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).*

The spatial extent of the impacts on the physical processes and characteristics depends on the physiographic shoreline unit.

- **Exposed Coasts and Partial Headlands** - Along exposed, or open, coasts, the physical impacts can extend in both alongshore directions and in the offshore direction. The offshore extent was defined in Part 2 of this Technical Guide as the limit of effective sediment motion. In the downdrift direction, the effects can extend to the end of the littoral cell. In the updrift direction, the extent of the impacts is generally proportional to the size of the protection works, especially the extent of the works into the nearshore. At shorelines with a strong net alongshore transport, the impacts will be predominantly downdrift except for accretion updrift (impact B.3). At shorelines where the net transport is small, yet the gross transport is relatively large, impacts can be equally evident in both the updrift and downdrift directions. This is because a similar quantity of material is being transported in either direction. If the net transport is small and the gross transport is small, the extent of the alongshore impacts may be relatively limited.

- **Headland/Bay Embayments and Naturally Well-Sheltered Areas** - In headland/bay embayments and naturally well-sheltered areas, the spatial extent of the physical impacts associated with the supply and transport of littoral materials will be limited to the littoral cell formed by the embayment or sheltered area.

- **Connecting Channels** - Along connecting channels, impacts of shoreline protection works are generally only apparent in the downstream direction. In general, the strong unidirectional flow of the water will limit the cross-channel extent of the impacts related to the supply and transport of littoral materials.

- **River Mouth** - At river mouths, the impacts can extend over a wide area as the flow disperses into the lake or channel.

- **Islands** - Along island shorelines, the spatial extent of the impacts will depend on the proximity of the island to other landforms and the exposure of the island shoreline to wind and wave action.

7.5.2 Potential Influences and Impacts on Physical Shoreline Processes and Characteristics

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.

a) General Physical Shoreline Processes and Characteristics

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:

i) 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. Structures which form physical barriers along the shoreline (i.e., groynes, 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.

ii) 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).

iii) 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. For example, the slope may be graded steeper and the lake bed elevation increased. Generally, protection works directly occupy the area where they are located. The works can significantly alter the existing surface features, including gradient, texture, interstitial spaces, by covering, replacement and/or removal. 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.

iv) 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.

v) 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.

Further details of physical shoreline processes and characteristics are provided in Part 1: The Great Lakes - St. Lawrence River System: Physical Features and Processes and Part 2: Recommended Shoreline Classification Scheme to Determine Shoreline Reaches, of this Technical Guide.

b) Potential Influences and Impacts

The following discussion is general in nature and applies to many situations in the Great Lakes - St. Lawrence River System. 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 described in this subsection and summarized in Table 7.2. 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 7.2, 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 7.1. 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 "✓".

If a particular shoreline management approach is being considered, a look to Table 7.2 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 7.5.4.** Environmental considerations regarding terrestrial and aquatic habitat are outlined in Part 8: Environmentally Sound Hazard Management, of this Technical Guide.

i) Supply and Transport of Littoral Materials

- **Influence A.1 - Decreases supply of sediments to the littoral zone**
  Erosion of the backshore and nearshore provides much of the littoral sediment supply. By protecting these areas from erosion, the sediment supply to downdrift shorelines is reduced. Revetments and seawalls reduce the erosion of the backshore but do not affect the supply from the nearshore. Groynes, artificial headlands and detached breakwaters may slow the downcutting of the nearshore thus decreasing the nearshore supply.

  . **Impact B.1** - A reduction in the sediment supply may result in **increased long-term erosional stress to downdrift shorelines**. A reduction in the sediment supply may cause a downdrift beach to experience a sediment deficit (less material coming into the beach than is being removed) and subsequent erosion. The extent of the increased erosional stress could extend to the end of the littoral cell where there might be a significant beach deposit. Along cohesive shores, the role of the sand cover over the nearshore profile in determining the overall recession rate is not well understood. Further discussion is provided in Section 7.4.2(b) and 7.5.4.

  Assessing the magnitude of the impact requires: an understanding of the total littoral budget within the littoral cell; an estimate of the amount of supply that has already been reduced and its impact; an estimate of the amount of supply that will be further reduced and the additional impacts. The magnitude of the reduction on an annual basis can be estimated by multiplying the length of the protected shoreline by the height of the bluffs plus the depth of effective sediment motion in the nearshore (if applicable) by the percentage of beach size sediments in the bluff and nearshore material by the average annual recession rate. This value can then be compared with the estimate of the total sediment supply for the littoral cell.

Table 7.2: 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 - bluff 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 Great Lakes - St. Lawrence River System. 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 7.1**, for initial evaluation of shoreline management approaches.
Refer to **Table 7.3**, to assess the relative significance of the potential impacts with respect to increasing updrift/downdrift flood, erosion and dynamic beach hazards.
Refer to **Tables 8.2, 8.3 and 8.4, Part 8**, to assess the biological impacts related to shoreline management practices.
Tables must be read in conjunction with Technical Guide text.

- **Influence A.2 - Increases supply of sediments to the littoral zone**
  Beach nourishment increases the sediment supply because it involves the introduction of additional, imported beach material.

  . **Impact B.2** - An increase in the sediment supply may result in **decreased long-term erosional stress to downdrift shorelines** or even increase the accretion rate. The beaches at adjacent downdrift shorelines may increase in width. The increased width may be of a temporary nature as the nourished material may be transported alongshore until it reaches a sink or deposition area and the downdrift shoreline returns to its previous state. The extent of the impact may extend to the end of the littoral cell.

- **Influence A.3 - Impedes alongshore transport of littoral material**
  Protection works that extend out perpendicular from the shoreline (such as groynes and artificial headlands) will impede the movement of alongshore transport by acting as a physical barrier to the passage of the material. They reorient the beach (i.e., in plan view, the shoreline becomes more closely aligned with the incoming wave crests) and reduce the alongshore transport rate. The reduced transport rate results in accretion of beach material on the updrift side of the structure. Works that create areas of reduced wave action (i.e., in lee of detached breakwaters) will also impede transport and cause accretion by reducing the nearshore currents.

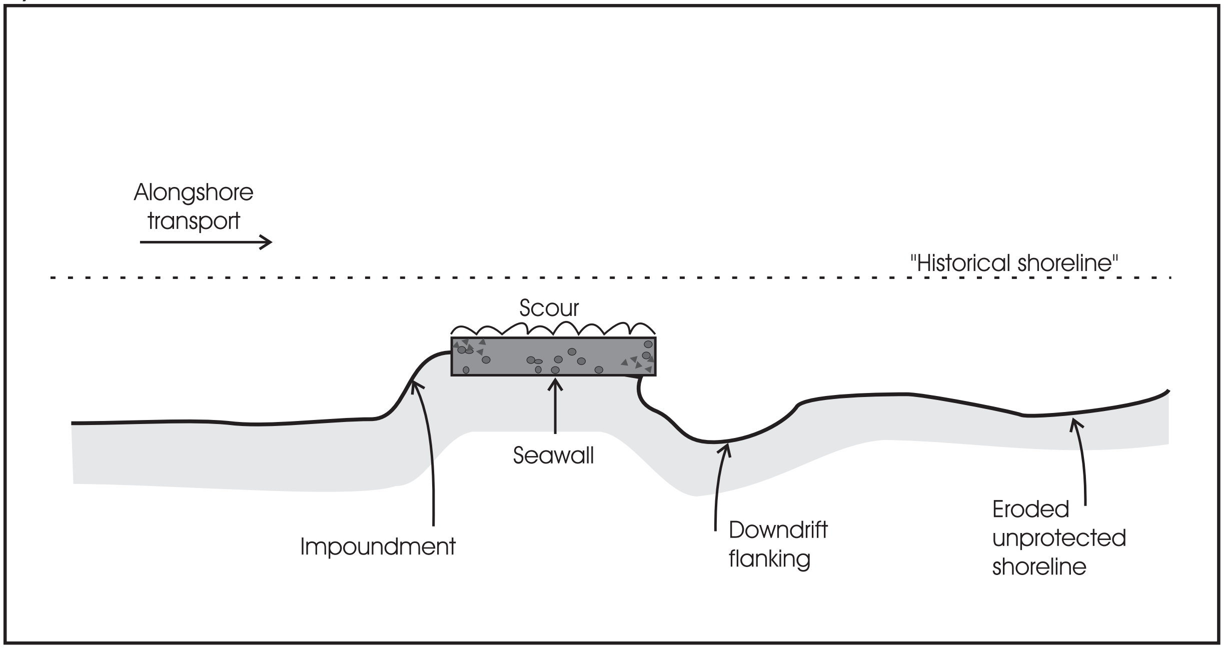
  . **Impact B.3** - A structure which impedes the alongshore transport can result in **accretion updrift and/or in the lee of the structure**. The littoral material can become trapped updrift of the structure (i.e., impounded updrift of a seawall that extends into the nearshore area, see Figure 7.35(a) or trapped on the updrift side of a groyne or jetty, see Figure 7.36(a)), between the structures (i.e., between two or more groynes, see Figures 7.36(b) and (c), or within embayments formed by artificial headlands) or in the lee of the structure (i.e., detached breakwaters, see Figure 7.37). The trapping, or accretion, may occur at the site, or further updrift, depending on the location of the structure with respect to the site property limits. In addition to the trapping of littoral sediments, perpendicular structures may also trap algae and debris.

  The extent of the trapping, in the alongshore direction, is a function of the size (i.e., length and height) and permeability of the structural works. A greater amount of alongshore littoral material will be intercepted by longer and higher groynes. A smaller gap-to-length ratio for detached breakwaters will increase the accretion pattern in the lee of the structures. The formation of tombolos in the lee of detached breakwaters will prevent any alongshore littoral material from bypassing the structure.

  The trapping also depends on the littoral transport characteristics (i.e., potential and actual transport, large or small net transport, high or low gross transport, short-term transport (proportion of sediment moved by a small number of large storms)). Figure 7.36(d) shows a possible scenario along a shoreline with transport in two directions. Accretion is occurring on both sides of the groyne even though the waterline shows a typical "one direction" configuration. The grain size characteristics of the littoral material must also be considered; coarser material, which moves closer to the shore will be more affected, while finer material may bypass shorter structures. Trapping will continue until the works are filled (i.e., in the compartments of a groyne field or the salient/tombolo formations behind detached breakwaters, see Figure 7.37). Once the structure is "full", bypassing of sediments will occur. Protection works that are prefilled (both within the structure and updrift) with imported material will not trap material unless they are "emptied" by storm activity and not refilled with additional imported material.

Figure 7.35: Potential Impacts of a Seawall on a Dynamic Beach Shoreline

a) Plan View



b) Profile View

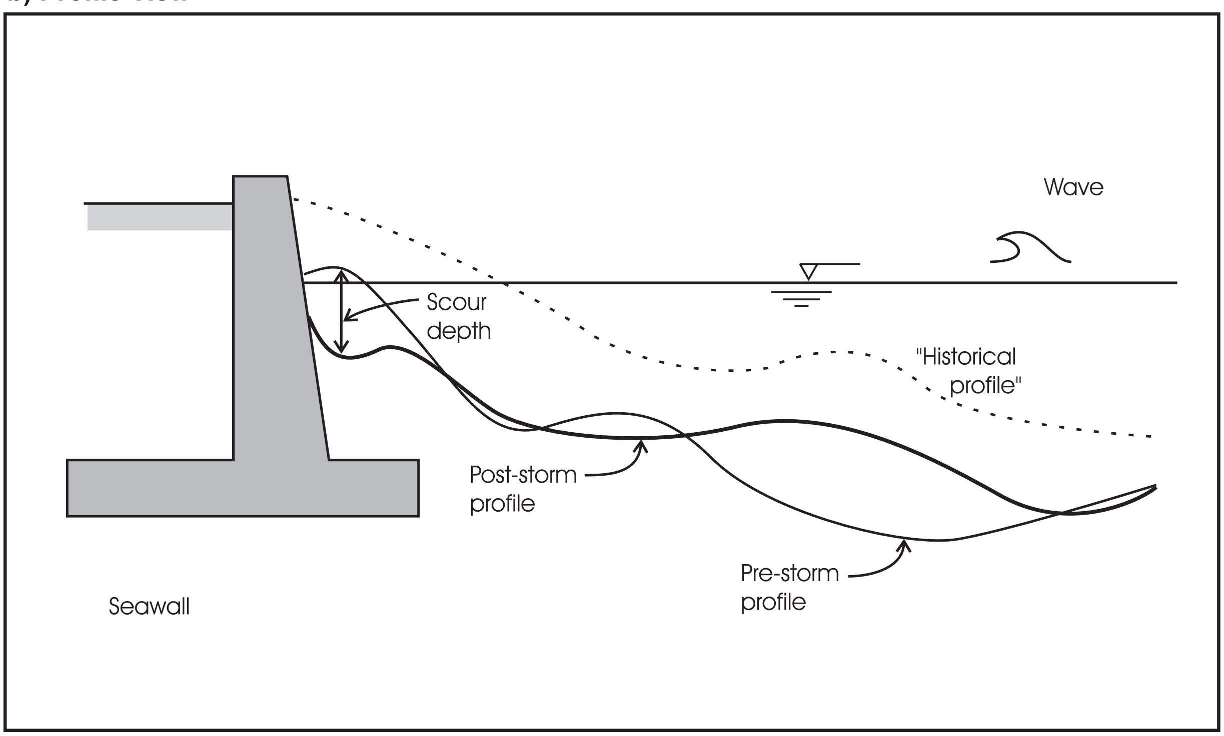


Figure 7.36: Accretion/Erosion at Groynes

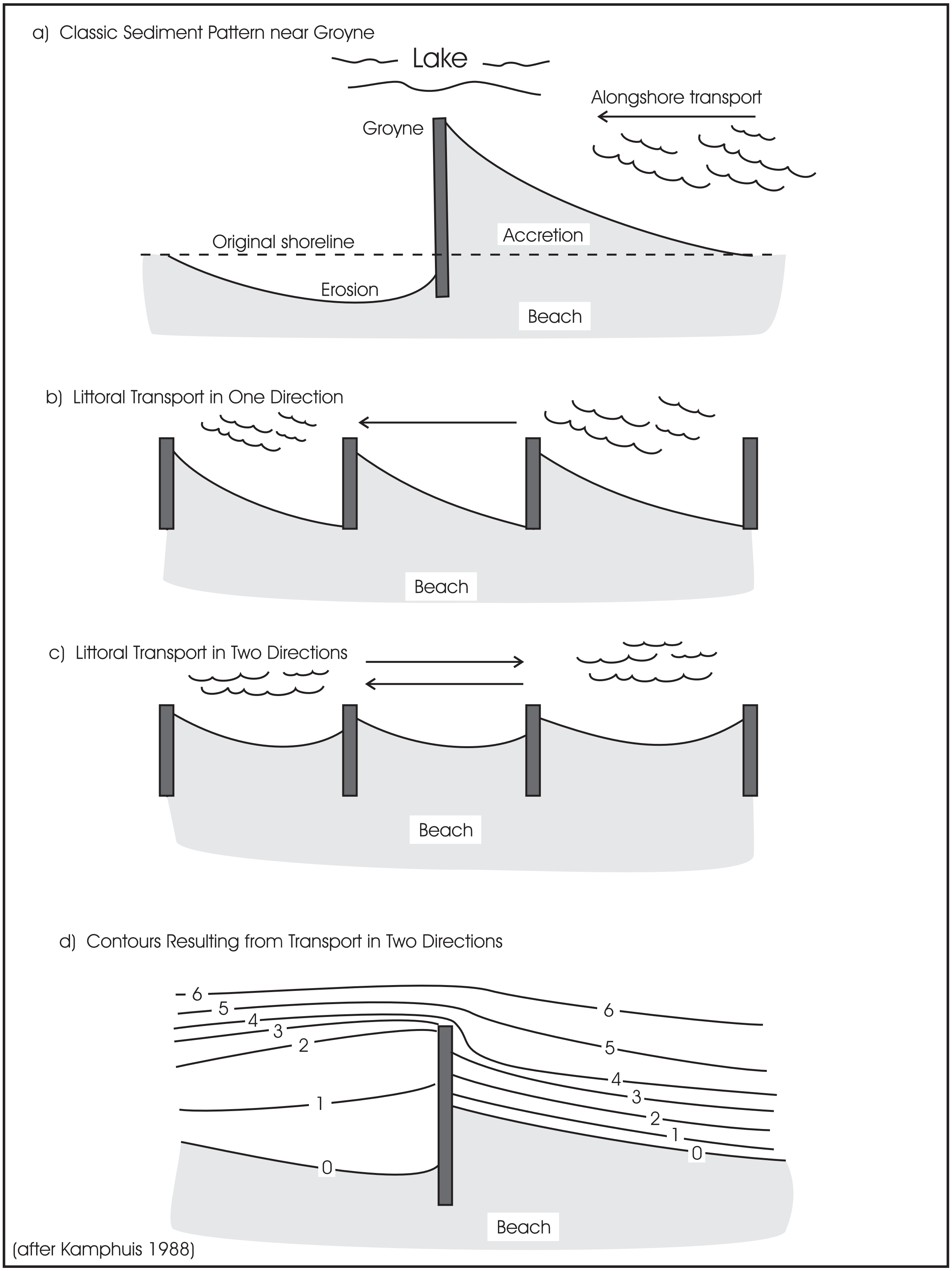


Figure 7.37: Accretion in Lee of Structure and Erosion Downdrift

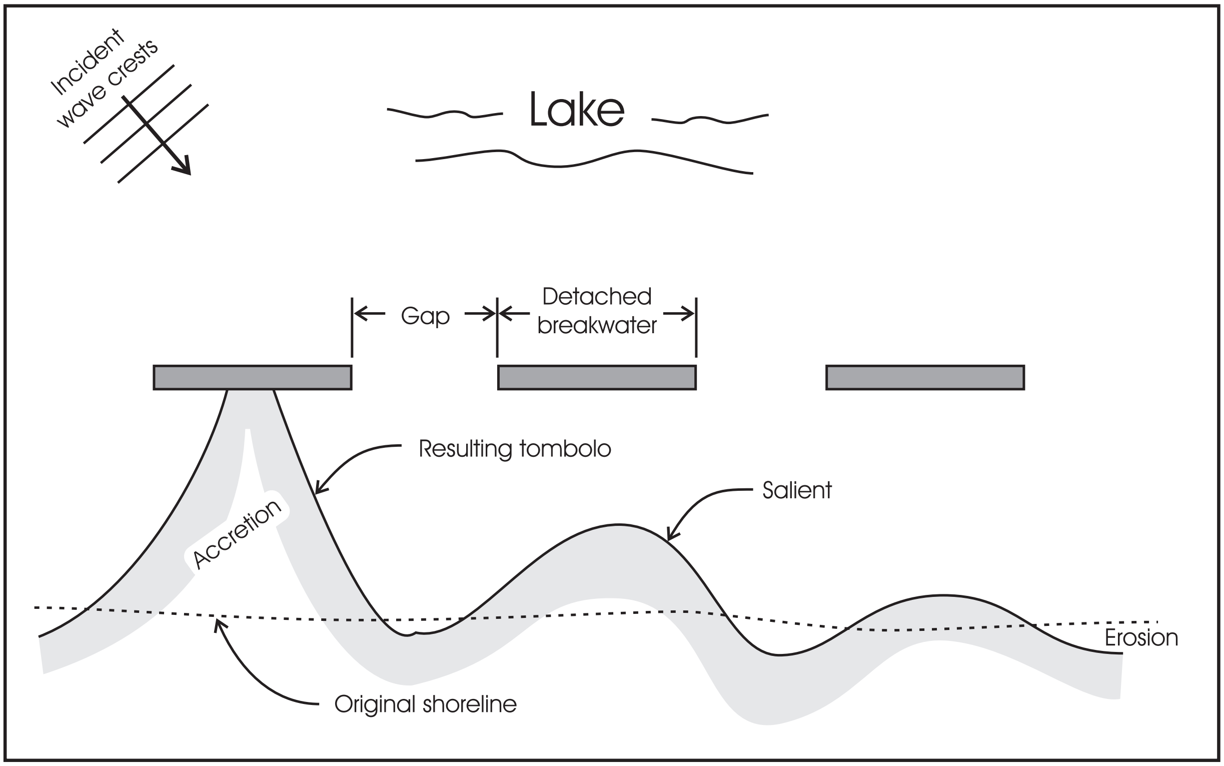
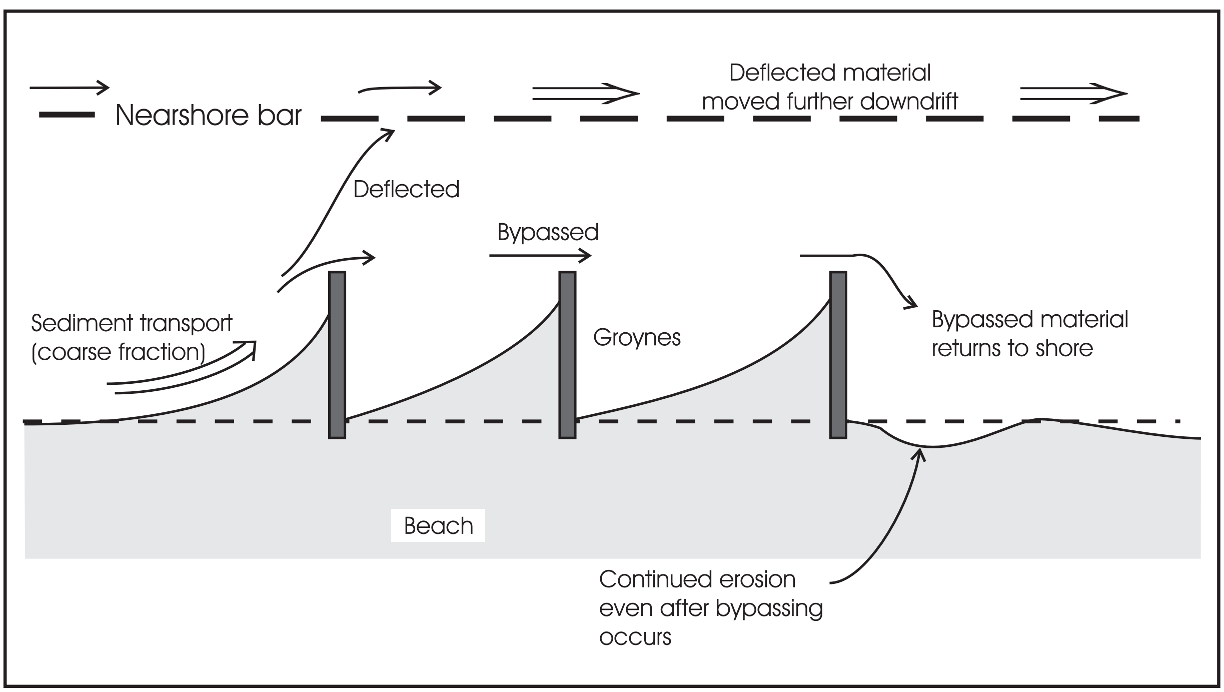


Figure 7.38: Alongshore Transport Deflected Offshore



. **Impact B.4** - Trapping littoral materials at a site (impact B.3), will result in less beach sediments at the downdrift properties. Less sediments may result in **increased erosion of downdrift shorelines until bypassing occurs**. The extent and duration of the increased erosion due to trapping is a function of the size of the protection works. The impact can extend to the end of the littoral cell but will likely be most pronounced immediately downdrift. Except as noted later in influence A.4, the increased erosion downdrift is transitory in nature; it will end once the protection structure is filled and the littoral material is bypassed. Bypassing may restore the downdrift sediment budget to the pre-structure conditions. Other factors may limit the return to a pre-structure condition immediately downdrift (see influence A.4). One is cautioned that this impact (B.4) along dynamic beach shores can be very significant but that its significance along cohesive shores can be unclear. Further discussion is provided in Section 7.5.4.

- **Influence A.4 - Diverts littoral sediments from close to shore to deeper water**
Structures may result in currents that deflect the coarser fraction of the alongshore littoral transport from near the shoreline to the nearest nearshore bar in deeper water (see Figure 7.38). In deeper water, it is more difficult for the waves to move the coarser materials back to the shoreline. Thus the material is moved along the bar, past the immediate downdrift property, and is only slowly returned to the shoreline further downdrift.

. **Impact B.5** - The offshore diversion of the littoral material results in a deficit of material immediately downdrift. This may result in **increased erosion immediately downdrift**. The extent of the diversion is a function of the size (length and height), orientation and form of the protection works. The immediate downdrift properties will experience an on-going sediment deficit even after bypassing around the updrift structures occurs and even if the updrift structure is pre-filled. The diversion and the resulting sediment deficit will continue as long as the updrift structure is in place.

- **Influence A.5 - Reduces cross-shore transport of littoral material**
A reduction in the wave climate in the lee of shoreline structures (i.e., detached breakwaters) will result in the natural cross-shore transport being altered.

. **Impact B.6** - Impeding the cross-shore transport will result in **less change of beach and nearshore profile during storms**.

- **Influence A.6 - Increases wave reflection from shoreline and increases localized currents**
Incoming waves are reflected back from natural shorelines and shoreline structures. In addition, incoming waves are concentrated, by reflection and diffraction, at the end corners and flank walls of structures. Reflection of waves implies a reflection of wave energy as opposed to energy dissipation. Wave action in front of a structure will increase if the wave reflection from the protection work is greater than the reflection from the existing shoreline. Wave action will decrease in the nearshore if wave reflection from the protection structure is less than the reflection from the existing shoreline.

Wave reflection will vary depending on the slope and permeability of the shoreline or protection work. Steeper, smoother and less permeable features result in more reflection than flatter, rougher and more permeable features. A rough guide to the reflection coefficient (ratio of reflected wave height to incoming wave height) is given as follows:

Shoreline or structure type	Reflection Coefficient
Vertical wall with crest above water	0.7 to 1.0
Vertical wall with submerged crest	0.5 to 0.7
Slope of rubble stones (slope of 1 on 2 to 3)	0.3 to 0.6
Natural beach	0.05 to 0.2

Refraction of reflected waves from a structure, at a site, back onto adjacent properties can occur in a very limited number of situations. In cases where the structure is built along a shoreline with no beach and nearly parallel with the bottom contours and the wave reflects from the structure at a large angle, the structure may combine with a steep nearshore bottom slope (that extends to a sufficient depth) to trap wave energy along the shoreline. Typically, for structures along the shores of the Great Lakes, the wave reflection angle is not large enough and the steep nearshore slope does not extend far enough offshore for wave reflection, back onto adjacent properties, to be a significant concern. A simple method for determining the potential for it to be a problem is presented in the Shore Protection Manual (USACE 1984).

- **Impact B.7** - The wave reflection may result in **localized erosion (scour) along the toe of and at the alongshore ends of the protection works**. The depth of the scour trough along the toe of the structure (see Figure 7.35(b)) may be of the order of the incident wave height. Since waves close to the shore are typically depth-limited, the scour trough will be of the order of the original depth of water. Scour along the toe of a structure can undermine the structure, resulting in its collapse (see Figure 7.39).

  End scour, often referred to as "flanking", is recognized as a potential impact. Flanking is defined in terms of excess recession, beyond the natural, ongoing erosion, caused by the structure. Ongoing erosion at adjacent unprotected shorelines should be taken into account when assessing if there will be any additional localized scour. Some limited guidance for determining the potential flanking due to seawalls and revetments along beach shores is provided in the literature (see Figure 7.40). McDougal et al. (1987) observed that for beach shores the depth of excess erosion is approximately 10% of the seawall length and that the alongshore length of the excess erosion is approximately 70% of the structure length. There is no similar rough estimate of end scour effects for cohesive shores.

Figure 7.39: Undermining of a Seawall by Wave Scour

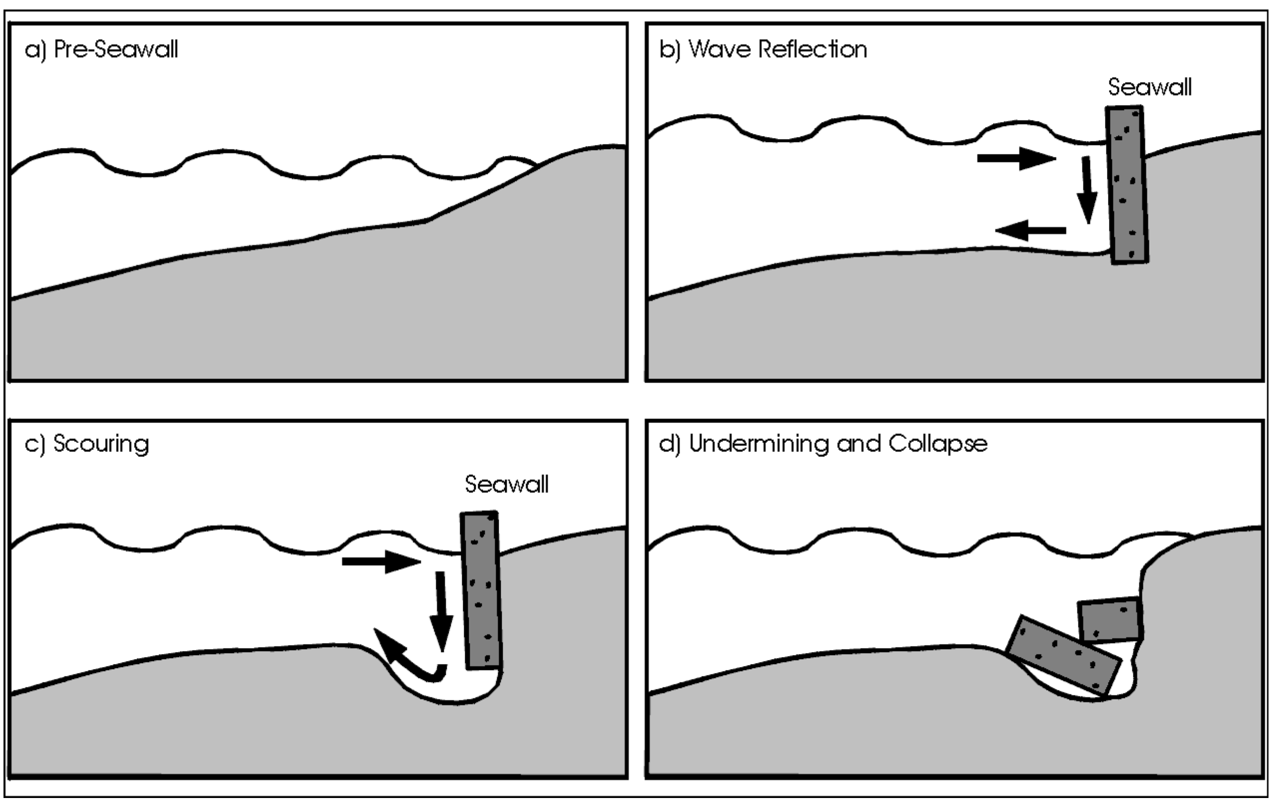
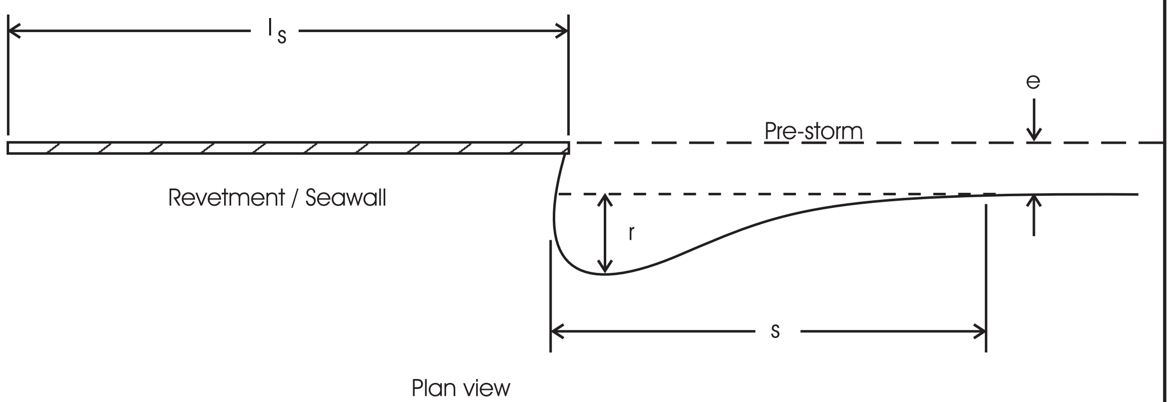
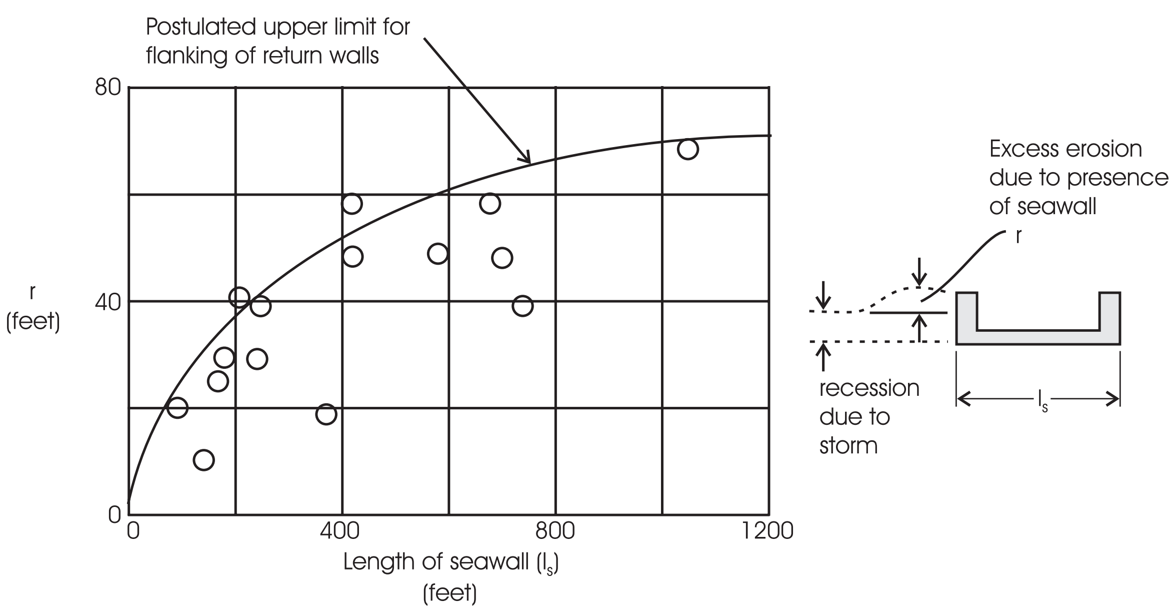


Figure 7.40: Revetment/Seawall End Scour on Dynamic Beach Shores



a) Typical scour pattern at end of seawall (from McDougal et al. 1987) The natural erosion process due to a storm is denoted "e", excess erosion due to the structure is denoted "r" in the cross-shore dimension and "s" in the longshore dimension. Structure length is designated "l_s".



b) Graph of seawall length vs. end scour based on post-Hurricane Eloise field data (after Walton and Sensabaugh 1983).

ii) Water Circulation

- **Influence A.7 - Increases sheltering of nearshore waters**
Nearshore protection works can reduce the exposure (or increase the sheltering) of the natural shoreline to lake processes, including waves and currents. Generally two different types of exposure can be considered; nearshore sheltering and shoreline exposure. Sheltering of nearshore waters occurs through the formation of distinct embayments or sheltered areas (i.e., detached breakwaters with very small gap-to-length ratio). Exposure of the shoreline can be assessed qualitatively by the exposure ratio (ratio of length of "unprotected" shoreline subject to natural lake processes to total shoreline length). The exposure ratio varies depending on the structure: for revetments and seawalls, the ratio is 0.0; for groynes, the ratio is approximately 0.9; and for detached breakwaters, the ratio varies depending on segment length and gap length).

  . **Impact B.8** - Structures such as detached breakwaters can result in **decreased nearshore wave action**. Less wave action may decrease the oxygen content in the nearshore and reduce the cleansing action of the waves which can "sweep" silt material from the nearshore substrate.

  . **Impact B.9** - Sheltering of the shoreline can result in **decreased mass water exchange/circulation of the nearshore waters** due to less mass exchanges of offshore water with nearshore water (through upwellings and downwellings) and a decrease of other lake currents. Decreased circulation can increase nearshore water temperatures and reduce nutrient exchange.

iii) Backshore and Nearshore Topography

- **Influence A.8 - Occupies backshore area**
The protection works directly occupy or cover the backshore area with imported materials (i.e., materials not from the site) and displace the natural terrain and relief. Along cohesive shores, the works will often occupy most or all of the typically narrow backshore area. In many instances, revetments and seawalls along cohesive shores will extend into the nearshore area. Protection works located on beach shorelines, if located at the landward edge of the backshore, will occupy a relatively smaller percentage than works on a cohesive shore. Protection works are constructed using various materials including steel, timber, concrete, timber, earth fill, quarried stone, sand, gravel, cobbles and fieldstone from inland sources. These materials may change the characteristics of the natural materials. Dune enhancement practices consist of encouraging growth of the existing dunes by controlling access points and planting vegetation.

  . **Impact B.10** - Occupying the backshore area will result in an **altered backshore topography at the site** (i.e., changes the terrain and native materials). Typically, the natural grade of the backshore will be altered by the protection works. For most structures, the grade will be steeper than the natural shore thus limiting access to the shore. With seawalls, there will be an abrupt change in grade. Backshore works are typically embedded into the shore (by excavating a toe trench) to protect against undermining due to wave scour and downcutting.

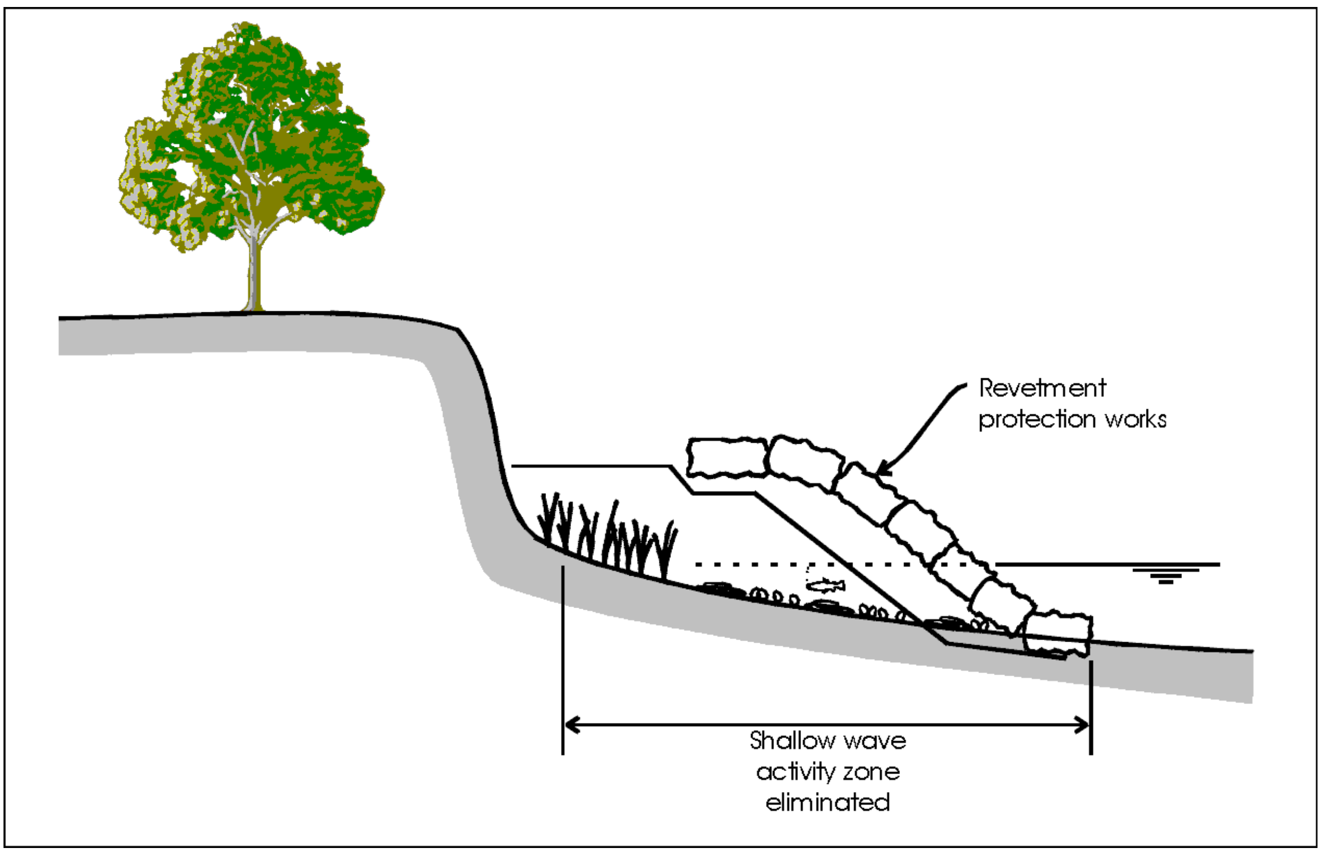
- **Influence A.9 - Reduces wave action at backshore**

  . **Impact B.10** - Reduced wave action may result in an **altered backshore topography at the site**. Typically, the profile becomes more stable; demonstrating less change due to storm waves.

- **Influence A.10 - Occupies nearshore area**
  The protection works directly occupy or cover the nearshore area and displace the natural terrain and relief. Groynes, artificial headlands and detached breakwaters are often accompanied by beach fill. Backshore works, such as revetments and seawalls that extend into the nearshore can effectively reduce the shallow wave activity zone (see Figure 7.41). This can ultimately result in an alteration of the natural function of the original land-water interface.

  . **Impact B.11** - While the initial installation of groynes and beach fill may result in **altered nearshore topography (changes bathymetry and materials)**, a "natural" land-water interface and shallow water wave zone (exposed to lake action) is maintained. Rubble mound structures in the nearshore can also provide aquatic habitat. The vertical relief, interstitial spaces, and irregular outline could provide the opportunity for development of fish habitat.

Figure 7.41 Backshore/Nearshore Areas Occupied by Protection Works



iv) Onshore Topography

- **Influence A.11 - Occupies onshore area**
  The placement of fill and/or the construction of dykes will directly occupy or cover a portion of the onshore area and displace the natural terrain and relief.

  . **Impact B.12** - Occupying the onshore area may result in an **altered onshore topography (changes terrain and materials)**. In order to construct protection works, access to the shoreline at the site is required. Most construction is landbased (i.e., access is from the land side). The shallow nature of the nearshore often makes access by barge impossible. The land access route must be of suitable width and grade for the construction equipment necessary to build the works. The grade of most eroding cohesive bluffs is too steep and must be cut back for the access route. Often the access route is left in place upon completion of construction to be used as a future access route for maintenance.

  Protection works located in the backshore often require grading of the onshore for maintenance access parallel to the shoreline.

- **Influence A.12 - Stabilizes toe of cliff/bluff/bank**
  Protection works will stabilize an eroding toe of cliff/bluff/bank. Bluff measures can pre-empt much of the self-stabilization.

  . **Impact B.12** - A bluff shoreline that is actively eroding is not at a stable slope condition. The toe of the slope is constantly being undercut thus maintaining an oversteepened condition. Once the toe of the slope is stabilized, the crest of the slope will continue to retreat until it reaches a stable slope condition thus resulting in an **altered onshore topography (changes terrain and materials)**. This is an important consideration for cohesive bluff shorelines. It is typically not as critical for bedrock cliff shores. Often the slope is graded to a stable slope at the time of construction, particularly for protection works located in the backshore.

v) Surface and Groundwater

- **Influence A.13 - Disrupts surface and/or groundwater drainage from land to lake/channel**
  Protection works potentially modify surface drainage patterns and surface flow rates. Surface drainage disruptions are primarily of concern in poorly-drained low plain shorelines.

  Essentially, the impact of impermeable structures is that they inhibit the lakeward movement of groundwater, causing an increase in the elevation of the water table. The effect varies in magnitude depending on structure type, height, permeability and physical setting of site. The problems associated with groundwater distribution are primarily of concern in poorly-drained low plain shorelines.

  . **Impact B.13** - Interfering with the groundwater drainage may result in **altered surface/groundwater drainage pattern in the onshore/backshore area**.

An additional potential impact, which is only applicable to connecting channels, is that filling and dyking located within the *flooding hazard* will increase water levels. This was discussed in Part 3: Flooding Hazard.

7.5.3 Assessing the Physical Impacts Off-Site

One of the requirements for environmentally sound development and site alteration within the *hazardous lands* is that new *hazards* are not created and existing *hazards* are not aggravated (Policy 3.1.3(b)). Protection works which are intended to address the *hazards* at a site, have the potential to create or aggravate *hazards* away from the site (i.e., "off-site", at updrift or downdrift properties). The shoreline *flooding, erosion and dynamic beach hazards* were described in Parts 3, 4 and 5 respectively of this Technical Guide. The *hazards* are a result of variations in water levels (i.e., higher static water levels, storm surge), wave action (i.e., wave uprush) and other water related hazards, slope instabilities, erosion of the shoreline and dynamic beach profile adjustments. Excluding instances of filling and dyking along connecting channels (see Part 3: Flooding Hazard), water levels are rarely influenced by shoreline management approaches. Influences to wave action, other water related hazards and slope instabilities, due to shoreline works, are generally limited to the site and have little or no impact off-site. Therefore, except for impacts to water levels along connecting channels, the supply and transport of littoral materials, as described in Section 7.5.2, is the only general physical shoreline process or characteristic that affects the *hazards* off-site (i.e., located updrift or downdrift of the site location). That is to say, the *erosion hazards* and *dynamic beach* profile adjustments at updrift or downdrift properties (i.e., off-site) can be adversely affected by the impacts caused by certain shoreline management approaches.

The potential impacts associated with the supply and transport of littoral materials (impacts B.1 to B.7, as identified in Section 7.5.2; see Table 7.2) vary in their significance, with respect to increasing *hazards* off-site, depending on the shoreline class, especially controlling nearshore substrate; bedrock, cohesive or dynamic beach.

7.5.4 Discussion of Relative Significance of Physical Impacts by Shoreline Class

The following discussion is general in nature and applies to many situations in the Great Lakes - St. Lawrence River System. 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 7.3 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 7.2) are listed across the top of Table 7.3. 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 7.3. 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 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*. Dynamic beaches that are not eroding (i.e., they are stable with no overall long-term recession) are not acting as a source of sediment to downdrift shores.

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 occurs.

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 (see Section 7.4.2(c)(ii)). 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.

Table 7.3: 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 7.3: 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 A3 continued...(See notes next page)

Table 7.3: 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
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 the Great Lakes - St. Lawrence River System. 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 7.1**, for initial evaluation of shoreline management approaches.
- Refer to **Table 7.2**, to assess the potential influences and impacts of shoreline management approaches on the physical shoreline processes and characteristics.
- Refer to **Tables 8.2, 8.3 and 8.4, Part 8,** 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.

i) Revetments and Seawalls on Dynamic Beaches

Knowledge of the long-term and short-term effects of revetments and seawalls on dynamic beach shores is limited and remains a source of debate and research (Kamphuis et al. 1992; Tait and Griggs 1990). Nevertheless, revetments and seawalls on beaches can serve a useful role in certain limited situations and if adequate attention is given to their effects on the physical processes. Seymour et al. (1996) concluded they are "capable of providing effective shoreline protection and of mitigating the effects of erosion when appropriately designed, sited and constructed."

The following are the conclusions presented by Tait and Griggs (1990) regarding revetments and seawalls along dynamic beach shorelines:

1) "Beach response to seawalls is variable and appears to be influenced by a number of interdependent factors. Assessment of the potential impact of a seawall on a beach should be site-specific and consider the entire range of possible controlling factors.

2) Field studies of beach response to seawalls, and especially of associated processes, are limited. More studies are needed, and attempts to predict beach-seawall interactions from the existing data should be made with caution.

3) The most important factor affecting the potential impact of a seawall on a beach is whether there is long-term shoreline retreat. Such retreat is a function of sediment supply and/or relative sea level change. Where long-term retreat is taking place...and this process cannot be mitigated, then the beaches in front of seawalls in these locations will eventually disappear.

4) One of the most critical factors controlling the impact of a seawall on the beach is its position on the beach profile relative to the surf zone. All other things being equal, the further seaward the wall is, the more energetically it can interact with the waves. The best place for a seawall, if one is necessary, is at the back of the beach where it provides protection against the largest of storms. By contrast, a seawall built out to the mean high water line may constantly create problems related to frontal and end scour, as well as upcoast sand impoundment.

5) The majority of field studies indicate that most of the direct effects of seawalls on beaches are temporary or seasonal in nature and that seawalls do not impede the post-storm recovery process.

6) The most prominent example of lasting impacts of seawalls on the shore is the creation of end scour via updrift sand impoundment and downdrift wave reflection. Such end scour exposes the back beach, bluff, or dune areas to higher swash energies and wave erosion.

7) In several cases beaches in front of seawalls have been attacked by storm waves and never recovered. The reasons for this are poorly understood. Factors such as deficient sediment supply, wave exposure, steep offshore gradients, or small grain size may have been involved. When the above factors are evident locally, construction of a seawall may not be advisable.

8) Seawall design may be able to offset partially some of the potentially adverse effects of seawalls on beaches. Questions remain as to the significance of permeability differences. Similar effects have been recognized and associated with both sloping, permeable walls and vertical impermeable walls. Large storm waves may diminish any benefits conferred by lower reflectivity in wall design. It is possible that differences in reflectivity are significant only with a certain range of wave energies, and that large waves nullify any benefit conferred by those differences. It is also probable that differences in seawall reflectivity are more significant under approximate monochromatic laboratory wave conditions and are less significant when several wave trains combine to generate a complex wave regime."

The preferred order to implementing the potential range of approaches along dynamic beaches was outlined in Section 7.4.2(c). Further discussion can be found in Kraus (1987), Pilarczyk (1990), Tait and Griggs (1990), Dean et al. (1991), Kamphuis (1993) and Kamphuis et al. (1993).

ii) Groynes and Artificial Headlands

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). Further, Kamphuis (1990) notes that prefilling groynes will not necessarily prevent either impact due to the nature of the Great Lakes water level variations. 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 and artificial headlands on dynamic beach shores should be carried out by a qualified coastal engineer.

iii) Detached Breakwaters

Detached breakwaters can have a major impact on downdrift and updrift dynamic beach shorelines. Pope and Dean (1986) provided the following summary of potential impacts based on the shoreline response in the lee of the breakwaters (see Figure 7.42):

- Permanent Tombolos - In this case, very little wave energy reaches the shore and the protected beach is stable. There is very little transport along the shore. Littoral transport maybe displaced into deeper water, seaward of the structure.

- Periodic Tombolos - One or more segments are periodically backed by tombolos. This is primarily due to variability in wave energy reaching the lee of the individual segments. During high wave energy, tombolo(s) may be severed from the structure resulting in salients. During low wave energy periods sediment accretes and the tombolo returns. The alongshore effect of this type of planform may be periodic trapping of littoral material followed by a release of a "slug" of sediment.

- Well-Developed Salients - The well-developed salient beach planform occurs when higher wave energy reaches the lee of the structure and is characterized by a balanced sediment budget. Well-developed salients are not apparent until sufficient time has passed for the project shore to stabilize relative to the structure configuration. Alongshore moving material enters and leaves the project at approximately the same rate. In addition, rip current development within the gaps is unusual and very little material is lost into the offshore.

- Subdued Salients - In this case, the shoreline sinuosity is not obvious, and amplitude of the salient is of lower relief. The project beach may periodically store and release sediment. Although the quantity of material retained in the project may remain generally balanced through time, there will be periods of increased loss or gain and the uniformity of the beach planform is not as assured.

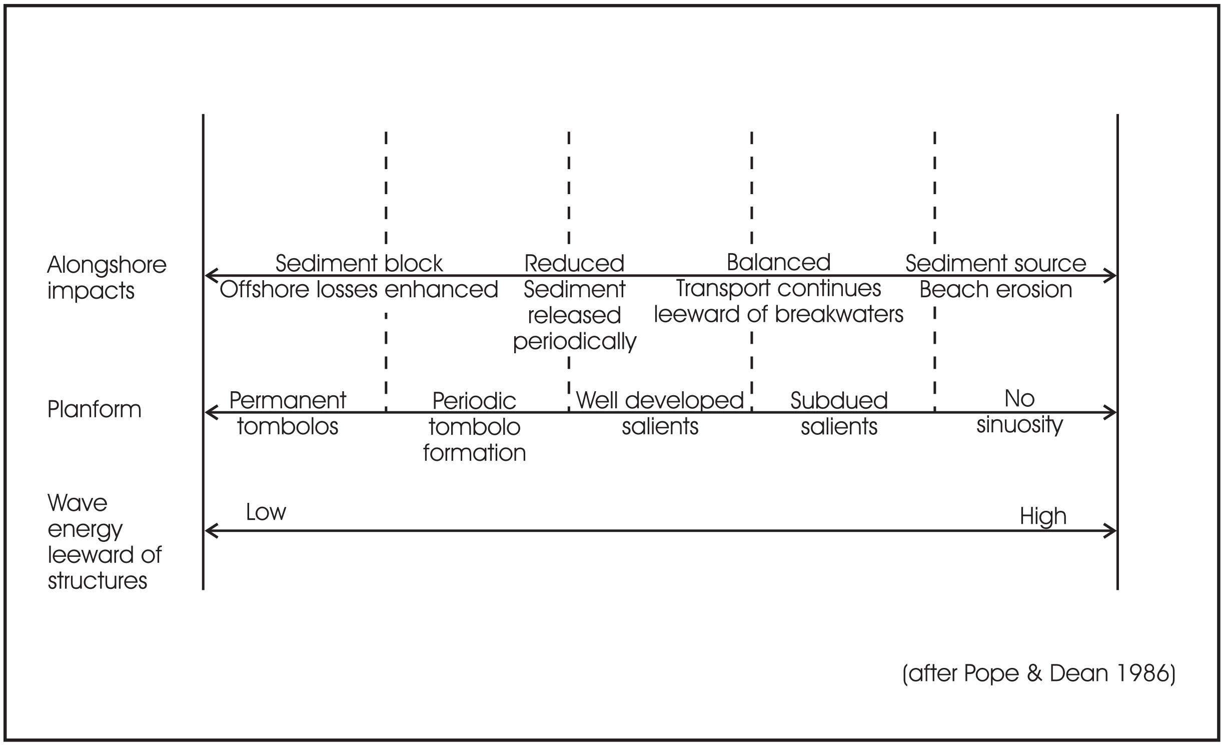
- No Sinuosity - If high wave energy reaches the beach, including the area directly behind the segments, the beach planform may not mirror the presence of the segments. Placed beach fill may actually serve as source of material for downdrift beaches. Although there is some minor trapping of material from neighbouring shores, the characteristic shoreline morphology is missing.

Assessment of the impacts of 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.

Figure 7.42: Potential Impacts of Detached Breakwaters on Dynamic Beach Shorelines



As discussed in Section 7.4.2(b)(ii), 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 coarse sediments are typically derived from erosion of the bluffs and the nearshore profile. 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.

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. Therefore it is difficult to assess whether or not the effects may be significant. Sand first acts as an abrasive agent and erodes the profile. However, as the volume of sand in the nearshore increases, it reaches a point where it acts to protect the profile. The protective characteristics of the sand cover is thought to then increase as the volume and stability of the sand increases. Therefore it is possible that cohesive shorelines with more than some threshold volume of coarse sediment present in the nearshore zone, to protect the underlying profile, will not be significantly impacted by a limited alteration in the supply and transport of littoral materials. However, a significant decrease in the sediment cover, caused by a reduction in the sediment supply, either through protection of eroding updrift bluffs or by trapping alongshore transport, may accelerate the erosion of the underlying cohesive profile. A significant reduction in the sediment supply could be caused by a single large project or by the cumulative effect of many smaller projects. There may be a lag of several years or even decades before the effect of a reduced sediment cover could be detected due to a possible reserve of material in the nearshore. Only as this reserve is diminished below some critical threshold volume, would accelerated erosion of the nearshore profile take place. Increased erosion of a cohesive shoreline is not reversible. Once the matrix of cohesive particles is broken down it can not be put back together again.

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.

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.

7.6 SUMMARY

7.6.1 Addressing the Hazards

For certain *development* and *site alteration* to be permitted within *hazardous lands* adjacent to the shorelines of the *Great Lakes - St. Lawrence River System*, 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)).

Part 7 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, bluff 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 7.1 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. In addition, Appendix A7.1 outlines design criteria that will help determine the ultimate success of the protection works including, but not limited to, water levels, waves, sediment transport processes, structure stability, construction and maintenance. Appendix A7.2 deals with addressing the hazards for existing development.

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 7.5. 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 7.2. Part 8 of this Technical Guide uses the influences and impacts identified in Section 7.5 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 7.3.

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 8: Environmentally Sound Hazard Management.

7.6.2 Suggested 7 Step Procedure: Addressing the Natural Hazards

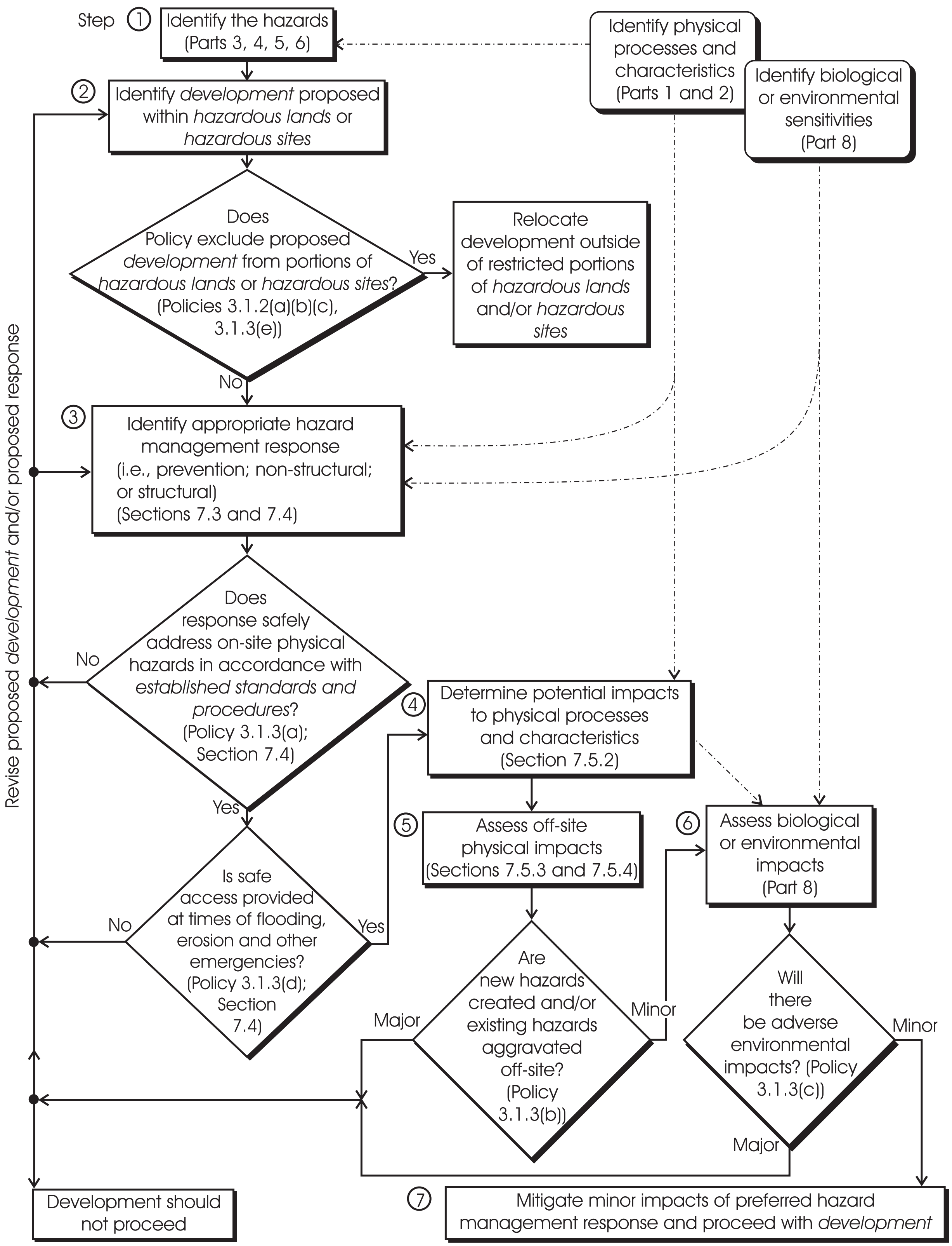
The suggested 7 step procedure is designed to aid decision-makers in evaluating an area, or particular location, within *hazardous lands* and *hazardous sites*. The procedure helps to ensure that consideration is given to both the physical and biological influences and impacts when selecting which, if 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 7.43. 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 (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 7.43: Suggested 7 Step Procedure: Addressing the 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 permits MNR requires includes ones for:

- dock, boathouse 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).

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.

i) Step 1: Identify Hazards

The Policy defines the areas of provincial interests as being *hazardous lands,* which includes lands adjacent to the shorelines of the *Great Lakes - St. Lawrence River System* which are impacted by *flooding*, *erosion* and *dynamic beach hazards*. The first step in this process involves identifying, or delineating, the areas of provincial interest. Completion of this step normally requires a sufficient level of understanding of the physical processes and characteristics.

ii) Step 2: Identify Development Proposed Within the *Hazardous Lands* or *Hazardous Sites*

Except for certain restrictions (i.e., Policy 3.1.3), there exists the flexibility to consider *development* and *site alterations* to be located within the least hazardous portion of the *hazardous lands* and/or *hazardous sites*. The second step then involves identifying the size and nature of the development that is proposed within the *hazardous lands* and/or *hazardous sites*. This is essential since the characteristics of the proposed development activity, or the resulting land use, can influence the type of hazard management response to be applied. For example, a high-density residential development will obviously require a greater degree of protection from *hazards* than non-habitable buildings.

Development can generally be grouped into three major categories:

- multi-lot, large lot and large scale development;
- residential or habitable infilling, redevelopment, replacement, major additions/alterations, minor additions/alterations; and
- non-habitable buildings and structures.

When undertaking this step, it should be acknowledged that Policy 3.1.2 identifies that *development* and *site alterations* should not be permitted within *defined portions of the dynamic beach* and *defined portions of the one hundred year flood level along connecting channels*. Also, Policy 3.1.3(e) identifies that *institutional uses* or *essential emergency services* or the disposal, manufacture, treatment or storage of *hazardous substances* should not be permitted within *hazardous lands*. All portions of the proposed *development* should then be relocated outside the restricted areas of the *hazardous lands*.

iii) Step 3: Identify Appropriate Hazard Management Response

Where *development* and *site alteration* may be considered within any of the areas of provincial interest, the *development* and *site alteration* should fulfil the *established standards and procedures* respecting:

- floodproofing;
- protection works; and
- access.

Step 3 involves an assessment of whether or not the selected hazard management response (i.e., prevention, non-structural or structural protection works) is considered to be appropriate, fulfils each of these standards and safely address the on-site physical hazards. Completion of this step normally requires a sufficient level of understanding of the physical processes and characteristics of the site.

If it is determined that these standards cannot be fulfilled, or if the proposed hazard management response does not safely address the on-site physical *hazards* (e.g., *erosion*, *flooding*, and *dynamic beach*; Policy 3.1.3(a)) or if safe ingress and egress is not provided at times of flooding, erosion and other emergencies (i.e., Policy 3.1.3(d)), then an alternative hazard management response should be selected and/or the proposed development revised.

iv) Step 4: Determine Potential Impacts to Physical Processes and Characteristics

One of the primary issues when considering protection works to address natural hazards is the need to assess the impacts of the selected protection works on the area's physical processes and characteristics.

Although a particular hazard management response may appropriately address the local or on-site flood and/or erosion hazard(s), the physical characteristics of the protection works (e.g., structural form and slope, size of material, permeability, etc.), the methods used in construction, the methods of maintenance, and the post-design life measures may individually and/or collectively affect the characteristics and physical processes of a given location. The "affects" or impacts may in turn cause harm to the ecosystem and pose physical risk or harm by increasing or exacerbating hazards on surrounding properties.

Step 4 essentially involves identifying the potential influences and impacts of the proposed hazard management response to the physical processes and characteristics. Completion of this step normally requires a sufficient level of understanding of the physical processes and characteristics.

In addition to understanding and addressing the type and magnitude of impacts on the physical processes and characteristics on-site, consideration should also be given to the spatial extent of the physical impacts in order to assess the impacts off-site (e.g., how far updrift/downdrift the physical impact is determined to extend; see Step 5). Evaluation of the spatial extent of the physical impacts is dependent on such factors as the type, design, configuration and sometimes the timing of the installation of protection works. The resultant impact(s) on the physical processes is also dependent on the physical characteristics of the area in which the works are being installed. For example, is the native soil structure highly susceptible to disturbance, is the area exposed, is it partially sheltered, and what is the magnitude and duration of the forces (e.g., wind, waves, flood flows).

Effective ecosystem and natural hazards management generally involves managing not only the physical hazards (e.g., *flooding, erosion, dynamic beaches*), but also understanding and accommodating the potential impacts of any such actions on the local environment or ecosystem. Step 6 deals with the biological impacts.

v) Step 5: Assess Off-Site Physical Impacts

Beyond the consideration of the range, magnitude and consequences of protection works on **on-site** physical processes and characteristics, one should also give consideration to the potential range, magnitude and consequences of the same protection works on **off-site** locations or surrounding properties (e.g., updrift/ downdrift shoreline properties).

Evaluations of potential **physical impacts** are often described in terms of **major** or **minor impacts**. The terms minor and major are defined in Section 7.5.1.

Where major off-site physical impacts result, the development should not considered to be fulfilling the intent of the policy (e.g., Policy 3.1.3(b), development is not to aggravate existing hazards, create new hazards). Where new hazards are created and/or existing hazards aggravated, one of three options should be implemented:

- an alternative method of "addressing the hazard" should be considered; or
- the development should be revised; or
- the development should not be permitted.

Where minor physical impacts are identified, a determination of whether this impact(s) can be further reduced using another form of protection works or an alteration to the design, installation method or timing should be considered.

vi) Step 6: Assess Biological or Environmental Impacts

The environmentally sound management of a particular location essentially involves an understanding not only of the physical processes impacted by various protection works, but also of the effects that these physical processes, and any changes to them, have on the ecosystem. The more complex or diverse the physical characteristics and processes that are shaping and reshaping the development site, the more diverse the range of habitat types for plant and animal species. A thorough examination and understanding of these diversities, therefore, would help to ensure that potential adverse environmental impacts are addressed and minimized.

The gradual encroachment of development on sensitive ecosystems have in the past resulted in impacts which were frequently overlooked until it was too costly, practical or late to remedy or recover affected habitats. It is essential, therefore, in any decision-making process, to ensure that environmental concerns are considered as an integral part of managing a particular location, and not as an isolated study component to be addressed at a later or last stage of the process. For environmental concerns to be duly recognized and properly evaluated and addressed, they should be considered at all stages of the land use planning process, from the formulation of alternative development strategies to the plan implementation and post-development monitoring stage.

To complete Step 6 essentially involves the evaluation of the biological or environmental sensitivities associated with a particular development site or area and an understanding and recognition of their importance to the ecosystem as a whole. As well, consideration should also be given to the potential physical impacts and their spatial extent developed during Step 4. Step 6 then builds on this knowledge by undertaking an assessment of how the biological elements and processes are impacted by the introduction of the development and any associated non-structural or structural works that may be proposed. Part 8 of this Technical Guide deals with the environmental issues.

vii) Step 7: Mitigate Minor Impacts of Preferred Hazard Management Response

The proposed *development* and *site alteration* may proceed when all of the matters outlined in Policies 3.1.2 and 3.1.3, and as outlined in Steps 1 through 6, are addressed and any minor impacts are mitigated by alterations to the design and/or to the timing and method of installation. The *development* should include a monitoring program.

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TECHNICAL GUIDE FOR
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APPENDIX A7.1

RECOMMENDED APPROACH FOR
DESIGNING SHORELINE PROTECTION WORKS

RECOMMENDED APPROACH FOR DESIGNING SHORELINE PROTECTION WORKS

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A7.1 RECOMMENDED APPROACH FOR DESIGNING SHORELINE PROTECTION WORKS

Unlike many other engineering disciplines, shoreline and coastal engineering design is not governed by a "code". For example, in building design, the structural engineer must follow well established and routinely updated building codes which detail requirements for design, such as minimum loads and factors of safety. The design of shoreline protection structures has no recognized standard code which defines design procedures, formulae or criteria. As stated earlier, the shoreline zone is characterized by a complex interaction of short-term and long-term water level variations, waves and currents, morphology, sediments and protection structures. These aspects are difficult to describe theoretically or mathematically and to measure reliably and accurately. Coastal engineering has been described as "an emerging technology" or as "more of an art than a science". However, great strides have been made in coastal engineering design methods in the last couple of decades. Ongoing research and development is resulting in a better understanding of the shoreline processes and their interaction with structures (e.g., Ollerhead and Davidson-Arnott 1993; Kamphuis et al. 1993; Bishop et al. 1992; Nairn 1992; Willis et al. 1990; Davidson-Arnott 1986).

While continued research is needed to better describe and predict the performance and impacts of shoreline protection works, especially along cohesive shores, many shoreline processes and wave-structure interactions can be reasonably approximated, for design purposes, by experienced, qualified coastal engineers using a combination of empirical equations, physical model studies and/or rigorous field observations. But the lack of recognized standards, or even well-defined criteria, makes it difficult for shoreline managers to understand and assess the suitability and long-term integrity of proposed shore protection works. The situation is further complicated by the wide range in the natural conditions and scale of developments along the shorelines of the *Great Lakes - St. Lawrence River System.*

To effectively review proposed protection works, this section presents a recommended approach that should be followed by coastal engineers designing shoreline protection works. **This section is not intended as a design manual. It is intended as a guide for shoreline managers to help them ask the right questions and to ensure that the proposed design addresses all the appropriate concerns and issues.** The recommended approach does not require the use of specific design procedures or formulae. These remain the responsibility of the qualified professional engineer. The approach does recommend that a consistent process be followed by qualified professionals to address the *hazards* in an environmentally sound manner.

A7.1.1 Overview of Design Approach

The *Provincial Policy Statement* (1996), Policy 3.1 governing Public Health and Safety: Natural Hazards, takes an ecosystem approach which encourages an appropriate balance between addressing the *hazards* and protecting the environment. It is the responsibility of the proponents' professional engineers and scientists, experienced and qualified in matters of coastal engineering and science, to carry out the shoreline protection design and impact assessment using accepted engineering practice and scientific principles. As noted in the introduction to this section, there is no accepted shoreline protection design "code". Therefore in this context, "accepted" practice and principles refers to the principles, methods and procedures that would be judged by a peer group of qualified coastal engineers (by virtue of their training and experience) as being reasonable for the scale and type of project being considered, the environmental sensitivity of the location, and the potential threats to life and property.

In order to aid shoreline managers in the review of proposed works along the shoreline, this Technical Guide recommends that a consistent approach be used in identifying, evaluating and documenting:

- the proposed development activity;
- the physical shoreline processes and characteristics;
- the proposed shoreline treatment;
- the *flooding, erosion and dynamic beach hazards*; and
- the potential impacts.

The use of a consistent, documented approach will help to ensure that all of the appropriate processes, *hazards* and potential impacts have been identified and considered. If a proponent, or a proponent's consultant, has a reasonable understanding of the processes, *hazards* and potential impacts, then the proponent can reasonably be expected to provide a satisfactory rationale or explanation regarding the proposed shoreline treatment and development activity and any subsequent impacts and mitigation measures.

a) Summary of Project Phases

A consistent approach can be achieved by following through the typical phases of a project as follows:

Phase 1 - Problem Identification
- 1.1 Preliminary site analysis
- 1.2 Initial background review
- 1.3 Initial shoreline classification and preliminary definition of *hazardous lands* limit
- 1.4 Problem confirmation

Phase 2 - Alternative Solutions
- 2.1 Inventory of shoreline processes and characteristics
- 2.2 Classification of shoreline and confirmation of *hazardous lands* limit
- 2.3 Identification of alternative solutions to the problem
- 2.4 Identification and evaluation of impacts of alternatives on coastal and other environmental processes
- 2.5 Selection of preferred solution

Phase 3 - Alternative Designs
- 3.1 Design criteria
- 3.2 Identification of alternative design concepts
- 3.3 Identification and evaluation of impacts of alternative design concepts
- 3.4 Selection of preferred design concept

Phase 4 - Preliminary Design
- 4.1 Preliminary design
- 4.2 Design report
- 4.3 Approvals

Phase 5 - Final Design, Construction and Monitoring
- 5.1 Final design
- 5.2 Construction drawings and specifications
- 5.3 Construction review
- 5.4 Monitoring

The general design approach above is similar to the planning and design process outlined by the Association of Conservation Authorities of Ontario in *Class Environmental Assessment for Remedial Flood and Erosion Control Projects* (March 1993) and the process presented by the Municipal Engineers Association of Ontario in *Class Environmental Assessment for Municipal Water and Wastewater Projects*.

The typical project phases and activities are described in more detail in Section A7.1.1(f). The actual design process followed and the level of detail provided for a given project will vary depending on the "level of concern" regarding the project. The level of concern is described in the following subsection.

b) Level of Concern

The overall "level of concern" a shoreline manager has with respect to a proposed shoreline development should be a function of the following:

- the type of development activity (i.e., land use, size and cost);
- the existing shoreline characteristics (i.e., recession rate, slope stability, height of shore above water, littoral processes);
- the proposed shoreline treatment (i.e., located in backshore or nearshore);
- the potential *hazard* (i.e., flooding, erosion, dynamic beach); and
- other factors such as environmental considerations.

To have an overall <u>low level of concern</u>, the proposed development must be small in nature and it should be readily apparent to qualified observers that the development exceeds the established and accepted criteria of the reviewing agency, with respect to safely addressing the *hazards*, and that there will be no negative impacts.

For an overall <u>moderate level of concern</u>, the proposed development should be relatively limited in scale/scope and in a non-sensitive environment and it should be apparent that all possible negative impacts can be avoided, mitigated or compensated. Through analysis by the proponent, it can be shown that the development meets the established and accepted criteria of the reviewing agency for safely addressing the *hazards.* Qualified observers consulted by the shoreline manager during the review concur with these findings and conclusions.

An overall <u>substantial level of concern</u> will be associated with substantial developments and/or all developments where it has been determined that negative impacts will occur that cannot be mitigated or where, even following further analysis and study, there is some uncertainty that the development can meet the established and accepted criteria of the reviewing agency for safely addressing the *hazards.* These characteristics would require a greater level of effort to properly identify, evaluate and document: the proposed development activity; the physical shoreline processes and characteristics; the proposed shoreline treatment; the *flooding, erosion and dynamic beach hazards*; and the potential impacts.

An overall <u>high level of concern</u> will be associated with large projects, or projects of a critical nature where there is a significant risk to public health and safety. There is likely a greater potential for detrimental impacts and/or a greater risk of inadequately addressing the *hazards.* Concerns raised by affected individuals, groups and agencies will be difficult to resolve without detailed study.

Table A7.1.1 has been prepared to assist shoreline managers to establish an understanding of the overall level of concern during the initial screening of proposed developments. Table A7.1.1 does not provide a definitive rating or ranking of level of concern. It does provide a quick step-by-step procedure to help identify the issues and concerns related to a particular shoreline development proposal. Using Table A7.1.1 will help the shoreline manager focus on the issues which will require the most effort in the identification, evaluation and documentation of the processes, *hazards* and impacts. It should be noted that in Table A7.1.1 the level of concern rating (i.e., low, moderate, substantial and high) provided for an attribute within a given factor is only relative to the other attributes within that factor and is not directly comparable with the attributes of other factors. No weighting of the factors has been attempted.

c) Level of Effort and Reporting Requirements

The level of effort required to appropriately identify, evaluate and document the project phases and activities will depend on the following:

- the overall level of concern with respect to *hazards* and potential negative impacts;
- the extent and reliability of the existing information; and
- the experience of the coastal engineer with the available information and the site.

Table A7.1.1 ADDRESSING THE HAZARD WITHIN THE HAZARDOUS LANDS - INITIAL SCREENING TO INDICATE LEVEL OF CONCERN

CATEGORY	FACTORS	LEVEL OF CONCERN (see Notes 1 and 2)			
		● ***low***	● ***moderate***	● ***substantial***	. . . . ● ***high***
A Development Activity	**1.** Land use (see Note 3)	● passive	● light	● active (habitable or occupied structures) [single unit residential . . . . ⇒	. . . . ⇒ multi-unit residential] ● infrastructure or public use [hazardous substances, institutional uses, emergency services]
	2. Type	● repairs/maintenance ● interior alterations . . . . ● minor structures	● swimming pools ● decks/boardwalks/fixed walkways . . . . ● minor additions . . . . ●septic systems	● major structures ● replacement dwellings	● major additions ● redevelopment ● new dwellings (infilling) ● new lots
B Existing Shoreline Characteristics	**1.** Shoreline freeboard, *F* (above 100 year flood level)	<u>Exposed shorelines</u> Steep shoreline slope (steeper than 1:5) ● ≥3.0 m	● 2.0 to 3.0 m	● 1.5 to 2.0 m	● <1.5 m
		Moderate to mild shoreline slopes (flatter than 1:5) ● ≥1.5 m	● 1.0 to 1.5 m	● 0.8 to 1.0 m	● <0.8 m
		<u>Sheltered shorelines</u> ● >1.0 m	● 0.5 to 1.0 m	● 0.3 to 0.5 m	● <0.3 m
	2. Wave exposure	<u>Wind waves</u> ● low energy (sheltered embayment)	● moderate energy (bay)	(partial bay) ● high energy (exposed) (partial headland)	● very high energy (headland)
		<u>Ship/boat waves</u> ● no	● minor boat traffic	. . . .	● in close proximity to ship traffic
	3. Shore ice	● no evidence of known problems	● evidence of some regional problems	● evidence of some local problems	● history of repeated damage
	4. Controlling substrate	● bedrock . . . . ● erodible bedrock	. . . . ● cobble/boulder till	. . . .	. . . . ● fine-grained cohesive ● boulder/cobble beach . . . . ● sand/gravel beach
	5. Average annual recession rate	0.0 m/yr . . . . ● <0.3 m/yr	● 0.3 to 0.7 m/yr	● >0.7 m/yr	. . . . ● >1.2 m/yr
	6. Geotechnical slope stability rating factor (see Note 5)	● low potential (<24)	● slight potential (25 to 35)	. . . .	● moderate potential (>35)
	7. Quantity of littoral material	● minimal littoral material evident	. . . .	● significant beach/nearshore deposits	● *dynamic beach* (classification #111 to #333) (see Note 4)

CATEGORY	FACTORS	LEVEL OF CONCERN (see Notes 1 and 2)			
		● *low*	**● *moderate***	**● *substantial***	**● *high***
C Proposed Shore Treatment	**1.** Location of proposed shore treatment	● onshore	● backshore, above 100-year flood level	● backshore, below 100 year flood level	● nearshore
	2. Type of proposed shore treatment	● substantial and engineered, using durable materials	. . . .	. . . .	● not engineered, light duty and/or "low cost"
	3. Existing adjacent shore treatment	● substantial, sound and coordinated	. . . .	. . . .	● unsound, uncoordinated and/or nonexistent
	4. Proposed flank setback and/or protection	● very good (>>SSA plus 5 m)	● adequate ($\geq$SSA plus 5 m)	. . . .	● inadequate (<SSA plus 5 m)
	5. Maintenance access to and along shore	● good landbased access (greater than 4-8 m wide, moderate slopes, only minor obstructions)	. . . .	. . . .	● access width to shore <4 m wide and/or steep slopes or major obstructions
D Potential Hazard	**1.** *floodproofing standard* factor (See Note 6)	● $\geq$1.2	● 1.0	. . . .	● <1.0
	2. Hazard (flood) allowance factor [F.A./{14x(*R-F*)$^{1.3}$}] See Notes 7 and 8	Cliff/bluff/bank a) Onshore not subject to ponding ● 1.5 b) Onshore subject to ponding . . . . ⇒ Dynamic Beach (see **D.4**)	● 1.0	● 0.75	● 0.5 Yes, evaluate overtopping rate
	3. Hazard (erosion) allowance factor [E.A./(AARR x 100)] (Assumes sound, engineered protection works are to be put in place) See Note 4.	Low recession rate ($\leq$0.3 m/yr) ● $\geq$ 1.0 Moderate recession rate (0.3 to 0.7 m/yr) ● $\geq$ 1.0 High to severe recession rate (>0.7 m/yr) ● $\geq$ 1.0	● 1.0 to 0.75 ● 1.0 to 0.85 ● 1.0 to 0.90	● 0.75 to 0.60 ● 0.85 to 0.75	● < 0.60 ● < 0.75 ● < 0.90
	4. Dynamic beach allowance	Stable Shoreline (AARR ≈ 0.0) ● development well landward of first foredune Erosional Shoreline ● as above, but with additional setback of 100 times AARR	● development $\geq$30 m from *FH* ● as above, but with additional setback of 100 times AARR	● development <30 m from *FH* and subject to wave action less frequently than once every 10 years ● as above, but with additional setback of 100 times AARR	● development <30 m from *FH* and subject to wave action more frequently than once every 10 years ● as above, but with additional setback of 100 times AARR
	5. Emergency ingress/egress (*access standard*)	● safe	. . . .	. . . .	● inadequate

CATEGORY	FACTORS	LEVEL OF CONCERN (see Notes 1 and 2)			
		● ***low***	● ***moderate***	● ***substantial***	. . . . ● ***high***
FOR OTHER FACTORS, REFER TO: *PART 8.0, ENVIRONMENTALLY SOUND HAZARD MANAGEMENT*					
F OTHER FACTORS	**1.** Aquatic habitat	● not significant	. . . .	. . . .	● significant
	2. Terrestrial habitat	● not significant	. . . .	. . . .	● significant
	3. Proximity to wetland	● no	. . . .	● *Adjacent Lands*	● *Provincially Significant Wetland*
	4. Accessibility to edge of water	● private lands	● low potential	. . . .	● high potential (waterfront trail)
	5. Water use	● very restricted potential for navigation (very shallow) ● minimal recreational use	. . . .	. . . .	● high potential for impact to navigation ● frequent recreational use (swimming, sailboarding, boating)

Notes

1) The suggested levels of concern are not the recommended standards. The levels of concern merely provide general guidance for initial screening of applications for development.
2) Level of concern ratings (*low*, *moderate*, *substantial* and *high*) are relative ratings with respect to a given factor and are not comparable between factors.
3) For description of land use (i.e., passive, light, active and infrastructure and public use), see Table 4.3. Also, present and historic land use may be of concern with respect to important cultural features and contaminated fill or subsurface materials.
4) Development not permitted within *defined portions of the dynamic beach*. For classification of beaches, see *Part 5.0, Dynamic Beach Hazard*.
5) For slope stability, refer to: *Part 4.0, Erosion Hazard*.
6) Floodproofing standard factor: for Great Lakes: [(freeboard of development above (100 yr. monthly mean water level+100 yr. storm surge))/(wave action allowance)];
for Connecting Channels: [(freeboard of development above 100 yr. flood level)/(wave action allowance)].
The wave action allowance should be determined on a site specific basis but can be estimated for initial screening purposes as follows: Great Lakes, 0.6 m; sheltered Great Lakes, 0.3 m; St. Lawrence River, 0.5 m; and other Connecting Channels, 0.3 m.
7) Hazard (flood, erosion and/or dynamic beach) allowances are measured landward of the stable slope allowance. In absence of approved study, using accepted geotechnical engineering principles, the allowance for stable slope is 1:3 (vertical:horizontal, see Part 4)).
8) Areas subject to ponding, due to wave uprush and overtopping, must be evaluated with respect to acceptable rates of overtopping for structural stability considerations of the protection works and drainage considerations (see Part 3).

Legend

E.A. - proposed erosion allowance (measured from stable slope allowance)
F.A. - proposed flood allowance (measured from stable slope allowance)
AARR - average annual recession rate
SSA - stable slope allowance
FH - *flooding hazard*
R - wave uprush (m) above 100 year flood level (If uprush extends beyond crest of structure or cliff/bluff/bank, determine *R* along an imaginary extension of the face of the structure or cliff/bluff/bank (R_s can be approximated for smooth, impermeable slopes, by $2.5H_s$, where $H_s \approx 0.8d_s$ for exposed shorelines))
d_s - depth of water (m), at toe of slope or structure, below 100 year flood level
F - freeboard (m), measured as difference in height between 100 year flood level and crest of protection works or cliff/bluff/bank.

To assist shoreline managers with establishing the appropriate level of effort and reporting requirements by the proponent, the following guidelines are provided:

i) Low Level of Effort and Reporting

The level of effort for small or very routine types of projects (e.g., minor additions), with a low to moderate overall level of concern, does not need to be extensive. The level of concern should be simply confirmed through a visual site reconnaissance, discussions with the owner and a reasonable knowledge of the regional shoreline conditions (including 100 year flood levels, representative recession rates, slope stability, shoreline classification, littoral processes). Knowledge of the regional shoreline conditions can be obtained through appropriate previous experience along the shoreline or by consulting the primary information sources and tools (i.e., local Shoreline Management Plan, see Section A7.1.1(d)). Identifying and confirming the problem (Phase 1 of typical project phases) should be provided in the form of a brief letter report (signed and sealed with A.P.E.O. stamp) from a professional engineer with a suitable level of experience with the local shoreline conditions and processes and who is familiar with the issues and concerns to be addressed, as outlined in this Technical Guide. The letter report should include a brief description of the proposed work and a summary of the problem to be addressed, the level of risk, the site reconnaissance observations, the discussions with the owner and the regional shoreline conditions (including 100 year flood levels, representative recession rates, slope stability, shoreline classification, littoral processes). Table A7.1.1 can be used as a checklist, along with Section A7.1.2(c), Summary of Conditions to be Satisfied for Shoreline Protection Works. Further discussion of the information requirements are provided in Section A7.1.1(f).

ii) Moderate to Substantial Level of Effort and Reporting

Projects with a moderate to substantial level of concern will require a greater level of effort involving additional investigation, further analysis and more detailed documentation. The five phases of the project (see Section A7.1.1(f)) will be relatively distinct and the level of detail and analysis more rigorous and complete than the low "level of concern" project.

A reconnaissance of the site as well as the updrift and downdrift shorelines, discussions with the owner and an advanced knowledge of the regional shoreline conditions will be required. Further field work such as beach and shore profiles, sediment sample analysis and nearshore diving reconnaissance may be required. Desk top studies by qualified coastal engineers will be warranted and may include the use of design manuals and aids, secondary references, aerial photographs, previous surveys and bathymetry field sheets. Numerical modelling may be appropriate depending on the nature of the problem. Consultation with other scientists and professionals (i.e., fisheries biologists, terrestrial ecologists, geomorphologists) may be necessary to determine the potential environmental impacts.

Documentation will include information relating to:

- problem to be addressed including the causes of the problem, the history of the problem and the acceptable level of risk;
- alternative solutions considered and the justification for protection works;
- environmental inventory, including the shoreline processes and characteristics;
- review and assessment of alternative design concepts for the protection works;
- rationale underlying the selection of the preferred alternative design concept for the protection works;
- identification and evaluation of the potential impacts;
- individuals, groups and agencies that have been contacted;
- issues and concerns that have been raised;
- identification of methods for avoiding or mitigating negative impacts; and
- information on construction timing and what construction guidelines will be used.

The work should be completed by a professional engineer qualified in coastal engineering (by virtue of his/her training and experience) and documented in a report (signed and sealed with A.P.E.O. stamp). The existing information should be summarized and all sources should be referenced. The report should include the details of the site reconnaissance and any other field work. The proposed development and any proposed shoreline protection works should be adequately described. The results of any analysis of the coastal processes should be presented along with the data, methodologies and procedures, assumptions and coefficients which were used.

For projects with a moderate overall level of concern, the documentation need not be extensive. For minor development activities this may simply be a brief report. As the development size, the hazard risk and/or the significance of the potential impacts increases, the level of detail of the report documentation should increase accordingly.

For projects with a substantial overall level of concern, the report documentation should be detailed. A major issue will be whether or not the net impacts associated with the proposed shoreline work are acceptable given the merits of the project. Thus the report should document the decision making process and the assumptions and value judgements made in selecting the preferred course of action. Criteria used should be explicitly outlined.

iii) High Level of Effort and Reporting

Projects with a high overall level of concern will require the most detailed and in-depth study, analysis and reporting. The five phases of the project should be very distinct. The level of detail and analysis will be the most rigorous and complete and should involve the most state-of-the-art techniques by expert coastal engineers. Very large or very critical projects may warrant physical modelling. The report should be very comprehensive.

d) Information Sources and Tools

In addition to this Technical Guide, there are a number of information sources and tools. The following list, which is not all inclusive, provides a list of commonly available reference materials that may be consulted and additional site investigations that may be undertaken:

<u>Reference Materials</u>

- Shoreline Management Plans - prepared by or for local Conservation Authorities and MNR districts
- Coastal Zone Atlas (EC/MNR 1976)
- Great Lakes Shoreline Classification and Mapping Study: Canadian Side (Geomatics 1992)
- Great Lakes Erosion Monitoring Programme, Final Report 1973 - 1980 (Boyd 1981)
- The Physiography of Southern Ontario (Chapman and Putnam 1951)
- MNR Great Lakes Wave Climate Database
- Erosion Monitoring Stations Profile Data (onshore and nearshore)
- Canadian Hydrographic Survey Charts and Field Sheets
- significant areas reports (i.e., ESA's, ANSI's)
- municipal and MNR District Land Use Plans
- 1:2000 and 1:10,000 mapping (Ontario Base Maps, Ontario/Canada Flood Damage Reduction Programme)
- MNR Quaternary Geology Maps
- air photos

<u>Additional Site Work</u>

- topographic survey (including shoreline profiles)
- hydrophysical survey
- diving survey
- cores of surficial sediment
- sounding survey

e) Design Aids and Procedures

There are coastal engineering design aids and procedures available for use, by experienced coastal engineers, to address the coastal conditions and design criteria. The methods include physical modelling, numerical modelling, empirical formulae, design charts and procedures from design manuals and technical literature and relevant past local experience. The magnitude of the project will guide the design methods used.

Design guides and manuals are appropriate for those with site and general coastal engineering experience. The design manuals and guides can include, but are not limited to:

- *Manual on the Use of Rock in Coastal and Shoreline Engineering* (CIRIA/CUR 1991);
- *Coastal Protection* (Pilarczyk (ed.) 1990);
- *Random Seas and Design of Maritime Structures* (Goda 1985);
- *Guidelines for Groyne Installations on the Great Lakes* (Philpott 1986);
- *Coastal Groins and Nearshore Breakwaters* (USACE 1992);
- *Engineering Design Guidance for Detached Breakwaters as Shoreline Stabilization Structures* (Chasten et al. 1993); and
- *Shore Protection Manual* (USACE 1984).

It should be noted that the *Shore Protection Manual* is considered by many to be "technologically outdated" (Seymour et al. 1996). The U.S. Army Corps of Engineers is preparing a new, up-to-date manual.

The use of design manuals and guides is often referred to as a "desk top study". The manuals and guides provide methods which are largely based on past empirical studies. Care must be taken by the designer to ensure that the methods used are applicable to the situation being evaluated. Input data is often poor or at best very limited and this requires sensitivity testing and trial and error methods to determine the most significant parameters. Further, the designer must have an appreciation of the accuracy and reliability of the results and incorporate the appropriate safety allowances into the final design. See Section A7.1.2(b)(iv) for a discussion of factors of safety.

Past experience with protection works is an invaluable part of coastal engineering design if used correctly. Correct use of past experience must include a critical evaluation of its relevance to the proposed works (i.e., are the present site conditions similar; was the past project subject to the full range of design conditions; and has it been in place long enough to truly be representative). Past experience with structure performance at water levels and wave conditions less than design conditions can be misleading. This is particularly important in the case of structures with limited reserve capacity or with effects that increase exponentially (e.g., wave overtopping increases rapidly for only small decreases in freeboard). Reserve capacity represents the ability of a structure to resist forces in excess of the design forces. Structures with a limited reserve capacity tend to fail suddenly and quickly once the design level is exceeded. For structures with a high reserve capacity, damage and failure beyond the design conditions is typically more gradual and occurs progressively.

Small or very routine projects typically rely on simple desk top studies. Moderate sized projects and projects with some potential for impacts on the nearshore processes (see Section A7.1.2(ix)) require more in-depth desk top studies and possibly some numerical modelling. As projects become larger and more complex, the reliance on standard guides and manuals should give way to more advanced study of the coastal processes, design criteria and predicted performance. A qualified coastal engineer will continually keep abreast of the latest advances in coastal engineering practice through journals, conference proceedings and seminars and will not rely solely on design manuals. Due to the costs and time involved, physical model studies are rarely warranted except for large or critical projects.

f) Detailed Description of Design Phases and Activities

A more detailed description of the design phases and activities summarized in Section A7.1.1(a) is presented here. It forms a "checklist" of items or activities that need to be completed and documented and questions that need to be answered by the proponent in order to develop the proper understanding of the shoreline processes, *hazards* and impacts.

Phase 1 - Problem Identification

1.1 Preliminary site analysis

- Through observations and discussions with the site owner and others knowledgeable of the area, establish and document (using site reconnaissance record, sketches, and plans):
  - past land use
  - description of existing site development (zoning, land use, buildings/structures (type (i.e., house, shed, deck, etc.), size (footprint, number of storeys, total floor area), age, general construction type (wood frame, concrete, steel, etc., foundation/basement), occupancy (habitable/nonhabitable, residential (seasonal/permanent), services (septic, sewer, water), industrial, institutional, etc.), location relative to shoreline
  - description of proposed development activity (repairs/maintenance, alterations, additions, redevelopment, existing developed lots, existing vacant lots, new development, etc.)
  - budget for protection works, intended purpose of shoreline structures (e.g., erosion control, flooding protection, protection from wave uprush) and secondary objectives (access to water for swimming, boating)), provision of continued access to the shoreline for future maintenance and repairs
  - historical changes to bluff/bank, shoreline and beach (e.g., how much land has been lost to erosion over a period of time, beach width at high and low water levels, removal of beach and nearshore boulders)
  - water level, wave conditions (including boat or ship waves) and ice conditions
  - description of any existing shoreline protection works (age, construction details, filters, foundation) and past performance (maintenance/repair/replacement history, stability, amount of wave uprush and overtopping)
  - ownership of the land on which the structure is going to be built. The legal definition of the lakeward limit of shoreline lots varies across the province. An owner should not assume, without supporting evidence, that a lot extends to the water's edge or into the lake. Due to varying interpretations of the lakeward property limit, it is imperative that the property owner obtain a copy of the registered survey/deed for the property. If the lot limits are unclear, the property owner should consult with a lawyer experienced with lakefront ownership issues. Further discussion of ownership of the Great Lakes shore can be found in MNR (1981) and ABCA (1994).

- From a site reconnaissance, document (using site reconnaissance record, sketches, and plans):
  - characteristics of bluff/bank (use slope stability rating chart, see Part 4 of Technical Guide) or dunes (maturity, vegetation, etc.)
  - type of beach material, if any (i.e., sand, gravel or cobble/shingle)
  - width, depth and length of above water beach deposit and offshore extent of beach deposits (i.e., to what depth do the beach deposits extend)
  - material underlying beach (i.e., fine-grained cohesive, cobble/boulder till or bedrock)
  - general nearshore profile shape (i.e., relatively flat and shallow, moderate or steep)
  - characteristics of shoreline exposure to waves and overall planform shape (i.e., pocket beach, headland-bay, partial headland-bay, exposed)
  - evidence of limit of wave uprush and overtopping (i.e, limit of wave debris, vegetation - forest and shrub thickets, woody perennials versus herbaceous species)
  - type, features (height, width, length, scour protection, overtopping protection, filter, drainage) and condition of existing shoreline protection structures
  - description of existing buildings
  - measurements from top of bluff/bank to existing buildings
  - nature of adjacent shorelines, structures, rivers, creeks, wetlands, sewer outfall.

1.2 Initial background review

- Review existing primary reference material for typical recession rates, shoreline classification, littoral processes (local Shoreline Management Plan, Coastal Zone Atlas (EC/MNR 1976), Boyd (1981), Geomatics (1992)).
- Consult with relevant approval agencies to solicit input.

1.3 Initial shoreline classification and preliminary definition of *hazardous lands limit*

- Based on the initial information, classify the shoreline at the site on a preliminary basis. Using the standard procedures available for defining the *flooding, erosion and dynamic beach hazards*, establish the preliminary *hazardous lands*. Local Shoreline Management Plans may provide the limits of the *hazardous lands*.
- Based on the initial information, establish and specify the requirements of the floodproofing standard, components of the protection works standard (design life of proposed shore treatment, stable slope allowance, hazard allowance) and the access standard.

1.4 Problem Confirmation

- Based on the information gathered, confirm the problem (i.e., *flooding, erosion, dynamic beach hazards*). An initial screening to determine the level of concern can be completed using Table A7.1.1.
- Documentation should include the situation or problem to be addressed including the causes of the problem, the history of the problem and an assessment of the level of risk.

Phase 2 - Alternative Solutions

2.1 Inventory of shoreline processes and characteristics

- Through desk top studies and using the relevant information sources and tools, complete an inventory of the shoreline features and processes and document the results. More detailed site investigations may be required. Numerical modelling may be appropriate in certain situations. Physical modelling will be limited to very large projects or projects of a critical nature. The following features and processes are discussed in more detail in Section A7.1.2(a) unless otherwise noted:

Onshore

- coastal geology and geomorphology
- geotechnical details such as slope stability and surface/groundwater conditions
- average annual recession rate of the shoreline in its natural form (i.e., without shoreline protection)
- land use (past, present and future)
- cultural information
- terrestrial environment (habitat characterization, wetlands, natural heritage features and areas; refer to Part 8: Environmentally Sound Hazard Management)
- requirements for access to and along water's edge

Backshore/Nearshore

- bathymetry (existing and evolving, including nearshore downcutting)
- nearshore substrate, including controlling substrate and surficial substrate (type, quantity and quality)
- water levels
- wave climate and currents
- wave uprush and overtopping
- ice conditions
- littoral processes, transport and sediment budget
- aquatic community and habitat characterization (refer to Part 8)
- navigable waters
- recreational water uses.

2.2 Classification of shoreline and confirmation of *hazardous lands* limit

- Complete shoreline classification (general shoreline type, controlling substrate, surficial substrate, and shoreline exposure and planform
- Define and map *hazardous lands*
    - *flooding hazard*
    - *erosion hazard*
    - *dynamic beach hazard.*

2.3 Identification of alternative solutions to the problem

- Considering the primary purpose of the works, potential impacts, total life costs and adjacent properties, identify alternative solutions to the problem (i.e., prevention, non-structural protection, structural protection). Table 7.1 may be a useful aid.

2.4 Identification and evaluation of impacts of alternatives on coastal and other environmental processes

- Identify potential impacts to the physical shoreline processes and characteristics (refer to Table 7.2) and the terrestrial and aquatic habitat (refer to Part 8). Mitigative measures should be identified.
- Evaluate the alternative solutions based on rational screening criteria and measures. Criteria should be established to provide a measurable basis for the evaluation of the alternative solutions. Each criterion should be selected based on its linkage to agency concerns, adjacent property owner concerns, components of the environment relevant to the project, and features needed to achieve the purpose of the proposed works. Measures for each criteria are then established to facilitate the ranking and evaluation of each alternative solution. Using an alternative solutions ranking matrix, evaluate the alternative solutions. In the matrix, the alternative solutions are evaluated with respect to how well they satisfy each criterion and then given a rank (e.g., high, medium, low, or out a scale of 1 to 5, etc.). Weights can be assigned to each criterion, however, the criterion are subjective and it may not be appropriate to assign weights unless there is a consensus regarding the weighting factors. The complexity of the ranking matrix will vary with the nature of the project. A benefit/costs analysis may be undertaken to help in the evaluation.

2.5 Selection of preferred solution

- Select the preferred solution. The preferred solution might be prevention, non-structural protection or structural protection. The selection process should be documented. Documentation should include alternatives considered and the justification for the proposed work (including assumptions and value judgements).

Phase 3 - Alternative Designs

3.1 Design criteria

- Identify and discuss the coastal engineering, environmental and social design criteria. The following shoreline protection design criteria are discussed in more detail in Section A7.1.2(b) unless otherwise noted.

- identify if the proposed development is within the defined *hazardous lands*;
- project life;
- structure design life;
- acceptable level of risk;
- factor of safety;
- water level and wave conditions (including return period);
- floodproofing;
- ice;
- structure performance (including wave uprush and overtopping) and stability analysis;
- response of littoral processes and impacts to updrift/downdrift shorelines;
- construction materials, methods and review;
- structure maintenance and replacement (i.e., life-cycle costs);
- adjacent protection works (risk of failure, anticipated useful functional life, flooding concerns, reliance of works at site on adjacent works);
- environmental soundness (see Part 8);
- aesthetics and recreational value; and
- benefit-cost evaluations.

3.2 Identification of alternative design concepts

- Considering risk, structure performance and stability, availability and cost of materials, access to site, construction methodology, impacts on coastal processes and aquatic and terrestrial environment, identify alternative design concepts (i.e., if the preferred solution is structural protection, then alternative design concepts might be flexible revetments/seawalls, groynes and artificial headlands).

3.3 Identification and evaluation of impacts of alternative design concepts

- Identify and evaluate the impacts that will be caused or that might reasonably be expected to be caused.
- Identify and incorporate mitigative measures.

3.4 Selection of preferred design concept

- Evaluate the alternative design concepts. A ranking matrix can prove to be a useful aid for evaluating the design concepts in a systematic, rational manner (see design phase/activity 2.4).
- Provide the rationale underlying the selection of the preferred design concept.

Phase 4 - Preliminary Design

4.1 Preliminary design

- Prepare site plan and typical cross-sections. Determine materials, quantities, construction approach, costs and schedule.
- Revise/refine initial (from Phase 1) requirements of the *floodproofing standard*, components of the *protection works standard* (design life of proposed shore treatment, stable slope allowance, hazard allowance) and the *access standard*.

4.2 Design report

- In addition to documenting the process and information, the report should demonstrate the following as required by the *Provincial Policy Statement* (1996):
  1) the works safely address the *flooding, erosion and dynamic beach hazards*
  2) new or existing *hazards* are not created or aggravated
  3) no adverse environmental impacts will result
  4) emergency access/egress is available
  5) the development is being carried out in accordance with *established standards and procedures*.
- Refer to Section A7.1.2(c), Summary of Conditions to be Satisfied for Shoreline Protection Works, for additional guidance.

4.3 Approvals

- Consult with approval agencies.
- Submit plans and report to approval agencies as required.

Phase 5 - Final Design, Construction and Monitoring

5.1 Final design

- Finalize design details, quantities, materials, cost estimate, construction schedule and construction approach.

5.2 Construction Drawings and Specifications

- Complete construction drawings and specifications.

5.3 Construction review

- Carry out periodic construction review to ensure continuity with design parameters and proper construction.

5.4 Monitoring

- Monitor performance of completed structure.

A7.1.2 Coastal Engineering Design Considerations

The coastal engineering design considerations can be divided into two main groups: 1) the shoreline processes and characteristics; and 2) the shoreline protection design criteria. These design considerations must be identified and documented. The following sections briefly outline the considerations.

a) Shoreline Processes and Characteristics

This section provides an outline of the shoreline processes and characteristics that are important considerations in the design process for shoreline protection works. The terrestrial and aquatic community and habitat characterization is discussed in Part 8: Environmentally Sound Hazard Management. The processes and characteristics discussed here expands on the outline presented earlier in the *Detailed Description of Design Phases and Activities* in Section A7.1.1(f). The following discussion is not necessarily comprehensive for each site, as site conditions can vary.

i) Coastal Geology and Geomorphology

Geology is defined as the scientific study of the history, composition, structure, classification and processes of the earth. Geomorphology is the scientific study of landforms and processes including their description, interpretation, evolution, classification and distribution. It is necessary to have an understanding of the evolution of the existing regional coastal forms, as outlined in Part 1: The Great Lakes - St. Lawrence River System: Physical Features and Processes (of this Technical Guide) in order to put the contemporary coastal processes into perspective. A knowledge of modern geomorphological processes that are occurring today is needed to determine if the present processes are different than the earlier formative processes. Knowledge of the geology will assist in classification of the shoreline (i.e., controlling substrate and general shoreline type; see Part 2: Recommended Shoreline Classification Scheme to Determine Shoreline Reaches). Information sources are listed in Section A7.1.1(d).

ii) Geotechnical Details

The onshore and backshore soil and groundwater conditions must be identified as outlined in Part 4: Erosion Hazard, including the "slope stability rating chart". This information will be used to assess slope stability (stable slope allowance), bearing capacity and other geotechnical considerations. Information can be gathered from site specific geotechnical studies and/or other sources including but not limited to previous studies in the vicinity and well records. The site details should be assessed by a qualified geotechnical engineer.

iii) Average Annual Recession Rate

The average annual recession rate is one of the most critical pieces of information about a site. Knowledge of the average annual recession rate at the site, under natural conditions (i.e., without protection works in place) indicates the degree of erosion hazard. The recession rate is used to determine the *erosion hazard* and the safe hazard allowance to address erosion allowance when protection works are proposed. The accuracy and reliability of the recession rate data must be taken into consideration when establishing the appropriate rate for purposes of defining the *hazardous lands*.

Recession rates can be determined from existing historical recession rate studies or from a comparative analysis of historic and recent shore positions taken from maps or aerial photographs. Part 4 of this Technical Guide recommends at least 35 years of sound "natural" recession information be used to determine recession rates. The "natural" recession rate is based on an unprotected and unaltered shoreline. The report should document the number of years, type of information (e.g., ground measurements, airphoto comparison) and proximity to the site. The report should clearly state what average annual recession rate was used to determine the *erosion hazard* and the hazard allowance (erosion). A more detailed discussion of recession rates and how they are determined is provided in Part 4 of this Technical Guide.

iv) Bathymetry

Details of the nearshore bathymetry are required to undertake studies of nearshore wave transformation, to establish the approach slope for wave uprush calculations, to estimate alongshore and cross shore sediment transport, and to determine depth of water at the structure location. Comparison of earlier bathymetry charts with the present bathymetry may prove useful in understanding how the bathymetry is evolving. Of particular importance is the identification, if possible, of nearshore downcutting along erodible bedrock and cohesive shores. Downcutting is described in Appendix A1.2: Lake/Land Interface. Bathymetry information can be obtained from Canadian Hydrographic Survey Canada charts and field sheets, and/or site specific sounding surveys.

v) Nearshore Substrate

Identifying the controlling nearshore substrate (i.e., bedrock, cohesive or dynamic beach) is a key element in establishing the shoreline classification and in understanding the shoreline processes. Information obtained from the review of the coastal geology and geomorphology (see i), previously) will assist in determining the controlling substrate along with further field investigations where required.

The surficial nearshore substrate influences the shoreline processes and characteristics. The surficial substrate also plays a role in establishing the range of biological and environmental processes occurring on a particular stretch of shoreline. Information on the type, quantity and quality of sediment should be provided. Details of grain size are required for modelling alongshore and cross shore transport. The thickness of surficial sediments over the controlling substrate and the distance to which the surficial sediments extend out into the lake are important factors in understanding the littoral processes. Further detailed discussions regarding the controlling nearshore substrate and the nearshore surficial substrate are provided in Appendix A1.2 and Part 2 of this Technical Guide.

vi) Water Levels

The influence of water levels on shoreline erosion and shoreline protection structure performance is a key consideration. Periods of high shoreline damage are linked directly to periods of high water levels. Shoreline structure stability and performance (i.e., uprush and overtopping) is a function of the freeboard (i.e., height of the structure above the water level) and wave action. The severity of the wave action is proportional to the depth of the water (i.e., depth-limited waves). Water level information, including return periods for monthly mean levels, peak instantaneous levels (monthly mean plus storm surge) and storm surge levels, is provided in Part 3.

vii) Wave Climate and Currents

Wave climate is described in Appendix A1.2: Lake/Land Interface. Deep water wave conditions can be derived using wave hindcast techniques. However, the accuracy of the hindcast procedures (i.e., wave height, period and direction) can be limited. Often, the major limitation is the proper representation of the wind field that generates the waves. If the wind data, which is used as input to the wave hindcast models, is inaccurate, then the resulting wave climate output will also be inaccurate.

Existing deep water wave hindcast databases are available. MNR maintains a database for all the Great Lakes and Lake St. Clair which may be appropriate for many shoreline protection projects. For larger projects, or projects that are heavily dependent on sediment transport considerations (i.e., groyne fields) it may be necessary to critically evaluate the available wave databases and/or develop a new one. Wave hindcasting should be carried out by qualified coastal engineers/scientists. The validity of a wave hindcast can only be proven through a proper calibration and verification exercise.

Deep water waves must be transformed (i.e., refraction, diffraction and shoaling) to determine the local or nearshore wave conditions. Refraction, diffraction and shoaling are described in Appendix A1.2. Waves from ship or boat traffic may be a consideration at some sites. Information on ship generated waves is presented in Part 3: Flooding Hazard.

To assess structure stability and wave uprush and overtopping for routine shoreline protection works, it is generally adequate to assume depth-limited wave conditions. A discussion of depth-limited waves is provided in Part 3 of this Technical Guide and in Atria (1997). Using a range of local wave conditions will show the sensitivity of the proposed work with respect to stability and wave uprush and overtopping.

For analysis of sediment transport, the nearshore wave climate must be carefully evaluated as it is critical to have the wave heights, periods, directions and frequencies properly represented. As discussed above, to prepare a nearshore wave climate requires the transformation of the deep water waves to the nearshore (i.e, refraction, diffraction, shoaling). Wave transformation techniques can be a major source of inaccuracy and require expert analysis by qualified coastal engineers/scientists. Nearshore currents are discussed in Appendix A1.2. Currents along connecting channels must be considered to determine scour potential.

viii) Wave Uprush and Overtopping

The limit of wave uprush and the wave overtopping characteristics at the shoreline must be evaluated. The standard allowances of 15 m for the Great Lakes shoreline *flooding hazard*, and 5 m for the connecting channel shoreline *flooding hazard,* can be used if further study is not required. Part 3 of this Technical Guide and *Wave Uprush and Overtopping: Methodologies and Applications* (Atria 1997) provide a full description of wave uprush and overtopping methodologies.

ix) Ice Conditions

A description of ice conditions at the site may be useful to asses possible structure damage, changes to sediment transport patterns, and limitations to nearshore waves. Part 3 provides additional information.

x) Littoral Processes, Transport and Sediment Budget

To design shoreline protection works properly, it is necessary to understand the littoral system. As outlined in Appendix A1.2, the littoral system consists of the supply of sediments from one or more sources (i.e., eroding bluffs, rivers, offshore areas), the transport of the material and the loss of the material to sinks or areas outside the littoral system. Sediment transport processes include both cross-shore and alongshore sediment transport. The gross alongshore transport rate is the total of the alongshore transport rates in both alongshore directions and the net alongshore transport rate is the rate in one direction minus the rate in the other direction.

Littoral materials at the shoreline form beaches. Beaches of significant size provide protection to the backshore bluffs. If a sufficient quantity of sand and gravel covers the lakebed in the nearshore area, and the sand and gravel cover is persistent, the underlying cohesive material will be protected from downcutting. Downcutting was discussed in Appendix A1.2 and in Section 7.4.2(b). Having an understanding of the scope of the littoral system (i.e., the quantity of littoral material, the net and gross alongshore transport characteristics, and the cross-shore transport processes) helps to define the limits of the littoral subcells, appropriate protection strategies, and potential impacts of alterations to the shoreline.

The supply of littoral material along the shorelines of the Great Lakes is typically provided by erosion of the bluffs, lakebed erosion in the nearshore area and input from streams and watercourses. An estimate of the sediment supply which is potentially available can be derived by dividing the shoreline into reaches and using the average recession rates within each reach along with the bluff height and nearshore depth of significant downcutting, the percentage of sand and gravel in the bluff and nearshore material and the percentage of shoreline protected. Fine materials such as silt and clay will be carried offshore by waves and should not be included in the sediment budget.

The evaluation of littoral transport processes and their interaction with nearshore shoreline structures is a complex undertaking and should be carried out by qualified coastal engineers and/or scientists. In areas where there is significant alongshore and/or cross-shore transport, structures in the nearshore zone can have a significant impact on these processes.

The alongshore transport rate may be estimated by using either a "bulk" or a "detailed" sediment transport technique. Bulk predictors, such as the CERC formula (USACE 1984) and the Queen's formula (Kamphuis et al. 1986) and the updated Queen's formula (Kamphuis 1991), are empirical expressions that relate the total potential alongshore transport rate to simple wave and beach parameters (i.e., breaking wave height and breaking wave angle, beach slope and beach sediment grain size). The accuracy of these models are limited with error bounds often quoted in the order of 50 percent to 200 percent. Detailed predictors are much more complicated and try to calculate transport rates at a large number of locations across the nearshore profile. Willis et al. (1990) discuss experiences with detailed and bulk predictor models.

When considering alongshore transport, it is important to distinguish between "actual" and "potential" transport rates. Potential rates are estimated based on available wave energy and assume infinite amounts of sand are available to be transported. The actual transport rate depends on the availability of sand to be transported. In sediment deficient environments (i.e, cohesive shores), short-term actual rates (say during a single storm) may reach potential rates until the sediment is removed. Potential rates when averaged over the long-term will likely exceed actual rates in which case the actual long-term rate can be estimated by a sediment budget analysis. In many cases along shorelines of the Great Lakes, the potential wave energy available to transport littoral sediments exceeds the availability of sediments. Kamphuis (1989) suggests a possible simplified method to handle supply limited situations. Detailed predictors can incorporate supply-limited scenarios.

Alongshore transport rate calculations can be very sensitive to nearshore wave height and breaking wave angle (Willis 1991; Kamphuis 1989b). A sensitivity analysis should be undertaken using a range of wave heights and directions.

Cross-shore transport takes place when the water level and wave conditions change. A more complete discussion is presented in *Cross-shore Profile Change Models, Great Lakes - St. Lawrence River Shorelines, Review and Typical Applications* (Acqua 1995). The discussion includes a comparison of the COSMOS 2-D, E-DUNE, and SBEACH models. It also provides a discussion of shoreline evolution models such as GENISIS and KUST. Further discussion of the computation of beach morphology is provided in Kamphuis (1992).

xi) Other Characteristics

Beyond environmental factors discussed in Part 8: Environmentally Sound Hazard Management, other characteristics of the shoreline may influence the protection works design. These other characteristics include land use, cultural heritage features of the site (i.e., features of historic or archaeological significance), access to and along the waterfront as part of strategic waterfront strategies, and recreational and navigational uses of the nearshore waters.

Land use aspects should be identified. The various categories of land use, identified in Part 4: Erosion Hazard, are passive, light, active and infrastructure and public use. Past land use may be a consideration where the site was used to handle or store contaminated or hazardous materials. Present land use is a factor in determining the existing hazard level. Understanding the future land use is necessary to establish the future hazard level. Proposed land use designation, zoning or official plan changes which further intensify the land use within the *hazardous lands* should not be supported.

Features of significant cultural value should be evaluated. Access to and along the shoreline may be important considerations where strategic waterfront plans are being considered or implemented. However, the issue of shoreline access can only be considered within the context of shoreline ownership.

The proximity of the site to boat and ship traffic may be a consideration. The Navigable Waters Protection Act, administered by Transport Canada, controls construction in navigable waters. Exemptions are usually obtained for backshore shoreline protection works.

b) Shoreline Protection Works 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 (see Section A7.1.1(c)).

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. A discussion of design aids and procedures is presented in Section A7.1.1(e).

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 exposed shorelines along the Great Lakes.

A shoreline protection works must be able to withstand severe or extreme conditions without sustaining significant damage. Structure performance and stability analysis is described in Section A7.1.2(b)(viii). The design condition may be an extreme single event or a series of lessor events. The level of acceptable damage varies with the nature of the works and with the definition of damage. For example, for structures with difficult access for repairs, the level of acceptable damage should be minimal. A sensitivity analysis may be appropriate to determine design requirements for specified damage levels at varying degrees of design conditions (e.g. "no damage" at 25 year return period design condition, 10% damage at 100 year return period design condition). Further discussion of level of risk is presented in Section A7.1.2(b)(iii).

i) Project Life

The project life is defined as the planning horizon, or length of time, over which the prevention setback or protection works must address the *hazard.* The *erosion hazard* defines the project life as 100 years by specifying that the allowance for erosion is 100 times the average annual recession rate.

ii) Structure Design Life

Structure design life is the length of time that a structure, with routine maintenance, is able to safely and adequately perform its function. Structures requiring replacement or significant rehabilitation have reached the end of their useful design life. The design life of a structure can be extended by rehabilitation or restoration provided there is sufficient funds available and suitable construction access.

The structure design life must be distinguished from the project life (discussed in previous subsection). The structure design life does not necessarily match the project life. In fact the design life will most often be less than the project life. As noted in Section 7.4.3(b) of this Technical Guide, the difference between the project life and the protection works design life is accommodated by the *hazard* (erosion) allowance.

Estimates of structure design life are based, to a large degree, on past experiences which have shown that the shoreline environment is very harsh and that maintenance is often neglected. There is no mechanism to ensure that regular maintenance will be carried out by the proponent, or by subsequent owners of the development, or that future restoration or rebuilding will take place. In a study of the historical changes and durability of structures in the Lake Ontario municipality of Stoney Creek, between 1934 and 1979, Keizer (1981) found that, on average, 71% of shoreline structures are damaged or destroyed within 10 years of construction and 87% within 20 years. Seawalls and groynes were the most common form of shore protection. Keizer concluded that the low durability reflected poor design and construction of the structures, lack of cooperation between property owners, and the stresses imposed by the coastal environment. Fulton-Bennett and Griggs (1986) evaluated coastal structures and their effectiveness and concluded that overall, few protective structures stood the long-term test of time, surviving unassisted and preventing damage and erosion, for more than 20 years.

There are no generally accepted values for structure design life. To assess the design life of a proposed structure at a specific location, it is necessary to consider two primary factors: 1) the durability of the structure itself including the component materials, sections and details; and 2) the stability of the underlying native material (i.e., controlling substrate) at the site where the structure is located. These two factors are further described in sub-sections that follow.

When considering existing structures, shoreline managers should be wary of design life claims similar to: "This protection structure has been here for 30 years and that proves it will be here for another 30 years". The mere fact that a structure has been in place for an extended period of time strongly suggests that the structural integrity and remaining material durability should be checked along with an evaluation of the possibility of ongoing lowering of the nearshore profile and undermining.

. Durability of Structure

The durability of a structure is the ability of its component parts (e.g., individual sections, connections) to resist degradation, abrasion and corrosion. Different materials respond differently in the harsh environment of the Great Lakes - St. Lawrence River System (e.g., freezing/thawing, wetting/drying, abrasion due to water-borne sediments and impact damage due to debris carried by waves). Materials such as sound, dense stone, heavy gauge steel, and properly designed concrete can be relatively durable. These materials, used in a robust structure (i.e., heavy sections, proper connections and details), may last many tens of decades. Weak stone, light gauge steel and poorly mixed or placed concrete or structures that are poorly detailed (i.e., with weak connections, inadequate overtopping protection) may suffer serious deterioration in a relatively short time.

. Stability of Underlying Material

The design life of a structure located on a stable, erosion resistant, underlying material, such as bedrock, may be governed to a large extent by the durability of the structure materials. Where the underlying shoreline materials are evolving (e.g., shifting position of dynamic beach) or are subject to downcutting (e.g., cohesive nearshore), it will be necessary to reduce the design life of the overall proposed protection works in accordance with the expected future instability of the underlying materials.

In areas with low recession rates (i.e., $\leq$ 0.3 m/yr), it may be appropriate to consider that a sound, well designed, properly constructed and well maintained structure will have a life span in the order of 25 to 40 years. This assumes that proper measures have been taken to address flanking of the protection. Evidence supporting a design life longer than 40 years should be clear and convincing and should include continuous and unobstructed access to the shoreline for future maintenance and repairs. Access is discussed further in Section A7.1.2(b)(xi). A design life greater than 50 years generally should not be considered without compelling evidence of the long-term stability of underlying material and the likelihood that the proponent, or subsequent owners, will undertake any necessary future repairs and/or rehabilitation.

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

In areas of high (i.e., 0.7 m/yr to 1.2 m/yr) to severe recession rates (i.e., >1.2 m/yr), undermining may become a significant concern within as little as 10 to 15 years. The life span of the structure should be evaluated by a qualified coastal engineer. Structural protection works that appropriately address the hazard will be relatively large and costly and may not be economically feasible over the long term. For example, Anglin et al. (1993) prepared a comparison of a revetment structure designed to address downcutting along a shore with a recession rate of 1 m/yr: for a design life of 25 years, the cost was $1,170 per linear metre; for a design life of 100 years, the cost increased to $3,240 per linear metre.

iii) Acceptable Level of Risk

The term "level of risk", in a generic sense, can be defined as follows:

level of risk = *risk of failure event being equalled or exceeded during design life* X *consequence of failure*.

For example, if the risk of failure is high (i.e, only designed to withstand a storm with a low return period, say 2 years) and the consequence of failure of a structure is severe (i.e., serious property damage), the resulting level of risk would be very high and would likely be unacceptable. By comparison, if the consequence of failure is still severe, but the risk of failure is extremely low (i.e., designed to withstand a storm with a high return period), the resulting level of risk may be acceptable. In the Netherlands, the failure of a dyke can result in extreme consequences (e.g., loss of many lives). To achieve an acceptable level of risk, they use a design storm surge which has a low probability of exceedance (1 in 10,000 years) and then add on the maximum wave uprush.

The probability "*R*", called "risk", that an event with a return period, "*T*", will occur at least once in "*n*" successive years is defined by the equation:

$$R = 1 - \left(1 - \frac{1}{T}\right)^n$$

where:
T is design return period in years;
n is design life in years; and
R is risk of being equalled at least once during the design life.

Using the Netherlands dyke example, and a design life of 100 years, one can determine from this formula that they accept a 1% risk that the design event will be equalled or exceeded. Table A7.1.2 presents return periods for various specified values of risk and expected design life. From Table A7.1.2, one can see that a flood level with a return period of about 100 years has a 40% risk of being equalled or exceeded at least once during a design life of 50 years. Even a 976 year return period event has a 5% risk of being equalled or exceeded at least once over a design life of 50 years. Table A7.1.2 shows that risk, also referred to as encounter probability, increases as the design life increases for a given return period.

Table A7.1.2 Return Periods in Years (*T*) for Various Degrees of Risk (*R*) and Different Design Life (*n*).

Risk, *R* (%)	Design Life, *n* (years)		
	25 years	50 years	100 years
5	488	976	1949
10	238	475	950
15	154	308	616
20	113	225	449
25	87	174	348
30	71	141	281
40	50	98	196
50	37	73	145
75	18	36	73

The use of the return period flood level must be clearly understood. The 100 year flood does not mean that the 100 year flood level will only occur once every 100 years, or that it will occur only 100 years from now. The 100 year flood level means that it will occur, on average, once every 100 years, and that during any one year, there is a 1% probability of occurrence.

With the *erosion hazard* limit (i.e., stable slope allowance plus erosion allowance of 100 times the average annual recession rate), the concept of probability (i.e., return period) does not apply. There is not a 1% probability in any year of the development of being damaged by erosion. The *erosion hazard* risk increases progressively as time passes. Conceptually, it can be assumed that for a long period (say 99 years) there is no risk of damage to the structure due to erosion. However, at the end of the period (say in year 100), damage to the structure is "guaranteed" to happen. Therefore, the net result is that over 100 years, the erosion damage will happen once.

There are no generally established values for the acceptable level of risk to be used in shoreline protection engineering design. The level of acceptable risk will depend on: 1) possibility of loss of human life; 2) economic repercussions; 3) possibility of repair of structure (i.e., damage versus total destruction of structure). Some further discussion of acceptable level of risk is provided in Section A7.1.2(b)(v).

iv) Factor of Safety

Conventional practice for the design of routine shoreline protection is typically based on the concept of a design load, or force, *L*, which should not exceed the resistance of the structure, *R (i.e.,* ability of the structure to resist the design load), as follows:

L (applied load) $\leq$ *R* (resistance of structure).

It has been common practice to define the design load as a characteristic value of the load (e.g., the 30 year return period wave condition) without consideration of the uncertainties involved. The resistance of the structure is typically defined in terms of the load which causes a certain design impact or damage to the structure (e.g., the mass of protective armour stone required to remain stable under the specified wave conditions with only to 5% damage). Often, no explicit safety factors are used. This approach does not permit the determination of the reliability (or the failure probability) of the design. Also, with this approach it is not possible to optimize the design as is now more commonly done for larger projects. Larger projects now are more often evaluated with more advanced probabilistic methods (e.g., Burcharth 1992). However, the design event approach is still applied for most routine shoreline protection projects.

Nevertheless, it must be recognized that there are uncertainties in the reliability and accuracy of predicted coastal processes and loads (e.g., water levels, nearshore wave heights and directions, nearshore downcutting and sediment transport) and in the predicted response of coastal structures to these processes (e.g., stability, wave uprush and overtopping, toe scour, sediment interaction). Most commonly used design formulae are empirical or semi-empirical and are based on central fitting to model test data. The test data often exhibits considerable scatter which typically is not considered by the ultimate designer because the formulae, as published in design manuals, typically only express the mean values. This can lead some to apply the results with a false sense of the reliability and accuracy of the methodology.

It is necessary to have an appreciation of the variability of the results predicted by most standard design formulae. Because the probability distribution of the data is rarely known, it is common to assume a normal distribution and a related coefficient of variation:

$$\textit{coefficient of variation} = \sigma' = \frac{\sigma}{\mu} = \frac{\textit{standard deviation}}{\textit{mean}}$$

For failure mode formulae, coefficients of variation of 15 to 20% or even larger are quite normal. Typical coefficients of variation for some environmental parameters are as follows (Burcharth 1992):

Environmental Parameter	Coefficient of Variation
Nearshore significant wave height	
- numerical models	0.10 - 0.20
- manual calculations	0.15 - 0.35
Mean wave period offshore, hindcast numerical models	0.10 - 0.20
Mean wave direction offshore, hindcast numerical models	15° - 30°

Shoreline managers should note that the lack of use of explicit safety factors for shoreline protection designs is not uncommon. Some shoreline protection "designers" do not recognize or consider the inherent variability of many of the present design methods. They tend to judge the resulting designs as "too conservative" or as "not practicable" or as "too costly". Subsequently they propose lower level designs without an explanation of the associated risks. Providing designs which provide a lower level of protection may be acceptable in certain situations provided the increased risk is clearly identified and explained to, and accepted by the owner and the reviewing agency.

Due to the uncertainties in estimating the nominal strength or resistance of a structure and because the environmental loads (e.g., waves) can only be predicted within a certain margin of error, it is advisable to apply a safety factor to any result, as follows:

$$R \text{ (resistance)} = S.F. \text{ (safety factor)} \quad X \quad L \text{ (load)}$$

The difficulty is that for the coastal engineering design of routine shoreline protection structures, there are no recognized safety factors. It may not be unusual to include a safety factor of about one standard deviation in design formulae (de Waal and van der Meer 1992). In geotechnical engineering a simplified approach is used to assess the stability of retaining walls The resistance of the wall to sliding and overturning must be greater than 1.5 to 2.0 times the loads which are acting on the wall (i.e., "factor of safety" of at least 1.5 to 2.0).

Another approach is that for a structure to be considered safe, its nominal strength or resistance, R, reduced by a performance factor or strength reduction factor, ϕ, to account for possible deficiencies, must be at least equal to the specified loads, L, as increased by load factors, α, to account for possible overloads, excess loads and uncertainties. An importance factor, γ, could also be applied to take into account the consequences of a failure of the structure (related to use and occupancy of the structure or protected area). This relationship can be written symbolically as:

$$\phi R \geq \gamma \alpha L$$

where: ϕ = performance factor (strength reduction factor)
R = resistance of structure
γ = importance factor
α = load factor
L = environmental load

As an illustrative example, consider that in concrete building design, the performance factor, ϕ, varies from about 0.65 to 0.9 and the load factor, α, typically varies from 1.4 for dead loads (self-weight of structure) to 1.7 for live loads (applied loads). In steel design, ϕ varies from 0.65 to 0.9, and α varies from 1.25 for dead loads and 1.5 for live loads. These values are derived from a significant amount of test data and experience and represent the importance of proper safe, sound design where failure can result in significant loss of human life. For shoreline protection design, established performance, importance and load factors are not available. Hence, the design must rely on the qualifications and experience of the coastal engineer.

v) Water Level and Wave Conditions

The water level and wave conditions used for design purposes should be specified. Ideally, a design will involve an evaluation of the performance and stability of a structure under a variety of storm conditions including maximum conditions, a series of lesser storms, and storms at high, average and low water levels. This approach is certainly necessary for large projects.

For routine shoreline protection structures it is common, accepted practice to use a single "design event" approach. The design event is specified by some minimum frequency (i.e., the 100 year flood level). It should be noted however, that the 100 year flood level is not the 100 year storm and that the 100 year storm does not necessarily produce the 100 year flooding, the 100 year erosion, nor the 100 year wave. Nevertheless, common practice for the design of routine shoreline protection structures is to assign a single frequency event.

The appropriate design frequency, or return period, for the water level and wave condition is determined once the acceptable level of risk and the design life have been specified. The province has established the minimum design water level as the 100 year flood level. The risk that the 100 year return period water level will be exceeded at least once, during a design life of 50 years, is about 40% (see Table A7.1.2). A higher standard (i.e., lower level of acceptable risk) may be appropriate in densely populated areas where evacuation would pose very difficult problems. In this situation, the appropriate level of risk for no significant flooding may be about 15% to 20%. With a design life of 50 years, the required design water level and wave condition would be the 200 to 300 year return period event (see Table A7.1.2). In the same densely populated area with difficult evacuation, the acceptable level of risk for no disastrous flooding may be about 5% and for a design life of 50 years the corresponding water level and wave condition would be approximately the 1,000 year return period event.

Wave conditions which would reasonably be expected to accompany the 100 year flood level can be used in the design to maintain the same overall level of risk. In Part 3: Flooding Hazard, it is recommended that wave conditions accompanying the 100 year flood level have a return period of 10 to 20 years. If more severe wave conditions are used, the return period of the combined water level and wave condition would increase and the associated acceptable level of risk would decrease. Different return periods can be used to assess different levels of performance.

Generally most shoreline protection works which do not require in-depth knowledge of sediment movement rely on depth-limited wave design. It may be of interest to know the deep water wave height required to produce the depth-limited wave height. Comparison of this associated deep water wave height with actual deep water wave statistics characteristic of the site will give some indication of how often the structure could be subjected to breaking waves as high as the estimated depth-limited wave. A sensitivity analysis, using varying high water level and wave conditions, is recommended. The low water level may be needed in the structure performance and stability analysis.

vi) Summary of Floodproofing and Access (Ingress/Egress) Criteria

The floodproofing criteria contained in the *Technical Guide for River and Stream Systems* (MNR, 1997) are generally applicable to shoreline areas provided that the additional factors of wave action and debris carried by wave action are also addressed where applicable. An overview of these criteria are outlined below. Additional guidance for floodproofing of shoreline residential structures can also be found in several U.S. Federal Emergency Management Agency (FEMA) publications (1986a, 1986b, 1986c, 1984).

. Site Selection and Layout

Whenever possible, flood-prone areas should be avoided and development located landward of the *hazardous lands*. If this is not possible it should be recognized that the risk and severity of flooding generally decreases with the distance from the lake or connecting channel. Buildings should be positioned in the area of the site that will experience the lowest flood levels and velocities. In other words, this means as far back from the shoreline as possible. In addition, buildings should be oriented to present their smallest cross-sections to the flow of floodwater resulting in a reduction of the surface area on which flood and storm forces can act.

When multiple buildings are to be placed on the same site, the objective of site design is the same as for an individual building. One approach is to disperse buildings throughout the site, applying the criteria discussed above to each building. An alternative to such dispersal, when local zoning allows, is to group buildings in clusters on the safest parts of the site, leaving the more vulnerable areas open. This approach not only reduces flood damage but can also allow greater flexibility in protecting the natural features on the site.

Adjacent buildings, bulkheads, or other structures should also be considered in site layout, both for their potential to screen and divert flood waters and water-borne debris and for their potential to become floating debris themselves. Bulkheads also tend to divert flood waters around their ends, adversely affecting adjacent sites.

Buildings elevated off the ground can be more vulnerable than other buildings due to wind. Data on expected winds appear in local building codes.

. Soil Conditions

The characteristics of the soil in a flood area can be important in determining an appropriate design. Highly erodible soil would not be desirable for use as fill in elevating a structure in a high flood velocity area unless the fill is properly protected. When erosion removes soils supporting building foundations, the foundations can fail. If the soil is too permeable (i.e., its ability to allow water to pass between the soil particles) then certain floodproofing methods, such as dykes and floodwalls, will be impractical. It may be necessary to consult a qualified geotechnical engineer familiar with the soils at the site.

. Vegetation

Vegetation helps prevent erosion and sedimentation associated with flooding. Natural vegetation should be retained wherever practical. Crushed stone can be used to control erosion under low-lying elevated structures and other locations where vegetation is difficult to maintain. Larger bushes and trees can be sited to deflect floating debris away from elevated foundations. Landscaping, trees, planting and fencing can also be used to screen elevated foundations from view.

. Flood Water Drainage and Storage

Good site drainage allows flood waters to recede from a site without eroding it or leaving standing water that causes damage to structural elements or health hazards from stagnant water. Additional information on water overtopping is discussed in Part 3 of this Technical Guide.

. Dune Protection

Dunes provide a natural shoreline defence against storm surges and waves. Policy 3.1.2(a) does not permit *development* and *site alteration* within the *defined portions of the dynamic beach*. To provide the greatest level of natural protection possible, dunes should not be cut or breached by site features such as walkways or beach access roads. Cross-over walkways should be provided (see Figure 7.10).

Existing dunes should be maintained or enhanced through vegetation and sand fencing, which limit wind losses and promote further dune growth (MNR 1996). If no dunes exist and the beach is sufficiently wide, successive tiers of sand fencing can induce dune formation. In some shoreline communities this action is required prior to a residence being built.

. Depth and Velocity (Threat to Life)

In stagnant backwater areas (i.e., zero velocity), depths in excess of about 1 m (3.3 ft) are sufficient to float young children, and depths above 1.4 m (4.5 ft) are sufficient to float teenage children and many adults. In shallow areas, velocities in excess of about 1.8 m/s (6 ft/s) pose a threat to the stability of many individuals.

The hazards of depth and velocity are closely linked as they combine to effect instability through an upward, buoyant force and a lateral, or sideways, pushing force. A reasonable approximation of the combined hazard of depth and flood velocity can be made with the product of depth and velocity (i.e., depth of flow multiplied by the velocity of the flow). A product of depth and velocity less than or equal to 0.4 m^2/s (4 ft^2/s) defines a low risk hazard, providing that the depth does not exceed 0.8 m (2.6 ft) and the velocity does not exceed 1.7 m/s (5.5 ft/s).

.   Depth and Velocity With Wave Action

In addition to the riverine depth and velocity criterion, additional consideration must be made for areas subject to direct wave action. In areas subject to direct wave action, the maximum depth of flooding to define a low risk hazard is 0.25 m. This was determined using the above noted product of depth and velocity of 0.4 m^2/s. Considering in shallow water, the wave velocity, *c*, is defined as:

$$c = (gd)^{0.5}$$

where: *g* = acceleration due to gravity (9.8 m/s^2);
d = depth of water (m),

and by setting the product rule (*d x c*) equal to 0.4, the depth, *d*, is derived as 0.25 m.

.   Wave Loads on Structures

Methods for evaluating water velocities and wave impact loads on structures are beyond the scope of this Technical Guide and can be found in such publications as USACE (1984) and Walton et al. (1989).

The U.S. Federal Emergency Management Agency (FEMA) is responsible for establishing standards for delineating flood hazards in the United States. To aid in determining level of flood risk or severity, FEMA identifies a "high hazard area" or "V-zone" (i.e., velocity zone) as being that which occurs wherever coastal base flood wave heights reach 0.9 m (3'). This wave condition generally arises when the water depth is at least 1.2 m (4') and the storm winds are onshore. Conversely, FEMA identifies a "A-zone", or "low hazard area", as being that portion of the 100 year coastal flood zone that is subject to wave action of lesser severity. In high hazard "V-zone" areas, the force of waves, flowing water and high winds will typically cause serious structural damage to housing. FEMA has concluded that attempting to protect property in the "V-zone" is very difficult and expensive and is not recommended. Davison (1993) recommends that more consideration of the coastal forces within the "A-zone" is necessary or that a more restrictive 0.6 m wave height (water depth 0.8 m) be used to delineate the extent of the "V-zone".

.   Wave-Borne Debris

Flood damage may result from floating debris colliding with the buildings and structures. The actual resultant impact loads are a function of the velocity of the object (assumed equal to the velocity of the water) and the time required to stop (decelerate) the object upon impact. The deceleration time is in turn related to the distance over which the deceleration occurs, which is considered equal to the deflection upon impact. Larger wave-borne debris can also wedge against foundation piling and bracing, increasing water forces on the foundation system. It should be further noted that all flood waters will include mud and silt, materials which will cause additional damage to an already flooded home.

The following discussion of flood impact loads is taken from the FEMA regulations:

> Normal impact loads are those which relate to isolated occurrences of logs, ice blocks or floatable objects of normally encountered sizes striking buildings or parts thereof. A normal impact load can be considered as a concentrated load acting horizontally at the 100 year flood level or at any point below it, equal to the impact force produced by a 1,000 pound mass travelling at the velocity of the flood water and acting on a one (1) square foot surface of the structure.
>
> Special impact loads are those which relate to large conglomerates of floatable objects, such as broken up ice floats and accumulation of floating debris, either striking or resting against a building, structure or parts thereof. Where special impact loads are likely to occur, such loads shall be considered in the design of the buildings, structures or parts thereof. Unless a rational and detailed analysis is made and submitted for approval, the intensity of the load shall be taken as 100 pounds per foot acting horizontally over a one-foot

wide horizontal strip at the 100 year flood level, or at any level below it. Where natural or artificial barriers exist which would effectively prevent these special impact loads from occurring, the loads may be ignored in the design.

Extreme impact loads are those which relate to large floatable objects and masses such as runaway barges or collapsed buildings and structures, striking the building, structure or component under consideration. It is considered impractical to design buildings having adequate strength for resisting extreme impact loads. Accordingly, except for special cases where exposure to these loads is highly probable and the resulting damages are extremely severe, no allowances for these loads need be made in the design.

Any measures or designs used must conform with the Ontario Building Code.

. Scour Depth

The depth of potential scour during the design storm will vary for each shoreline location. It is critical that structures and piles be embedded well below the anticipated general lower limit of the beach profile adjustment plus the localized scour depth, immediately around the pile, to provide adequate foundation support during a storm. Standard "inland" construction practice for structure embedment depth is inadequate in many shoreline areas. Inland “rules of thumb”, such as "piles should be embedded as much below ground as above ground" generally underestimate the required embedment depth and have not taken scour into consideration. Historical data on local scour depth at the shoreline may be helpful in determining the embedment depth. It should be noted that the scour hole around a pile within the surf zone tends to fill in the waning stages of a storm, suggesting that immediate post-storm field observations could underestimate the maximum scour. A rule-of-thumb suggests localized scour depths of about 1.5 to 3 times the pile diameter (Nicholls, Davidson and Gambel 1993). This is in addition to the dynamic beach profile adjustment. Further guidance can be found in Nicholls, Davidson and Gambel (1993).

. Vehicular Access

Ingress and egress from a floodproofed area by the most "typical" automobiles will be halted by flood depths above 0.3 - 0.5 m (1 - 1.5 ft). A maximum flood velocity of 3 m/s (10 ft/s) would be permissible providing that flood depths are less than 0.3 m (1 ft). A depth in the range of 0.9 - 1.2 m (3 - 4 ft) provided there is no wave action, is the approximate maximum depth for rapid access of large emergency vehicles.

. Structural Integrity (Above Ground)

A depth of 0.8 m (2.6 ft.) is the safe upper limit for floodproofing the above ground/superstructure of conventional brick, brick veneer and concrete block buildings using closures and seals. Beyond this, structural integrity is threatened/certain.

The structural integrity of elevated structures is more a function of flood velocities (which may erode foundations, or footings, or fill) rather than depth. The maximum permissible velocity depends on soil type, vegetation cover and slope but ranges between 0.8 - 1.5 m/s (2.6 - 5 ft/s).

It should be noted that sub-surface conditions can also pose a threat to structural integrity. The build up of groundwater (hydrostatic pressure) around the foundation of a building may cause basement floors to uplift and walls to buckle. In addition, surcharging may cause the back up of water into basements through floor drains. Standards that may exist in local building by-laws should be consulted in addressing such matters.

. Fill

Floodproofing by elevation on fill is less complex than techniques involving piles, columns and posts. However, complexity does increase at flood depths beyond about 1.8 - 2.4 m (6 - 8 ft). Fill exposed to wave action must be suitably protected.

. Dykes and Floodwalls

Floodproofing by dykes and floodwalls is considerably more complex than it would first appear. Complexity is as much related to foundation, seepage and drainage conditions, as it is to height.

. Professional Guidance

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

- Where the product of flood depth and velocity 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;
- Where dykes and floodwalls in excess of 1 m (3.3 ft) in height are proposed; and
- Where piles, columns and posts are proposed.

The Ontario Building Code contains provisions for such matters as dynamic loading, hydrostatic uplift and waterproofing and as such, should be consulted.

vii) Ice

Ice formations at times cause considerable damage on shores in local areas, but their net effects are largely beneficial. Spray from winds and waves freezes on the banks and structures along the shore, covering them with a protective layer of ice. Ice piling on a shoreline by wind and wave action can occur and has reached heights of 12 m (Boyd 1981b). However, ice piling does not, in general, cause serious damage to beaches, bulkheads, or protective rip-rap, but often provides additional protection against severe winter waves. (USACE 1977). In some local areas, there has been a history of damage to shoreline structures extending perpendicular to the shoreline. In many instances, these structures have been lighter structures such as timber crib boat docks or piers. Some abrasion of timber or concrete structures may be caused, and individual members may be bent or broken by the force of the ice mass. Piles have been slowly pulled up by the repeated lifting effect of ice freezing to the piles or attached members such as wales, and then being forced upward by a rise in water levels or wave action. Canadian experience suggests that rubble-mound structures which have been designed properly for wave loads will also survive ice action (MacIntosh, Timco and Willis 1995).

Ice interaction with rubble-mound structures includes:

- rubble field formation - in this case, broken ice forms along the structure forming a protective layer;
- ice ride-up - ice can move up and possibly overtop the structure;
- plucking - the ice sheet can remove individual armour stones;
- ice push - a moving ice sheet can push and re-arrange a few stones on the structure slope; and
- bulldozing - a moving ice sheet can push and remove an entire section of the structure.

MacIntosh, Timco and Willis (1995) provides a summary of some Canadian experience with ice and rubble-mound structures:

- A conventional breakwater with one tonne armour stone on a 1:1 slope was extensively damaged due to bulldozing by a moving ice sheet showing that ice damage can occur. The "projected" area (surface area of individual stones that may be impacted by ice sheets) may be a design consideration.

- In the St. Lawrence River, it was inferred that 600 kg stone on a 1:3 slope in 0.6 m ice or 1.5 m waves was too small and that 1 tonne stone on a slope of 1:2 above the water line and about 1:4 or flatter below the water line was preferred.

For routine shoreline protection design, there is little specific ice design guidance. Basic considerations include:

- along exposed shorelines, design for wave forces;
- sloping structures are generally subjected to lower ice forces because the ice tends to fail by bending as it "rides" up the sloping surface rather than crushing against a vertical face;
- balance roughness required to dissipate wave energy with smoothness required to encourage ice ride-up;
- use steeper slope above water line to reduce ride-up and flatter slopes at or below water line, or berms, to encourage ice rubble buildup;
- consider "projected" area of individual stones; and
- avoid abrupt changes in shoreline configuration and orientation.

Horizontal ice forces may be caused by thermal expansion of the ice sheet or by moving ice flows. Wortley (1984) recommends using a design value of about 150 kN/m at the water level for most exposed Great Lakes structures with vertical sides (such as cribs); 75 kN/m in areas of large snowfalls or weak, unsound ice; and 300 kN/m for clear ice in confined boat harbours (without sloping banks) and under unusually warm periods following very cold weather. Wortley further notes that the importance of the structure to the overall project also will be a factor in selecting the ice design values and safety factors. Based on Wortley's observations of ice in the Great Lakes and on cribs that are still standing, he believes that 75 to 150 kN/m are reasonable ice thermal thrust values for this region. USACE (1984) suggests that structures subject to blows from floating ice should be capable of resisting 140 psi to 170 psi.

viii) Structure Performance and Stability Analysis

The analysis of the performance and stability of the protection works should be carried out by a qualified professional engineer. The burden for all analysis should be on the proponent of the protection works. Walton et al. (1989) presented an analysis approach for evaluating the performance and stability of coastal flood/protection structures and it has been adapted in Table A7.1.3. Design aids and procedures are outlined in Section A7.1.1(e).

ix) Response of Littoral Processes and Impacts to Updrift/Downdrift Shorelines

A prime consideration is the potential impact of the proposed protection works on the updrift and downdrift shorelines. As discussed in Section 7.5 of the Technical Guide, the supply and transport of littoral materials is the only one of the five general categories of physical shoreline processes and characteristics which may affect the flood and erosion hazards at updrift/downdrift properties.

The response of the littoral processes to the placement of shoreline protection structures includes changes in sediment supply and the alongshore transport and cross-shore transport. These changes may result in sediment accretion or erosion; leading to changes in the cross-shore profile and the beach plan. The response of the littoral processes must be evaluated. This becomes critical for structures placed into the nearshore at shorelines where there is a significant quantity of littoral material present. For nearshore structures, such as beach nourishment, groynes, artificial headlands and detached breakwaters, the response of the littoral processes is an integral part of the design (i.e., the response of the littoral processes will determine whether or not these types of structures work).

Evaluation of littoral responses should be carried out by professional engineers qualified and experienced in coastal engineering. Input data is often poor requiring sensitivity testing and trial and error methods. Results must be checked to ensure that they make sense according to what is expected both intuitively and theoretically. As noted earlier, predicted littoral transport results can easily be 50% to 200% off the actual values. In addition, ongoing studies and research are improving our understanding of the processes and their interaction with shoreline structures (e.g., Kamphuis et al. 1993). These advances must be taken into consideration.

Table A7.1.3 Features of a Shoreline Protection Structure Performance and Stability Analysis (adapted from Walton et al. 1989)

1) Calculate wave uprush on the structure at 100 year flood level to determine if uprush is above or below the crest of the structure.

2) If uprush exceeds top of structure, calculate wave overtopping at 100 year flood level.
- 2.1) Check for adequacy of crest protection against overtopping (i.e., "splash pad").
- 2.2) Assess overtopping rate with respect to:
  - 2.2.1) Usage considerations
  - 2.2.2) Structural stability
  - 2.2.3) Flooding/drainage considerations.

3) Estimate nearshore downcutting potential. Provide measures to deal with or protect against downcutting.

4) Evaluate localized toe scour potential in front of protection works. Check adequacy of toe scour protection.

5) Evaluate structure stability for minimum lake level, no wave height and saturated soil conditions behind the structure. Stability check is to be made with or without scour depending on adequacy of toe protection (step 4).
- 5.1) Dykes/revetments. Geotechnical checks are to be made for potential dyke failure in landward direction by rotational gravity slip of dyke/embankment.
- 5.2) Gravity/pile-supported seawall.
  - 5.2.1) Check for sliding toward lake (assume rigid foundation).
  - 5.2.2) Check for overturning toward lake (assume rigid foundation).
  - 5.2.3) Check adequacy of foundation based on maximum pressure developed in sliding and overturning calculations.
- 5.3) Anchored Bulkheads.
  - 5.3.1) Check for shear failure in bulkhead.
  - 5.3.2) Check for moment failure in bulkhead.
  - 5.3.3) Check for adequacy of tiebacks to resist tension load.
  - 5.3.4) Check for adequacy of deadman size and allowable soil pressure to resist deadman loadings.

6) Evaluate structure stability for critical lakeward water level (which might be any water level from minimum to 100 year flood level) to include hydrostatic and hydrodynamic (wave) loading (including wave uplift) on the lakeward side of the structure (with the assumption of soil deformation (i.e., no soil pressure) on the landward side in the case of seawalls or bulkheads). Use a condition of scour in front of the structure if inadequate toe protection is provided.
- 6.1) Dykes/revetments.
  - 6.1.1) Geotechnical checks are to be made for potential dyke failure in lakeward direction by rotational gravity slip of dyke or by failure of the foundation because of inadequate bearing strength under wave and water loading.
  - 6.1.2) Check revetment stability (if applicable) for the following items:
    - Stability of primary layer of rock/rip-rap/armour blocks to wave action.
    - Toe stability of structure.
    - Uplift forces on blocks or impervious surfaces.
    - Adequacy of geotechnical filter (to retain backfill or native material).
    - Adequacy of graded rock underlayer filter material.
- 6.2) Gravity seawall/pile-supported seawall.
  - 6.2.1) Check for sliding toward land (assume rigid foundation).
  - 6.2.2) Check for overturning toward land (assume rigid foundation).
  - 6.2.3) Check adequacy of foundation based on maximum pressure developed in sliding and overturning calculations.
- 6.3) Anchored Bulkheads.
  - 6.3.1) Check for shear failure in bulkhead.
  - 6.3.2) Check for moment failure in bulkhead.

  Assume tiebacks do not provide support in these calculations.

7) Check for material adequacy against cracking, spalling, deterioration, abrasion, corrosion, rotting (i.e., durability of stone, wood, concrete, steel, etc.).

8) Check flank protection or coordination with adjacent protection.

Note: Details of structure performance and stability analysis may vary according to site specific requirements.

### .		Sandy Shores

Along sandy shores, there are design and assessment methods which can be used to obtain a reasonable estimate of the response of the littoral processes. These methods can involve engineering design guides and manuals and numerical modelling. Only very large, critical projects would warrant physical modelling. Some of the design guides are listed in Section A7.1.1(e). Cross-shore profile numerical models include, but are not limited to, EDUNE, CROSS, COSMOS-2D and SBEACH. Alongshore transport and beach plan evolution models include, but are not limited to, GENISIS, KUST2 and the Queen's University model. A more complete description of the models and their availability, along with a comparison of the performance of the EDUNE, COSMOS-2D and SBEACH models, is provided in the MNR report *Cross-Shore Profile Change Models, Great Lakes - St. Lawrence River Shorelines, Review and Typical Applications* (Acqua 1995).

### .		Cohesive Shores

For cohesive shores the design and assessment approach is much less certain than for sandy shores and there is very limited design guidance. Cohesive shores do <u>not</u> respond in the same manner as sandy shores to a reduction in sediment supply. The downcutting of the cohesive profile is influenced by the quantity and volatility of the sand and gravel surficial sediments. Appendix A1.2 and 7.5.4(c) should be consulted for further information.

### x)		Construction Materials, Methods and Review

The design of protection works will depend on the construction materials and methods. The materials must be assessed for their long-term durability in the harsh coastal environment. Exposure to cycles of freezing/thawing and wetting/drying, abrasion, corrosion and vandalism requires the materials to be of a robust nature. If vandalism is a concern, materials should be selected which cannot be easily cut, carried away, dismantled or otherwise damaged. For example rip-rap can thrown into the water, fabric bags can be slashed with a knife, and wire baskets can be cut open.

Some appropriate materials are quarried stone, concrete and steel sheet piles:

> **Armour stone** should be selected, hard, sound, durable, quarried stone with a high resistance to weathering and disintegration under freezing, thawing, wetting and drying cycles and should be of a quality to ensure permanence in the climate and conditions in which it is to be used. The individual stones should be free from weak bedding planes, cracks or crevices or other defects that would tend to increase its deterioration from natural causes or breakage in handling or placing. Argillaceous material such as shales or quarried stone from thinly bedded strata of shaley nature should not be accepted. Armour stone should be from quarries which have produced armour stone, of the size specified, with a conclusive history of previous successful use in riverine or coastal structures. The armour stone should meet minimum requirements for: minimum relative density (tested to ASTM C127); maximum absorption (tested to ASTM C127); maximum abrasion wear (Los Angeles Abrasion test to ASTM C535). Specific values for density, absorption and abrasion should be treated as indicators and not as absolute values. Examination of the stone by a qualified geological expert can provide a more meaningful assessment of the stone durability.
>
> **Concrete** should have low permeability, provided by the water-cement ratio recommended for the exposure conditions (consider freeze/thaw in saturated condition, possibility of de-icing chemicals), adequate strength, air entrainment, adequate coverage over reinforcing steel and durable aggregates. Some precast concrete blocks produced from surplus concrete have exhibited problems with bad joints and poor quality concrete.
>
> **Steel** should have the allowable working stresses reduced to account for corrosion and abrasion. Lightweight steel sheet pile suppliers for routine shoreline protection projects have suggested the following guidelines: 10 gauge for only the most favourable conditions (clean water, clean backfill, no abrasion); 8 gauge in most applications where abrasion or chemical action are not severe (should not be used for severely exposed structures such as breakwaters or groynes); 5 gauge recommended for most fresh water applications, especially exposed structures such as breakwaters and groynes.

While dense, sound quarried stone, good quality concrete and heavy gauge steel sheet piles are acceptable, some other materials are not acceptable such as junk cars, thin concrete slabs, weak concrete, old tires and empty fuel drums or tanks. In between these extremes is a range of materials that if used with care and/or in combination with other materials can be incorporated into shoreline protection works. The availability of material, equipment and labour influences the design and determines, to a large extent, the construction procedure. For example, the lack of good quality stone within an economic hauling distance would require the use of some other material. Access and environmental considerations (see Part 8) are important factors in determining the construction procedure. For example, armour stone requires the use of heavy construction equipment which must be able to access the shoreline.

To ensure quality control and the continuity of the design intent, the designer should undertake construction review. Small or routine projects may involve periodic on-site review, while large projects may warrant full-time review.

xi) Structure Access, Maintenance and Replacement

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 maintained. 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. Where the feasibility of future maintenance is low, the original design should be such that the structure requires little or no maintenance and the design life should assessed accordingly.

To carry out maintenance activities requires access <u>to</u> the shoreline and access <u>along</u> the shoreline. The required characteristics of the access (i.e., width, overhead clearance, gradient, bearing capacity of subgrade, presence of underground utilities, services and pipes, the proximity and sensitivity to damage of adjacent structures and trees, and the ability to remove obstacles) depends on the nature of the construction equipment and hauling vehicles to be used. The equipment to be used depends on the nature of the work to be carried out (i.e., size of materials, duration of project), the budget, the required efficiency of the work and the access constraints. Heavy construction equipment (i.e., large crawler mounted hydraulic backhoes or cranes), necessary to efficiently move large armour stone, typically requires a minimum access width of 4 to 5 m. Sufficient additional clearance must be provided alongside structures, such as basement foundations, to prevent damage to the structures due to increased loading and vibrations. This additional clearance, on each side, is typically a horizontal distance equivalent to a minimum of one times the depth of the foundation but can vary depending on the nature of the subsurface materials and the adjacent structure. Lighter construction equipment (i.e., smaller backhoes and front end loaders), used to haul and place smaller materials such as rip-rap and cobbles, may require an access width of 3 to 4 m to the shoreline.

Access along the shoreline may need to be wider than access to the shoreline to permit room for the efficient manoeuvring of equipment and the handling of materials. However, site specific conditions and budgetary considerations may make it possible to reduce the required width of the maintenance access along the shoreline. In some situations, this could be accomplished through the construction of a temporary access along the shoreline which is removed after construction or incorporated into the protection works.

If no equipment access to the shoreline is available, maintenance or repairs would have to involve other construction techniques such as pumping concrete. If such other techniques are not appropriate, repairs would have to be carried out from a barge from the lakeside. Barge-based operations are in most instances more costly than land-based operations unless constraints along the shore are extremely or completely restrictive. The depth of water lakeward of the protection works dictates the feasibility of a barge accessing the site. Other considerations include the proximity of a harbour for the loading of equipment and materials and the docking of the barge when lake conditions become too rough.

xii) Adjacent Protection Works

If adjacent properties do not have protection works, the design of the protection works at the site must address concerns regarding outflanking and/or there must be a provision for an appropriate flank *hazard* (erosion) allowance (see Section 7.4.3(c)).

If the adjacent properties have existing protection works, the existing works must be assessed and the alongshore ends of the proposed work must coordinated with the adjacent works. The assessment of the adjacent works must examine risk of failure, anticipated useful functional life, flooding concerns, and the reliance of works at site on adjacent works.

xiii) Environmental Soundness

Ensuring that the protection works can be implemented in an environmentally sound manner is of paramount importance. Environmental considerations, as discussed in Part 8: 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).

xiv) 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.

xv) Benefit-Cost Evaluations

The *Provincial Policy Statement* (1996) does not direct the shoreline manager to examine the economic "sense" of constructing protection works and the relationship of the present and future costs of the works to the market value of property. Many shoreline property owners place a considerable intrinsic value to their property and wish to maintain it at almost "any cost". Further, the *Provincial Policy Statement* (1996) does not restrict the expenditure on the protection works nor does it require any specific benefit-cost ratios be met (e.g., greater than 1.0). However, this Technical Guide provides information regarding the initial and long term costs of constructing, maintaining and replacing protection works over the life-cycle of the development. Through a greater understanding of the potential real costs of protection works, proponents will be in a better position to make an informed decision. In some instances, a benefit-cost analysis may suggest that acquisition and/or removal of buildings from *hazard* susceptible shorelines is more appropriate than the implementation of protective works.

MNR (1983) benefit-cost evaluation guidelines provide a methodology for estimating the direct benefits and costs of protection works. If the limitations of this method are recognized, it can be a useful tool in the decision making process. Shoreline protection is often difficult to justify in narrow benefit-cost terms unless the circumstances are exceptional, such as in urbanized areas. A broad approach to project appraisal is necessary to include environmental concerns, nature conservation and recreational aspects. The direct benefit-cost analysis should be accompanied by an evaluation of the indirect and intangible benefits and costs including the environmental impacts and the relevant recreational and social aspects.

c) 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 (see Section 7.6.2).

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 (refer to Section A7.1.1(e)).

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.
   - 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).

## .		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.

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APPENDIX A7.2

EXISTING DEVELOPMENT WITHIN THE HAZARDOUS LANDS

EXISTING DEVELOPMENT WITHIN THE HAZARDOUS LANDS

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A7.2 EXISTING DEVELOPMENT WITHIN THE HAZARDOUS LANDS

Municipalities and planning boards may establish local standards and procedures to deal with existing development within the *hazardous lands*. These standards and procedures are to recognize local conditions, the potential risks associated with being located with in hazard susceptible shoreline areas and preserve the overall intent of the *Provincial Policy Statement* (1996) to minimize the potential risk to life and property.

It is not the intent of the Provincial Policy Statement (i.e., Policy 3.1 governing Natural Hazards) that the presence of existing development be used as a justification for increasing or intensifying the development. The first and primary premise of Policy 3.1 is to direct *development* and *site alteration* to locations outside of the *hazardous lands*. Standards and procedures to guide possible development in existing built-up shoreline areas should not be applied all along the shoreline but limited to select areas. Where infilling or redevelopment, or additions/alterations to existing development, is being considered within the *hazardous lands*, the *development* and *site alteration* must adhere to Policy 3.1.2 (identifies where *development* and *site alteration* is not permitted) and fulfil <u>all</u> of the requirements outlined in Policy 3.1.3. Where all of the requirements of Policy 3.1.3 cannot be fulfilled, the *development* and *site alteration* is to be directed to a location outside of the *hazardous lands*.

As previously identified, addressing the *flooding*, *erosion* and/or *dynamic beach hazards* in areas of existing development should be done in a coordinated manner. Shoreline management plans provide the best means of examining these *hazards* on a broad, ecosystem basis ensuring that all prevention, protection and emergency response approaches are properly evaluated and approaches considered to be "best management" approaches are identified for possible application within specific shoreline reaches. This may include identifying the type(s) and locations where protection works may be appropriate, the floodproofing requirements to be met, and methods for determining the setbacks (i.e., stable slope allowance, hazard allowance) to be applied in conjunction with the protection works.

Given that the preferred management approach is prevention, prior to any structural protection works being considered, it should be clearly demonstrated that the following options are not feasible:

- relocation of existing building;
- siting of building/structures landward of the *hazardous lands*; and
- acquiring adjacent properties to provide additional developable area landward of the *hazardous lands*.

Where *development* (including additions, alterations, infilling, redevelopment, replacement, etc.) is being considered within the *hazardous lands*, there should be a critical evaluation of this development with respect to the *flooding, erosion and dynamic beach hazards*, ingress/egress provisions, the creation or aggravation of *hazards* at other sites and environmental considerations. This critical assessment should include, but not be limited to a number of key factors:

- differentiation between types of development (i.e., repairs/maintenance, interior alterations, minor additions, major additions, redevelopment, replacement, minor or major structures, swimming pools, septic systems, decks, infilling, creating new lots);

- considering the size, use and expected lifespan of the proposed development;

- ensuring that new buildings are in keeping with size and nature of existing buildings, wherever possible;

- utilize the total lot depth to maximize the landward siting of development;

- discouraging proposed changes which intensify the land use (i.e., seasonal to permanent);

- consideration of the various and "preferred" floodproofing measures as outlined in Section 7.4.3(a);

- ensuring that the development does not encroach within the stable slope allowance;

- using extreme caution in areas of high to severe recession rates;

- being aware of and recognizing that along cohesive shorelines ongoing downcutting of the nearshore profile may seriously undermine existing protection works in the short-term and that this undermining may go undetected by a casual, visual observation of the protection works from the shore;

- ensuring that buildings be readily moveable by design;

- evaluating the condition, effectiveness, and estimated residual design life of any existing protection works at the site (residual life should be determined based on suggested design life of new structures (see Appendix A7.1) less the approximate age of the existing structure);

- evaluating the condition, effectiveness, and estimated residual design life of adjacent protection works;

- minimizing impacts to dynamic beach shores; and

- ensuring that other policies addressing the same shoreline areas are not compromised (e.g., natural heritage, fish habitat, wetlands, water quality and quantity, etc. which may not permit development)

Shoreline protection works which may be allowed for existing development should meet all the requirements of the protection works standard to the greatest extent that is functional and aesthetically tolerable, must be environmentally sound and must not aggravate or cause *hazards* on the site itself and/or at updrift/downdrift locations. The three key components of the protection works standard, as presented in Section 7.4.3(b), are as follows:

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

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

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

At a minimum, two of the three key components must be fully addressed on a site specific basis, when dealing with the requirements for protection works for existing development, before the requirements for the remaining component can be "relaxed". For example, in an infilling situation where proper access for future repairs may not be not feasible, it is imperative that well designed, sound, durable protection works and complete, safe stable slope and hazard allowances be provided. Conversely, in an infilling situation where there is good and ready access for future repairs or replacement, it may be appropriate to permit a lesser hazard allowance (i.e., flooding, erosion, dynamic beach) provided the protection works are substantial and well designed.

Table A7.2.1 provides a summary of considerations that can serve as the basis for preparing recommended guidelines for existing development within each of the three components that define the *hazardous lands* (i.e., *flooding*, *erosion*, and *dynamic beach hazards*). Municipalities and planning boards are encouraged to review these considerations and then establish existing development guidelines which are most applicable to their local shoreline conditions and planning and development issues. This review should critically examine all the issues and identify the rationale for specific development requirements that may be established to guide and govern development within and along their shorelines. In all cases, regardless of the planning issue being evaluated, the overall intent of the *Provincial Policy Statement*, to minimize the potential risk to life and property, is to be preserved.

Table A7.2.1 Summary of Considerations for Preparing Recommended Guidelines for Existing Development Within the *Hazardous Lands*

Development Activity	***Flooding Hazard (FH)***	***Erosion Hazard (EH)***		***Dynamic Beach Hazard (DBH)***
		Stable Slope Allowance	**Erosion Allowance**	
Existing Developed Lots				
Repairs/maintenance	No restrictions - advise of flood risk and potential damage	No restrictions - advise of imminent risk	No restrictions - advise of long-term erosion hazard	No restrictions -encourage goals of no development within *DBH*
Interior alterations	No restrictions - advise of flood risk and potential damage	No restrictions - advise of imminent risk	No restrictions - advise of long-term erosion hazard	No restrictions -encourage goals of no development within *DBH*
Minor additions -construction that is the lesser of less than 30% for erosion hazards, or 50% for flooding hazards, of the foundation area or market value of the existing structure. Limit of two additions per structure	Permitted provided it incorporates *FPS* floodproofing measures to the maximum extent and level possible based on site-specific conditions. The proponent shall demonstrate a "best effort" has been made to floodproof to the highest level that is functional and aesthetically tolerable. As a minimum, should not be significantly more flood vulnerable than the existing structure (including exposure to wave uprush, wave overtopping, wave spray and other water related hazards. Dry passive floodproofing is preferred and wet floodproofing is not acceptable for habitable use. Do not reduce existing ingress/egress.	Not permitted	Permitted provided: 1) it has a setback of the greater of a) not at risk to erosion hazard for 25 years or b) a minimum setback of 7.5 m from stable slope crest; and 2) it does not increase occupancy of existing structure; and 3) maintenance access to existing protection works is not diminished	Encourage goals of no development within *DBH.* Not permitted within defined portions of *DBH.* Permitted outside defined portions of *DBH* provided design minimizes impacts to dune areas. Follow 4 step preferred order of approaches as described in text.
Major additions/alterations -construction that is the greater of greater than or equals to 30% for erosion hazards, or 50% for flooding hazards, of the foundation area or market value of the existing structure	Permitted provided it has protection to full *PWS* and dry passive floodproofing to full *FPS* except where it significantly impacts on or is significantly out of context with neighbouring properties in which case other approaches (dry active or wet floodproofing) may be considered. Wet floodproofing not acceptable for habitable use. Proponent shall demonstrate a "best effort" has been made to floodproof to the highest level that is functional and aesthetically tolerable. As a minimum, major addition shall not be more flood vulnerable than the existing structure (including exposure to wave uprush, wave overtopping, wave spray and other water related hazards. Should meet full *AS* but as a minimum, access should be considered "safe" during times of flooding.	Not permitted	Permitted provided: 1) it meets requirements of *PWS* and *AS* to the maximum extent and level possible based on site-specific conditions; and 2) it utilizes maximum lot depth and width; and 3) as a minimum, uses the greater of a) erosion allowance based on planning horizon of not less than 50 years or b) minimum setback from stable slope allowance of 15 m; and 4) it does not increase occupancy of existing structure; and 5) it does not diminish maintenance access to any existing protection works.	Encourage goals of no development within *DBH.* Not permitted within defined portions of *DBH.* Permitted outside defined portions of *DBH* provided design minimizes impact to dune area. Follow 4 step preferred order of approaches as described in text.
Redevelopment - existing structure removed and new structure erected	See <u>New dwellings (infilling)</u>	See <u>New dwellings (infilling)</u>	See <u>New dwellings (infilling)</u>	See <u>New dwellings (infilling)</u>

Table A7.2.1 Summary of Considerations for Preparing Recommended Guidelines for Existing Development Within the *Hazardous Lands*

Development Activity	***Flooding Hazard* (*FH*)**	***Erosion Hazard* (*EH*)**		***Dynamic Beach Hazard* (*DBH*)**
		Stable Slope Allowance	**Erosion Allowance**	
Replacement of dwelling destroyed by forces other than flood or erosion	Advise of flood hazards but permitted if same size or smaller and utilizes maximum lot depth for setback. Provide same or better ingress/egress as previous structure and incorporate appropriate floodproofing measures to same or higher level. Consider relocation or acquisition (willing buyer/willing seller arrangement).	Advise of slope stability hazards but permitted if same size or smaller and utilizes maximum lot depth for setback. Provide same or better ingress/egress as previous structure. Incorporate appropriate slope stabilization measures. Consider relocation or acquisition (willing buyer/willing seller arrangement).	Advise of erosion hazards but permitted if same size or smaller and utilizes maximum lot depth for setback and if structure readily moveable. Provide same or better ingress/egress as previous structure. Consider relocation or acquisition (willing buyer/willing seller arrangement).	Advise of dynamic beach hazards and encourage goals of no development within *DBH*. Permitted if same size or smaller and utilizes maximum lot depth for setback and if design minimizes impact to dunes - provide same or better ingress/egress as previous structure - consider relocation or acquisition (willing buyer/willing seller arrangement).
Replacement of dwelling destroyed by forces of flooding and/or erosion	Not permitted at same location. For replacement at new landward location, see <u>New dwellings (infilling)</u>	Not permitted	Not permitted at same location. For replacement at new landward location, see <u>New dwellings (infilling)</u>	Not permitted at same location. For replacement at new landward location, see <u>New dwellings (infilling)</u>.
Major structures -non-habitable buildings that do not qualify as minor structures -does not include shoreline protection works	Permitted provided it has dry passive floodproofing to full *FPS* except where it significantly impacts on or is significantly out of context with neighbouring properties in which case other approaches may be considered (dry active, where minimum 6 hours warning available, or wet floodproofing) . The proponent shall demonstrate a "best effort" has been made to floodproof to the highest level that is functional and aesthetically tolerable. Do not reduce existing ingress/egress.	Not permitted	Permitted provided: 1) it meets requirements of *PWS* and *AS* to the maximum extent and level possible based on site-specific conditions; and 2) it utilizes maximum lot depth and width; and 3) as a minimum, it uses the greater of a) erosion allowance based on planning horizon of not less than 50 years or b) minimum setback from stable slope allowance of 15 m; and 4) it does not diminish maintenance access to existing protection works <u>or</u> With no protection works, the building shall be readily moveable by design with no permanent foundations and temporary foundations to be removed when structure moved, relocation plan submitted and greater of 1) minimum setback of 30 times AARR from stable slope allowance or 2) not less than 15 m from stable slope allowance.	Encourage goals of no development within *DBH*. Not permitted within defined portions of *DBH.* Permitted outside defined portions of *DBH* provided design minimizes impact to dune area. Follow 4 step preferred order of approaches as described in text.

Table A7.2.1 Summary of Considerations for Preparing Recommended Guidelines for Existing Development Within the *Hazardous Lands*

Development Activity	***Flooding Hazard (FH)***	***Erosion Hazard (EH)***		***Dynamic Beach Hazard (DBH)***
		Stable Slope Allowance	**Erosion Allowance**	
Minor structures -non-habitable, moveable structures (sheds, gazebos) with no utilities and maximum size of 14 m^2 - does not include shoreline protection works	Advise of flood risk. Permitted provided safety concerns due to flood hazards are addressed considering site conditions and nature and use of structure. Do not reduce existing ingress/egress.	Not permitted	Advise of erosion risk. Permitted provided safety concerns due to erosion hazards are addressed considering site conditions and nature and use of structure and maintenance access to any existing protection works is not decreased. It is recommended if any structure is within 5 m of stable slope crest, that surcharge effects on slope stability be assessed by a geotechnical engineer.	Encourage goals of no development within *DBH*. Not permitted within defined portions of *DBH*. Permitted outside defined portions of *DBH* provided design minimizes impact to dune area. Follow 4 step preferred order of approaches as described in text.
Swimming pools	Not permitted unless meets full requirements of *FPS*	Not permitted	Permitted provided: 1) not at risk to erosion hazard for 20 years for inground pools or 10 years for above ground pools; and 2) drainage is addressed; and 3) maintenance access to existing protection works is not decreased; and 4) existing ingress/egress is not reduced. Iit is recommended if any structure is within 5 m of stable slope crest, that surcharge effects on slope stability be assessed by a geotechnical engineer.	Encourage goals of no development within *DBH*. Not permitted within defined portions of *DBH*. Permitted outside defined portions of *DBH* provided design minimizes impact to dune area. Follow 4 step preferred order of approaches as described in text.
Septic systems	Not permitted	Not permitted	Permitted provided it is landward of primary dwelling and conforms to setbacks as required under EPA, Section VIII . Do not reduce existing ingress/egress.	Permitted provided it is landward of primary dwelling and conforms to setbacks as required under EPA, Section VIII
Decks, boardwalks, fixed walkways (not connected to dwelling)	Permitted provided safety concerns due to flood hazards are addressed considering site conditions and nature and use of development. Advise of flood risk and potential damage. Do not reduce existing ingress/egress. Level of safety varies with ingress/egress (i.e., limited access points or continuous access).	Decks and fixed walkways and boardwalks along the shore not permitted. Perpendicular access to shoreline by fixed walkways and boardwalks may be permitted.	Permitted provided not at risk to erosion hazard for 10 years. It is recommended if any structure is within 5 m of stable slope crest, that surcharge effects on slope stability be assessed by a geotechnical engineer.	Encourage goals of no development within *DBH*. Not permitted within defined portions of *DBH* except as dune cross-overs at selected points. Permitted outside defined portions of *DBH* provided design minimizes impact to dune area. Follow 4 step preferred order of approaches as described in text.

Table A7.2.1 Summary of Considerations for Preparing Recommended Guidelines for Existing Development Within the *Hazardous Lands*

Development Activity	***Flooding Hazard* (*FH*)**	***Erosion Hazard* (*EH*)**		***Dynamic Beach Hazard* (*DBH*)**
		Stable Slope Allowance	**Erosion Allowance**	
Relocation of dwelling away from shoreline	Optional on part of owner but recommended. Relocate outside *FH*.	Optional on part of owner but recommended	Optional on part of owner but recommended. Relocate outside *EH*.	Optional on part of owner but recommended. Relocate outside *DBH*.
Existing Vacant Lots				
New dwellings (infilling) -development on previously undeveloped lot(s), with foundation area less than 500 square metres, generally bounded by existing development on adjacent sides of property	Permitted provided it provides protection to full *PWS* and dry passive floodproofing to full *FPS* except where it significantly impacts on or is significantly out of context with neighbouring properties in which case other approaches (dry active or wet floodproofing) may be considered. Wet floodproofing not acceptable for habitable use. Proponent shall demonstrate a "best effort" has been made to floodproof to the highest level that is functional and aesthetically tolerable. Should meet full *AS* but as a minimum, access should be considered "safe" during times of flooding.	Not permitted	Permitted provided more than 50% of existing lots/parcels in the residential or cottage area are developed and: 1) the proponent demonstrates that it meets requirements of *PWS* and *AS* to the maximum extent and level possible and that a "best effort" has been made to provide the maximum erosion allowance that is functional and aesthetically tolerable; and 2) it utilizes maximum lot depth and width; and 3) as a minimum, uses the greater of a) an erosion allowance based on planning horizon of not less than 60 years or b) minimum setback from stable slope allowance of 15 m; and 4) proper maintenance access is provided to any existing protection works (see Note 7).	Encourage goals of no development within *DBH*. Not permitted within defined portions of *DBH*. Permitted outside defined portions of *DBH* provided design minimizes impact to dune area. Follow 4 step preferred order of approaches as described in text.
New dwellings (infilling)... with foundation area greater than or equal to 500 square metres...	See New Development, Create new lot(s)	See New Development, Create new lot(s)	See New Development, Create new lot(s)	See New Development, Create new lot(s)
Buildings which by the nature of their use are located in close proximity to water	Requires detailed site specific evaluation. Observe overall intent of Policy to minimize potential risk to life and property.	Requires detailed site specific evaluation. Observe overall intent of Policy to minimize potential risk to life and property.	Requires detailed site specific evaluation. Observe overall intent of Policy to minimize potential risk to life and property.	Requires detailed site specific evaluation. Observe overall intent of Policy to minimize potential risk to life and property.
Septic systems	Not permitted	Not permitted	Permitted provided it is landward of primary dwelling and conforms to setbacks as required under EPA, Section VIII - do not reduce existing access	Permitted provided it is landward of primary dwelling and conforms to setbacks as required under EPA, Section VIII.

Table A7.2.1 Summary of Considerations for Preparing Recommended Guidelines for Existing Development Within the *Hazardous Lands*

Development Activity	***Flooding Hazard* (*FH*)**	***Erosion Hazard* (*EH*)**		***Dynamic Beach Hazard* (*DBH*)**
		Stable Slope Allowance	**Erosion Allowance**	
New Development				
Create new lot(s)	Permitted provided it meets full requirements of *FPS* and *PWS* - incorporate dry passive floodproofing measures - wet floodproofing measures not considered acceptable - must meet requirements of *AS*	Not permitted	Permitted provided it meets full requirements of *PWS*	Encourage goals of no development within *DBH*. Not permitted within defined portions of *DBH*. Permitted outside defined portions of *DBH* provided design minimizes impact to dune area. Follow 4 step preferred order of approaches as described in text.
Technical severance	No restriction	No restriction	No restriction	No restriction
Lot consolidation	No restriction	No restriction	No restriction	No restriction
Land use designation/zone changes	Support changes to planning documents to natural hazard designation in accordance with the Policy			
	Do not support proposed zoning, land use designation or official plan changes which further intensify land use (i.e., seasonal residential to year-round residential, or single family residential to multi-unit dwelling)			

NOTES:

1) All development to adhere to requirements of Policies 3.1.2 and 3.1.3 unless specifically noted otherwise.
2) All of the above is subject to appropriate setbacks and maximum lot coverage requirements as listed in municipal zoning by-laws.
3) Development which by the nature of its use must be in close proximity to or within the water (i.e., water intakes, docks, non-habitable boathouses, utilities) may require a more detailed evaluation to determine the acceptable potential risks. In all 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.
4) Dry passive floodproofing measures preferred for all development.
5) "Not at risk to erosion hazard" includes consideration of protection works, stable slope and erosion allowances.
6) Stable slope allowance is 1:3 unless geotechnical study carried out.
7) Maintenance access to the shoreline typically requires sufficient width (i.e., approximately 4 m to 5 m) for heavy construction equipment.
8) *FPS*: *Flood Protection Standard*
   PWS: *Protection Works Standard*
   AS: *Access (Ingress/Egress) Standard*
   AARR: Average annual recession rate