TECHNICAL GUIDE FOR
GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

PART 2

RECOMMENDED SHORELINE CLASSIFICATION SCHEME

TO DETERMINE SHORELINE REACHES

RECOMMENDED SHORELINE CLASSIFICATION SCHEME TO DETERMINE SHORELINE REACHES

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2.1 INTRODUCTION

Crucial to the implementation of the flood, erosion and dynamic beach hazard policies is the proper identification and classification of the *Great Lakes - St. Lawrence River System* shorelines based on a consistent, technically sound and functional set of procedures.

The purpose of Part 2 of this Technical Guide is to outline the recommended shoreline classification scheme intended to support the definition and implementation of the provincial policies governing natural hazards (i.e., *flooding , erosion and dynamic beach hazards*) adjacent to the *Great Lakes - St. Lawrence River System* (i.e. Policy 3.1, Public Health and Safety: Natural Hazards, *Provincial Policy Statement*, 1996). The criteria and procedures for the actual definition and calculation of each of these *natural hazards* policy standards are summarized in the *Natural Hazards Training Manual* (1996) and discussed in greater detail in this Technical Guide (i.e., Parts 3, 4 and 5).

In general, the recommended shoreline classification scheme facilitates the division of a given stretch of shoreline into manageable shoreline segments referred to as shoreline reaches. By definition, shoreline reaches are segments of shoreline usually having relatively uniform physical characteristics. The recommended shoreline classification scheme provides the criteria for identifying the common physical characteristics.

In outlining the recommended shoreline classification scheme, Part 2 of this Technical Guide contains the following:

- **Section 2.2** describes the recommended shoreline classification scheme; provides a description of the classification criteria; namely, controlling nearshore substrate, general shoreline type, surficial nearshore substrate and shoreline exposure and planform.

- **Section 2.3** outlines the recommended procedures for defining shoreline reaches (i.e., shortest alongshore lengths of shoreline used in the mapping of shorelines) based on the classification criteria.

- **Section 2.4** provides an initial overview on the collection and use of background materials required to map shoreline reaches.

2.2 CRITERIA FOR CLASSIFICATION OF GREAT LAKES - ST. LAWRENCE RIVER SYSTEM SHORELINES

2.2.1 Shoreline Classification

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

The primary purpose of the recommended shoreline classification scheme is to aid in the determination and identification of these unique segments of shoreline (i.e., based on shore type), to highlight those factors and processes within each distinct shore type that are considered significant controls on flooding, erosion and dynamic beach hazards, and ultimately, to facilitate the identification of shoreline *hazard* areas and the proper application of the *Provincial Policy Statement* governing *natural hazards* (i.e., *flooding, erosion and dynamic* beaches) along the shorelines of the *Great Lakes - St. Lawrence River System*.

In establishing the classification criteria, the following factors were considered:

- must be based on the physical processes or factors controlling the overall form and evolution of the shoreline;
- must provide a description of the shoreline materials and form using commonly accepted terminology;
- must include or recognize features that would allow a linkage between the physical processes and the biological processes;
- must provide a reasonable approach and be consistent with existing science so that it would be applicable province-wide; and
- must provide a distinction between different classes at a scale or level that minimizes the number of classes without rendering them meaningless.

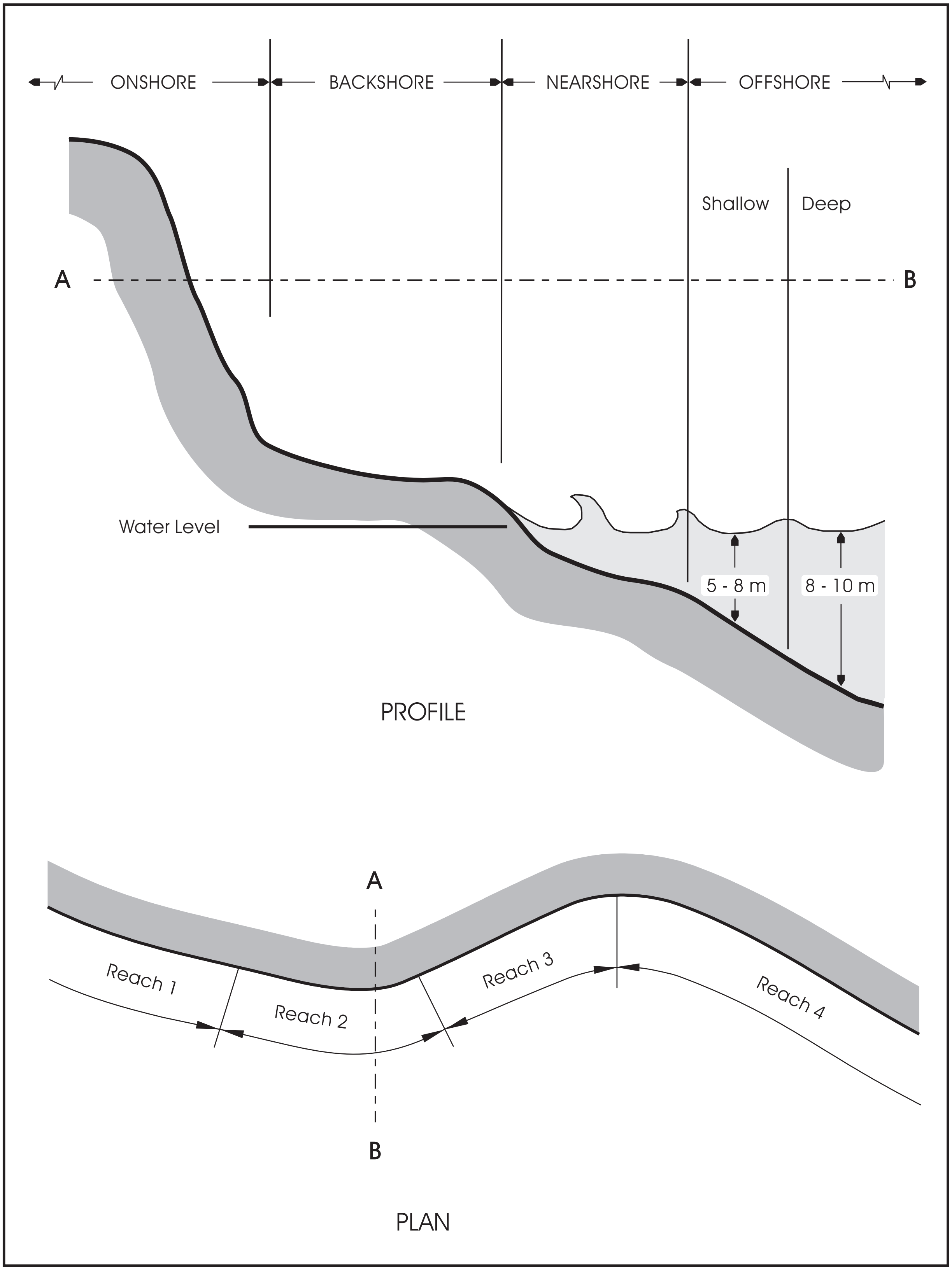
To aid in the descriptive classification model, the cross-shore profile is considered to consist of three distinct zones; namely onshore, backshore and nearshore (see Figure 2.1). These were presented in Appendix A1.2.1 Section A1.2.1 - Definition of the Coastal Zone.

- The **onshore** is the area landward of and generally beyond the limit of wave action by a particular water body. This may include shoreline bluffs, sand dune fields, wetlands, and areas subject to occasional inundation.

- The **backshore zone** extends from the landward limit of the nearshore to the point of development of vegetation or change in physiography (i.e., where the bluff or dune starts). The backshore zone is typically only affected during severe storms particularly at high water.

- The **nearshore zone** is an indefinite zone extending from just beyond the breakers zone to the landward limit of the swash zone or the landward limit of the foreshore zone. The swash zone is the portion of the nearshore zone in which the beach face is alternatively covered by the uprush of the wave swash and exposed by the backwash. The foreshore is the sloping portion of the beach profile lying between the berm crest, or in the absence of a berm crest, the upper limit of wave swash, and the lower limit of the backrush of wave swash. The term foreshore is often nearly synonymous with the beach face but is commonly more inclusive, containing also some of the flat portion of the beach profile below the beach face.

Figure 2.1: Illustration of Shoreline Zones and Reaches



2.2.2 Criteria for Shoreline Classification

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

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

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

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

Given these guiding principles, and the considerations outlined in Section 2.2.1, the recommended shoreline classification scheme involves four distinct steps of site evaluation and classification (see Figure 2.2):

1) controlling nearshore substrate,
2) general shoreline type,
3) surficial nearshore substrate, and
4) shoreline exposure and planform.

These steps are discussed in the following sub-sections:

a) Step 1: Classification of Controlling Nearshore Substrate

The purpose of Step 1 of the recommended shoreline classification scheme is to identify the most critical factor influencing the physical processes impacting on the land/water interface along a particular stretch of shoreline, namely the "controlling nearshore substrate".

As outlined in Appendix A1.2, Lake/Land Interaction, a basic characteristic which controls the long term, large scale evolution of the Great Lakes shorelines is the controlling substrate. Controlling substrate was defined as the dominant underlying material which makes up the main body of the lakebed.

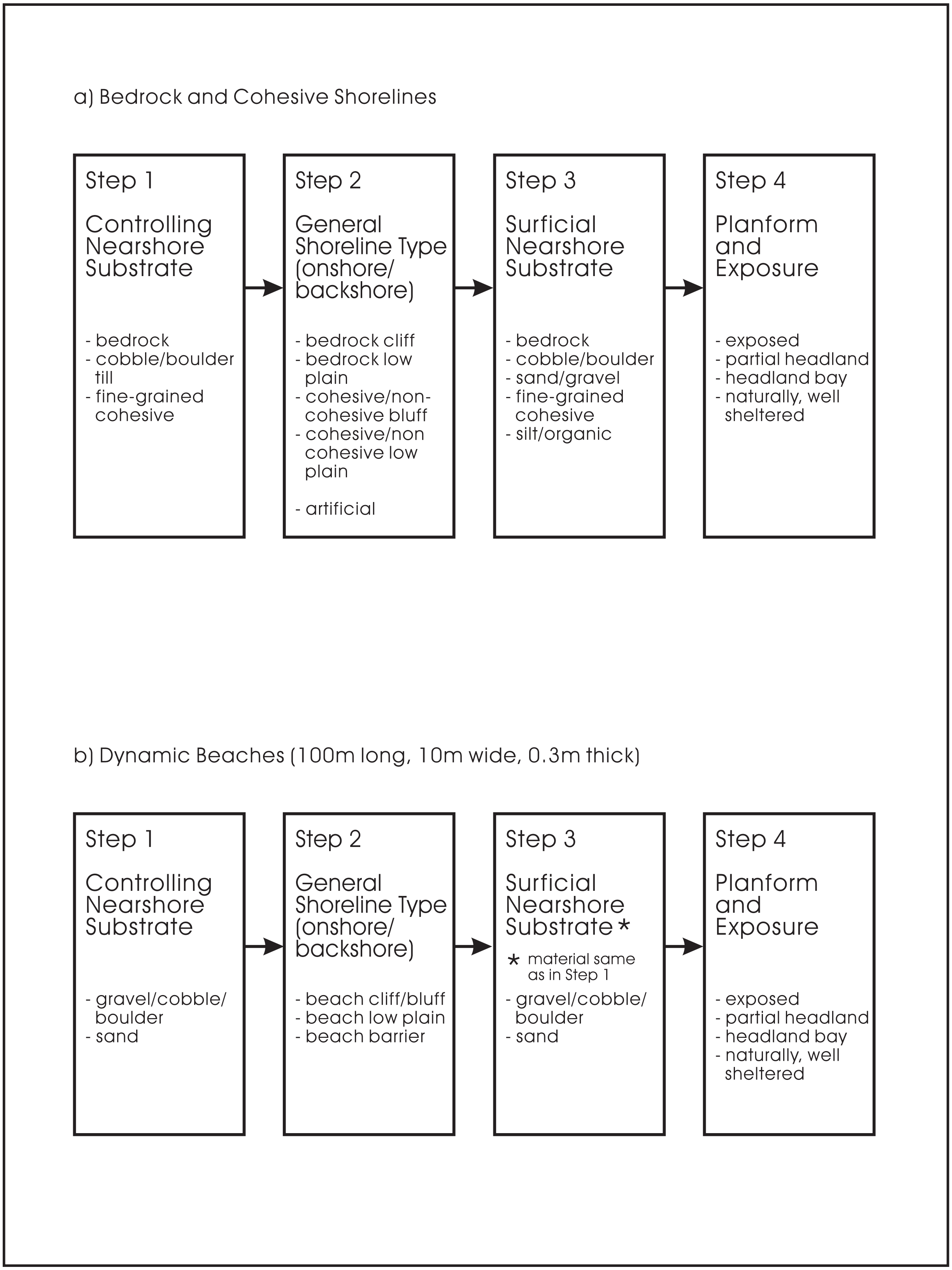
Step 1 of the recommended shoreline classification scheme addresses this critical factor by dividing the shoreline into three types of controlling nearshore substrate for bedrock and cohesive shorelines (see Figure 2.2a):

- Bedrock
- Cobble/Boulder Till (i.e., cohesive material)
- Fine-Grained Cohesive

and two controlling nearshore substrate for the "dynamic beaches" (see Figure 2.2b):

- Gravel/Cobble/Boulder
- Sand

Figure 2.2: Recommended Shoreline Classification Scheme



i) Bedrock Shorelines

Bedrock shorelines include all shorelines where the nearshore and part or all of the backshore consists primarily of bedrock. These areas may be characterized by bedrock and boulders exposed in many places along the shoreline, there may be extensive rock outcrops in the nearshore, or there may be only limited amounts of surficial sand or cobbles overlying the bedrock.

In general, bedrock shorelines are more resistant to erosion than cohesive shorelines due to the strength of the materials in which they are developed. Recognition must be given, however, to the degree of bedrock strength, defined in terms of resistance to erosion by wave action and weathering processes, since bedrock strength varies with rock type and structure.

The differences in bedrock strength can best be demonstrated when comparing bedrock structures consisting of igneous and metamorphic, and limestone and dolomite, with sedimentary materials. The igneous and metamorphic rocks of the Canadian Shield are generally considered extremely resistant to erosion by waves with recession rates in most of these areas being so small that they are virtually immeasurable. As such, erosion rates would be expected to be low along virtually all of the igneous and metamorphic bedrock shorelines of eastern Georgian Bay and Lake Superior.

Thickly-bedded limestones and dolomites bedrock outcrops, generally located along parts of the Bruce Peninsula and along parts of the eastern end of Lake Ontario, are a second form of bedrock structure considered to be quite resistant to erosional forces as demonstrated by their low recession rates. By comparison, sedimentary rocks such as sandstones, shales and thinly-bedded limestones are often much less resistant to wave action and to weathering. Their inherent strength depends more on the nature of the cementing material and on the structure itself, specifically, the joints and bedding planes within the rock formation. As such, sedimentary bedrock outcrops, typical of those found along some portions of Lake Ontario and the east end of Lake Erie, may experience recession rates on the order of 0.10-0.15 metres per year.

The resulting nearshore profiles, characteristic of these softer bedrock types, may be similar in shape to the erosion-resistant cobble/boulder till materials.

ii) Cohesive Shorelines

The cohesive shoreline classification basically includes all shorelines developed in sedimentary deposits that contain some fine sediments, such as silts and clays, and which may possess some degree of strength as a result of the cohesion forces associated with the clays within the stratigraphic structure of the shore face. For all cohesive shores, the erosion of the material which comprises the controlling substrate is irreversible (see Appendix A1.2). However, the recession rates and the resulting nearshore profiles can differ depending on the nature of the cohesive material. For the purpose of the classification scheme used in this Technical Guide, cohesive shorelines (i.e., the controlling substrate) have been subdivided into two groups:

- Cobble/boulder till is a cohesive material (e.g., glacial till) with a high content of cobbles and boulders. Winnowing away of the fines, by wave action in the nearshore, and erosion of onshore bluffs with a high content of cobbles and boulders produces a cobble/boulder lag deposit which protects the nearshore. This results in a convex, shelf-type profile (see Figure A1.2.3(b)). In other instances, the cobble/boulder material in the nearshore may have originated from other sources other than from the underlying material. Resulting recession rates tend to be moderate to high.

- Fine-grained cohesive material contains a relatively small percentage by volume of coarser grained material especially cobbles and boulders. As such, no protective lag deposit is able to build up in the nearshore. Ongoing downward erosion of the nearshore results in a convex-shaped profile with the highest rate of downcutting closest to the shore (see Figure A1.2.3(a)). The downcutting rate diminishes as one proceeds offshore. Over time, the profile shape tends to remain constant and is merely translated shoreward. Resulting recession rates tend to be high to severe.

Extensive sections of shoreline along Lake Ontario, Lake Erie and southern Lake Huron consist of sediments deposited by glaciers, in glacial lakes, or by rivers flowing from ice sheets. In some areas, such as the Lake Ontario shoreline between Hamilton and the Niagara River and the Lake Huron shoreline between Grand Bend and Point Clarke, the shoreline is developed almost entirely in glacial till consisting largely of silts and clays with small amounts of sands and gravels. While glacial deposits possess some strength due to cohesion, a large part of their initial strength is derived from over-consolidation due to the weight of overlying glacier ice during, or subsequent to, deposition. What is important to recognize, however, is that these sediments are prone to irreversible downward erosion in the nearshore.

In some areas, such as Lake St. Clair and small embayments, the cohesive sediments consist of relatively recent alluvial sediments deposited by river or lake currents. Shorelines consisting of alluvial sediments will possess some strength due to cohesion but not due to over-consolidation.

iii) Dynamic Beaches

In general, the term "beach" applies to any accumulation of sediments that have been transported by wave action and deposited along the shoreline. These include, sediment accumulations or pockets of sediment material that are found along many of the bedrock and bluff shorelines of the *Great Lakes - St. Lawrence River System*.

For the purposes of the recommended shoreline classification scheme, the term dynamic beach will be applied only to those areas where beach deposits are greater than 10 metres in width, 0.3 metres in thickness and 100 metres in length and where the beach deposits are not located in embayments, along connecting channels or in other areas of restricted wave action. Restricted wave action generally takes place where the maximum fetch distance measured over an arc extending 60° on either side of a line perpendicular to the shoreline is less than 5 km. Where the beach in question exceeds these criteria, there is a sufficient volume of sediment such that significant changes in the profile of the beach can take place as a result of wave action and water level fluctuations. Shore types which adhere to these criteria are considered to be dynamic beach shorelines. More detailed information on dynamic beaches is presented in this Technical Guide (Part 5: Dynamic Beach Hazard).

iv) Other Features

It should be noted that river mouths may be treated as special cases as required. Some river mouths are drowned river valleys (i.e., rivers existed at earlier glacial times, under much lower lake levels). Not only does the submergence of the old river valley result in an embayment feature, but the lakebed within the drowned river valley may be significantly modified by fluvial sediments deposited over the lakebed. This may result in isolated locations of sandy or silty lakebed conditions along shorelines that are otherwise cohesive or bedrock (see Figure 2.3).

b) Step 2: General Shoreline Type Classification

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

Terrestrial habitat considerations are discussed in this Technical Guide (Part 8: Environmentally Sound Management Within Hazardous Lands).

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

Figure 2.3: River Mouth

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

Within Step 2, there are four basic shoreline types (i.e., bedrock, cohesive/non-cohesive, dynamic beach and artificial) which are based on the nature of the material forming the onshore/backshore. The onshore/backshore material can differ from the controlling substrate material in the nearshore (Step 1). These four basic types are then further subdivided based on the relief/slope and physical characteristics of the shoreline to form the eight general shoreline type classifications:

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

Differentiation is then made between eight general onshore/backshore shore types based on shoreline composition and shore relief. In addition to differentiating shore types based on physical attributes, recognition of the dynamic response of these shore types should also be documented. The range of dynamic response is usually determined by the influence or impact of shoreline processes on the shore type (i.e., wave climate, wind setup potential, nearshore downcutting, alongshore sediment transport patterns and beach sediment budgets, and post-glacial lake history). Human-related activities, such as harbour construction, the placement of fill and the installation of protection works, also have an impact on shore type and should be duly recognized in any determination of shore type (see Part 1: The Great Lakes - St. Lawrence River System: Physical Features and Processes, of this Technical Guide)..

i) Bedrock Shorelines

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

In general, bedrock shorelines are more resistant to erosion than cohesive shorelines due to the strength of the materials in which they are developed. Recognition must be given, however, to the degree of bedrock strength, defined in terms of resistance to erosion by wave action and weathering processes, since bedrock strength varies with rock type and structure (see Step 1, Figure 2.2(a)).

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

- bedrock cliff shorelines, and
- bedrock low plain.

Bedrock cliff shorelines generally consist of bedrock features that rise steeply (i.e., steeper than 1:3, vertical:horizontal) from the shoreline to elevations exceeding 2 metres in height (Figure 2.4), and as such, have only a very narrow zone at the base of the structure that is subject to flooding and/or wave action. Much of the east shoreline of the Bruce Peninsula is a typical example of bedrock cliff shorelines.

The second sub-classification of bedrock shorelines, bedrock low plain shorelines, have a gentle slope (i.e., flatter than 1:3 vertical:horizontal) inland from the shoreline or a relief of less than 2 metres in height (Figure 2.5). On low plain shorelines, where the relief is less than 2 m high and the slope is steeper than 1:3, the shoreline is described as a bank. Low plain shorelines permit wave action to extend some distance inland usually exposing the onshore to flooding during storms and/or high water periods. Portions of the west shoreline of the Bruce Peninsula and the east end of Lake Ontario fall into this sub-classification of shore type.

ii) Cohesive/Non-Cohesive Shorelines

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

Extensive sections of shoreline along Lake Ontario, Lake Erie and southern Lake Huron consist of sediments deposited by glaciers, in glacial lakes, or by rivers flowing from ice sheets. In some areas, such as the south shore of Lake Ontario between Hamilton and the Niagara River and the Lake Huron shoreline between Grand Bend and Point Clarke, the shoreline is developed almost entirely in glacial till consisting largely of silts and clays with small amounts of sands and gravels. While glacial deposits possess some strength due to cohesion, a large part of their initial strength is derived from over-consolidation due to the weight of overlying glacier ice during, or subsequent to, deposition. What is important to recognize, however, is that once these sediments are exposed at or near the surface, they may lose much of their strength due to weathering processes such as repeated wetting and drying, freezing and thawing and to positive pore water pressures.

In some areas, such as Lake St. Clair and small embayments, the cohesive sediments consist of relatively recent alluvial sediments deposited by river or lake currents. Shorelines consisting of alluvial sediments will possess some strength due to cohesion but not due to over-consolidation.

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

- cohesive/non-cohesive bluff shorelines, and
- cohesive/non-cohesive low plain shorelines.

For the purposes of the recommended shoreline classification scheme identified in this Technical Guide, the term "bluff" in cohesive/non-cohesive bluff shorelines applies to a steeply sloping (i.e., steeper than 1:3, vertical:horizontal) shoreline with backshore elevations greater than 2 metres developed in sedimentary deposits (Figure 2.6). This differs from the term cliff, which for the purposes of the recommended shoreline classification scheme, applies to bedrock shorelines. With bluff shorelines, wave action and flooding are generally confined to the area between the base of the bluff and the lake.

In comparison, cohesive/non-cohesive low plain shorelines (Figure 2.7) are defined as areas with a gentle inland slope from the shoreline (i.e., flatter than 1:3, vertical:horizontal) or where the relief is less than 2 metres.. On low plain shorelines, where the relief is less than 2 m high and the slope is steeper than 1:3, the shoreline is described as a bank. Along low plain shorelines, wave action and flooding may extend a considerable distance inland. Most exposed cohesive/non-cohesive shorelines along the *Great Lakes - St. Lawrence River System* are subject to high rates of erosion and shoreline recession. Recession rates along cohesive/non-cohesive shorelines generally exceed 0.5 metres per year and along some portions of the north shore of Lake Erie may exceed 1.5 metres per year.

Figure 2.4: Bedrock Cliff

Figure 2.5: Bedrock Low Plain

Figure 2.6: Cohesive Bluff

Figure 2.7:   Cohesive Low Plain

Figure 2.8:   Low Plain Beach

iii) Dynamic Beaches

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

- dynamic beach backed by cliff/bluff,
- dynamic beach low plain (i.e., mainland dune), and
- dynamic beach barrier.

Under these sub-classifications, cliff or bluff beaches are essentially beaches that are backed by either a bedrock cliff or a cohesive/non-cohesive bluff and as such, the landward extent and the effect of wave action and flooding are limited.

Low plain beaches have a gently sloping shoreline and as such, are subject to wave action and flooding (Figure 2.8). However, the slope is dependent on the underlying bedrock or cohesive material on which the beach is developed. For example, on sandy beach shorelines, sand dunes may develop landward of the beach and while the relief of the dunes is often greater than 2 metres, the dunes can be eroded rapidly even during a single storm event.

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

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

iv) Artificial

For the majority of *Great Lakes - St. Lawrence River System*, the physiographic characteristics of the shoreline provide the basis for the identification of the shore type in the recommended shoreline classification scheme. There are a few shoreline locations, however, where the physiographic characteristics have been significantly altered and as such, do not meet any of the recommended shoreline classification scheme criteria identified to this point. For the purposes of this Technical Guide and the recommended shoreline classification scheme, the significantly altered shorelines will be defined as artificial shore types. The criteria used to define the artificial shore type includes those shorelines that:

- cannot be classified on the basis of their physiographic characteristics due to human activities and/or alterations to the shoreline;

- involve structural changes that extend inland (i.e., well into the onshore zone);

- involve protection works that exist above and below the waterline and that extend continuously alongshore for about 1 km;

- have the protection works under public ownership and/or are maintained by a public agency (e.g., Conservation Authority, municipality, harbour commission) or a significant private concern; and

- have shoreline processes and flood, erosion and dynamic beach hazards which have been significantly altered by the protection works.

The artificial shore type is predominately found along the waterfronts of major metropolitan centres such as Toronto, Sarnia and Sault Ste. Marie and at many major harbour developments (see Figure 2.9). Understanding the local flood, erosion and/or dynamic beach hazards along artificial shorelines often requires site specific studies. In addition, these site specific investigations must examine the functional longevity of the protection works and assess their potential impacts on the physical and biological environment should the protection works fail.

Figure 2.9: Port Credit Harbour

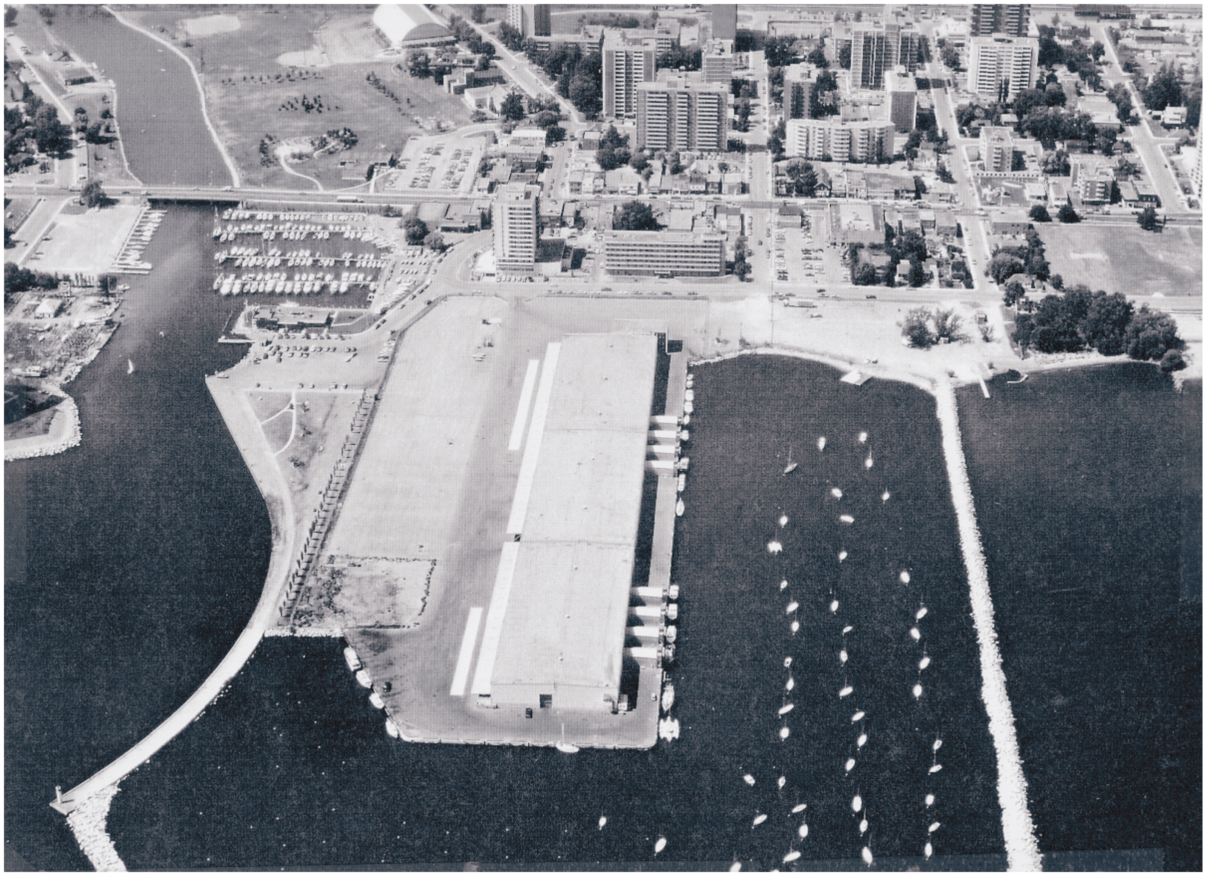


Figure 2.10: Shoreline Protection by Small Scale Protection Works

The artificial shore classification does not apply to shorelines where small scale and/or uncoordinated protection works have been installed by individual property owners, even where the protection works continuously extend over long distances alongshore. The primary rationale is that the natural shoreline type can still be determined and many of the shoreline processes are still taking place. Also, small scale protection works are generally placed on a individual basis and provide different lifespans and differing levels of flood and erosion protection and tend not to have consistent maintenance and repair activities. Collectively, this tends to lead to inconsistent, short-term design life protection and with it, a variety of associated problems. For a more detailed discussion on the functional design life, associated problems, and the applicability of various small-scale protection works, Part 7: Addressing the Hazards, of this Technical Guide, should be consulted.

Shorelines protected by small scale protection works (Figure 2.10) should be classified according to their controlling nearshore substrate and onshore/backshore physiographic shore type (e.g., bluff) with a recognition of the presence of protection works at the shoreline or in the nearshore.

Where protection works currently exist within a shoreline defined as a dynamic beach, the shoreline should still be classified as a dynamic beach and <u>not</u> artificial. The presence of the existing structures and any evidence of physical and/or environmental impacts should be noted and addressed through the evaluation processes identified in Part 5: Dynamic Beach Hazard and Part 7: Addressing the Hazards, of this Technical Guide, and through the broader shoreline management planning process.

c) Step 3: Classification of Surficial Nearshore Substrate

The primary purpose of Step 3, of the recommended shoreline classification scheme (see Figure 2.2(a)) is to recognize the integral importance and need to properly identify the surficial substrate and the role that nearshore surficial sediments have in determining the range of biological or environmental processes occurring on a particular stretch of shoreline.

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

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

- bedrock
- cobble/boulder
- sand/gravel
- fine-grained cohesive
- silt/organic

and two surficial nearshore substrate in "dynamic beach" shorelines:

- gravel/cobble/boulder
- sand

For "dynamic beaches", the surficial nearshore substrate material will be the same as the underlying controlling substrate.

The distinction between the various surficial substrate types is based on size, interstitial spaces and consolidation. Terms such as "clay", "silt", "sand", "gravel" and "cobble/boulder" are used as descriptive terms to suggest a certain size of material. The actual size limits of the various terms vary according to the classification system used. Different disciplines (e.g., biologists, geologists, geotechnical engineers and coastal engineers) tend to favour certain classification systems. Table 5.2, in Part 5: Dynamic Beach Hazard, provides a description of the various size ranges based on the Wentworth and Unified Soils classification systems.

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

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

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

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

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

d) Step 4: Classification of Shoreline Exposure and Planform

The purpose of Step 4 of the recommended shoreline classification scheme (see Figure 2.2(a)) is to describe in further detail the exposure of the shoreline to wave action and the physical characteristics described in terms of its "planform". The exposure and planform helps to define the littoral transport characteristics and are indicators of the long-term stability or evolution of the shoreline.

Step 4 results in the description of a shoreline in the following manner:

- exposed
- partial headland
- headland-bay
- naturally, well sheltered

The four exposure and planform classifications are applied in bedrock, cohesive (i.e., cobble/boulder till and fine-grained cohesive) and "dynamic beach" shoreline environments. Section 5.4.3, in Part 5: Dynamic Beach Hazard, provides more detailed information on the planform of shorelines. The wave energy reaching the shoreline (i.e., "exposure") for the different planform shapes can be described in a relative sense as follows:

Shoreline Planform Type	Typical Wave Exposure
· exposed	· high wave energy
· partial headland	
- partial headland	· high wave energy
- partial bay	· high wave energy
· headland-bay	
- prominent headland	· very high wave energy
- prominent bay	· moderate wave energy
· naturally well sheltered	· low wave energy

e) Summary of the Recommended Shoreline Classification Scheme

The four steps of the recommended shoreline classification results in a range of shoreline types that are summarized in Table 2.1. Table 2.1 also indicates whether or not the different shoreline types are prone to flooding, erosion and dynamic beach hazards. The actual extent of the hazard will of course depend on the site specific conditions.

The various shoreline classes are subject to different levels of flooding, erosion and dynamic beach hazards. As previously noted, the flooding hazard is a function of the height and steepness of the onshore area (see Part 3: Flood Hazard). Erosion processes are described in Part 4: Erosion Hazard. For descriptive purposes, erosion hazards can be rated as follows:

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

As a result of the dynamic beach classification process, a total of eighteen (18) general beach types or classes are developed. Under the recommended shoreline classification scheme, each of these beach classes is differentiated by name and number (see Table 2.2). For more information, a detailed description of each beach class is provided in Part 5: Dynamic Beach Hazard, of this Technical Guide. Figure 2.11 provides schematic illustrations of some example shoreline classifications.

Table 2.1 Summary of Shoreline Classes

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

LEGEND

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

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

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

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

5 - a beach is 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.

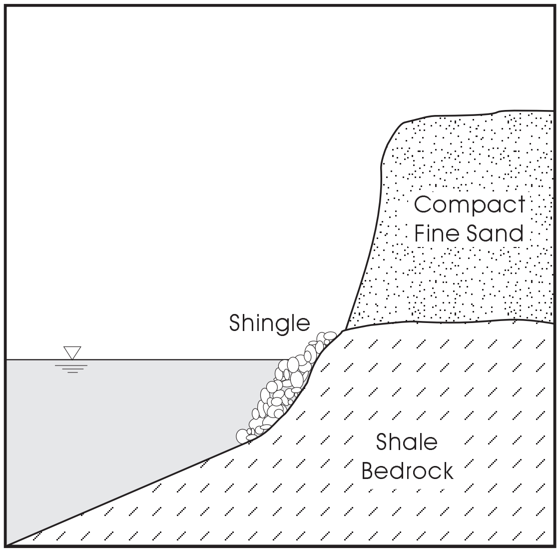
Table must be read in conjunction with accompanying Technical Guide text.

Table 2.2
Dynamic Beach Classification

Step 2 General Shoreline Type	Step 4 Exposure and Planform	Steps 1 & 3 Materials * (controlling & surficial substrate)	Class #
CLIFF/BLUFF	Headland-Bay	cobble sand	111 113
	Partial Headland	cobble sand	121 123
	Exposed	cobble sand	131 133
LOW PLAIN	Headland-Bay	cobble sand	211 213
	Partial Headland	cobble sand	221 223
	Exposed	cobble sand	231 233
BARRIER	Headland-Bay	cobble sand	311 313
	Partial Headland	cobble sand	321 323
	Exposed	cobble sand	331 333

* The term "cobbles" is used for simplicity although the class includes material ranging from gravel through cobbles to boulders.

Figure 2.11: Schematic Illustrations of Some Example Shoreline Classification

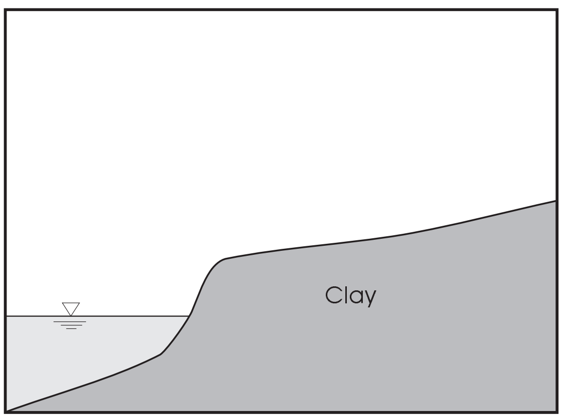


Example (a)

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

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

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

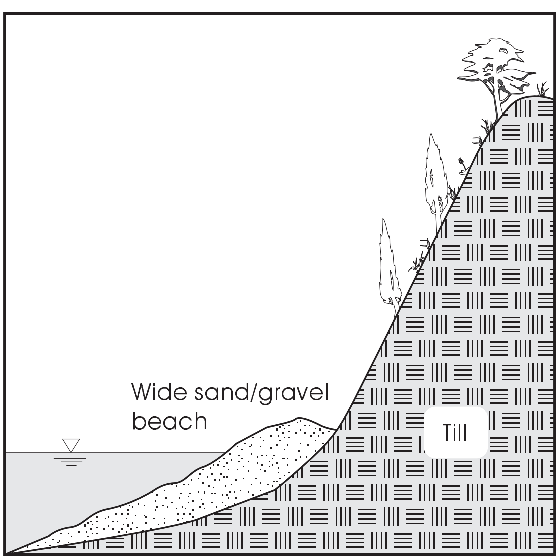


Example (b)

Controlling Substrate - Nearshore fine-grained cohesive.

General Shoreline Type - Onshore/Backshore cohesive low plain.

Surficial Substrate - Nearshore fine-grained cohesive.



Example (c)

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

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

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

2.3 PROCEDURE FOR CLASSIFYING AND MAPPING SHORELINE REACHES

Classifications, or definitions of shore type, and the subsequent mapping of these shore classifications are usually based on a defined length of shoreline unit, usually referred to as a shoreline reach (see Figure 2.1). Under the recommended shoreline classification scheme, a shoreline reach is defined as a stretch of shoreline where the onshore/backshore/nearshore consists of a single class (e.g., non-cohesive bluff with a bedrock (erodible) controlling substrate and cobble/boulder (shingle) surficial sediments in the nearshore, see Figure 2.11a) and where the shoreline has relatively uniform physical characteristics.

The alongshore boundaries of the shoreline reach are defined by either:

- a transition to a different shore type (i.e., from a non-cohesive bluff to a low plain cohesive shoreline, or from a low plain beach to a barrier beach), or

- a change in some significant shoreline characteristic within one shore type (i.e., a change in direction of net sediment transport, presence of a complete natural or artificial (i.e., large harbour jetty) littoral barrier, a significant change in bluff or cliff height, or a significant change in land use (i.e., urban to rural).

On most of the lower Great Lakes and connecting channels, shoreline reaches will typically be measured in terms of kilometres, usually ranging from between 0.5 to 20.0 kilometres in length. On the upper Great Lakes, particularly in areas where there are few development pressures (i.e., few influences on natural shore processes from human-related activities, actions and developments) and extensive areas of bedrock predominate, shoreline reaches can initially be much longer than 20.0 kilometres in length.

In the initial stage of shoreline assessment, maps at a scale of 1:10,000 to 1:100,000 will probably prove most useful for actual boundary definition. However, as the need for a more definitive delineation and assessment of shoreline reaches is required other sources of mapped information may be utilized. These may include the 1:2,000 FDRP mapping, 1:10,000 OBM mapping, accurate municipal mapping, consultants reports prepared as part of the development of Shoreline Management Plans, vertical aerial photographs, topographic maps, surficial and bedrock geology maps, shoreline classifications produced for the International Joint Commission, and local knowledge or information bases.

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

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

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

2.4 SOURCES OF INFORMATION

Integral to the initiation of any mapping process is the collection of background information, particularly those related to the physical characteristics of the shoreline and to the processes affecting the shoreline. This, combined with information obtained from field inspections, will generally provide the foundation for the determination of the classification of each shoreline reach, its alongshore boundaries, and ultimately, the definition and delineation of the *hazardous lands* along shorelines of the *Great Lakes - St. Lawrence River System*.

Some potential sources of information are listed as follows:

- Shoreline Management Plans - various local Conservation Authorities and Ministry of Natural Resources' offices.

- Geomatics International Inc. and Davidson-Arnott, 1992. Great Lakes Shoreline Classification and Mapping Study: Canadian Side. International Joint Commission, Great Lakes - St. Lawrence River Levels Reference Study Board.

- Reinders and Associates Ltd., 1988. Littoral Cell Definition and Sediment Budget for Ontario's Great Lakes. Final report prepared for Ontario Ministry of Natural Resources, March.

- Environment Canada/Ministry of Natural Resources, 1976. Coastal Zone Atlas, Canada-Ontario Shore Damage Survey.

- Boyd, G.L. 1981. Canada/Ontario Great Lakes Erosion Monitoring Programme - Final Report 1973-1980. Ocean Science and Surveys, Department of Fisheries and Oceans, Manuscript Report Series No. 12, Burlington, Ontario, Unpublished Manuscript, 200pp.

- Quaternary Geology Mapping - various, Ontario Geological Survey.

- Nearshore Sediment Characteristic Maps - various maps prepared by Dr. N. Rukavina at the Canada Centre for Inland Waters.

- Canadian Hydrographic Services Charts and Field Sheets.

- Chapman, L.J. and Putman, D.F., 1951. The Physiography of Southern Ontario: 2nd ed. 1966, University of Toronto Press, 385pp.

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

- reports from various government ministries and agencies which deal with the sections of the shoreline under review

- papers published in journals, university theses and any other documents dealing with various aspects of the shoreline and the processes affecting various shorelines

- aerial photographs from several different years, where possible, should be examined to determine changes in the shoreline through time. Of particular interest should be changes in the beach width over time (i.e., when using these sources, one should note that oblique aerial photographs and colour slides often provide better detail than black and white verticals)

- videotapes of the shoreline from a helicopter or small plane can often provide useful information, particularly where coverage over different periods in time are available (i.e., where this is not already available, the Conservation Authority/MNR Office should give consideration to the need, usefulness and acquisition of video coverage of the shoreline under their jurisdiction)

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

- fetch window or the range of directions from which waves approach and affect the shoreline unit;
- fetch lengths at 22.5^o angles for that fetch window;
- deep-water wave climate for the nearest offshore station based on studies carried out for the Ontario Ministry of Natural Resources;
- gross alongshore sediment transport patterns and the net volume of alongshore sediment transport into and out of the shoreline unit;
- sources of sediment supply to the shoreline unit (e.g., alongshore sediment transport from updrift, gully erosion, nearshore and bluff recession);
- nearshore bathometry from available hydrographic charts;
- historical rates of shoreline erosion/accretion based on at least a 35 year interval; and
- the limit of erosion/wave action during the 1953, 1972-73, and 1985-86 high water periods.

INDEX - PART 2

RECOMMENDED SHORELINE CLASSIFICATION SCHEME

TO DETERMINE SHORELINE REACHES