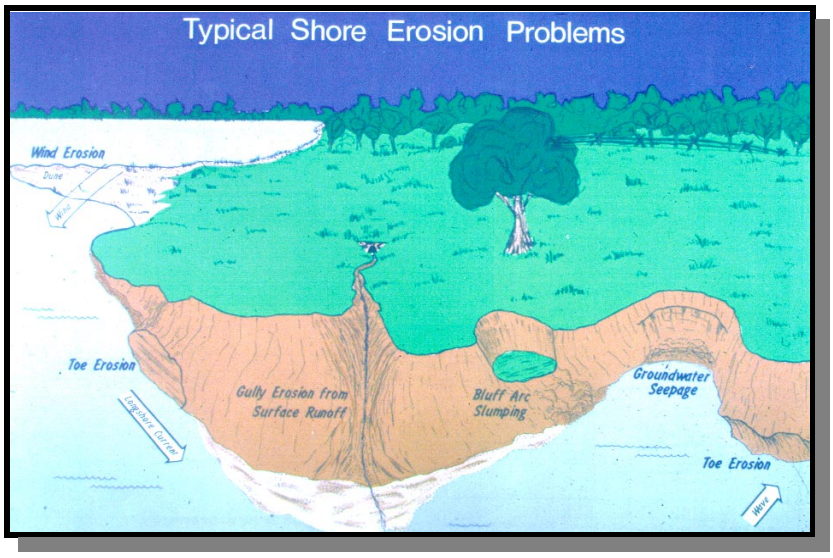
PART 1

THE GREAT LAKES - ST. LAWRENCE RIVER SYSTEM:

PHYSICAL FEATURES AND PROCESSES



GREAT LAKES - ST. LAWRENCE RIVER SYSTEM:
PHYSICAL FEATURES AND PROCESSES

TABLE OF CONTENTS

LIST OF FIGURES

APPENDICES

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX A1.1

APPENDIX A1.2

1.1 INTRODUCTION

Although the *Great Lakes - St. Lawrence River System* constitutes one of our most precious natural resources, their effects on shoreline residents are not always benign. Like other natural phenomena, the behaviour of the lakes and their connecting channels is often unpredictable and beyond human control.

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

The primary focus of Part 1 is to provide background information on the *Great Lakes - St. Lawrence River System* and introduce the dynamics of *flooding, erosion and dynamic beach hazards*. This introductory information is supported by Appendices A1.1 and A1.2 which describe in more detail the origin and evolution of the *Great Lakes - St. Lawrence River System* and the processes that control and influence shoreline changes. This discussion is outlined through:

- **Section 1.2** providing an introduction to the *Great Lakes - St. Lawrence River System*, describing the main components of the physical and biological system as well as human occupation of the Great Lakes basin.

- **Section 1.3** providing an introduction to the dynamics of *flooding, erosion and dynamic beach hazards* as they relate to the manner and location of human occupation and encroachment into the *Great Lakes - St. Lawrence River System* shorelines.

- **Appendix A1.1** providing background information on the most important processes and factors that control shoreline dynamics and evolution in the *Great Lakes - St. Lawrence River System.* This material is designed to provide an understanding of the nature of shoreline hazards and of the potential impacts of various approaches to hazard mitigation. To understand the processes currently affecting the evolution of the existing *Great Lakes - St. Lawrence River System* shoreline, this appendix provides a description of the relationship between the underlying bedrock geology and the development of the Great Lakes basin supported by a brief description of the history of ice sheets and the formation of glacial and post-glacial lakes within the basin. The section concludes with a brief description of the present lakes, including those features located within the United States.

- **Appendix A1.2** providing an overview of the interactions occurring between lake and land features and the factors controlling these interactions. To complement the discussion of lake/land interactions, this appendix reviews the effects of winds, waves and currents in controlling erosion, transport and deposition of sediments along the shoreline; the modifying effects of other factors such as ice and weathering; the sources of sediment supply to the shoreline; and concludes with a description of littoral cells, sediment budgets and shoreline sources and sinks.

1.2 THE GREAT LAKES SYSTEM

The *Great Lakes - St. Lawrence River System* is an extensive, significant, and physically and biologically diverse environmental resource. The system, consisting of a series of large lakes connected by channels or rivers, outlets into the Atlantic Ocean through it's largest connecting channel, the St. Lawrence River (Figure 1.1). Each of the system's lakes and connecting channels are considered to have their own unique combinations of interrelated and interdependent sets of terrestrial, wetland and aquatic environments.

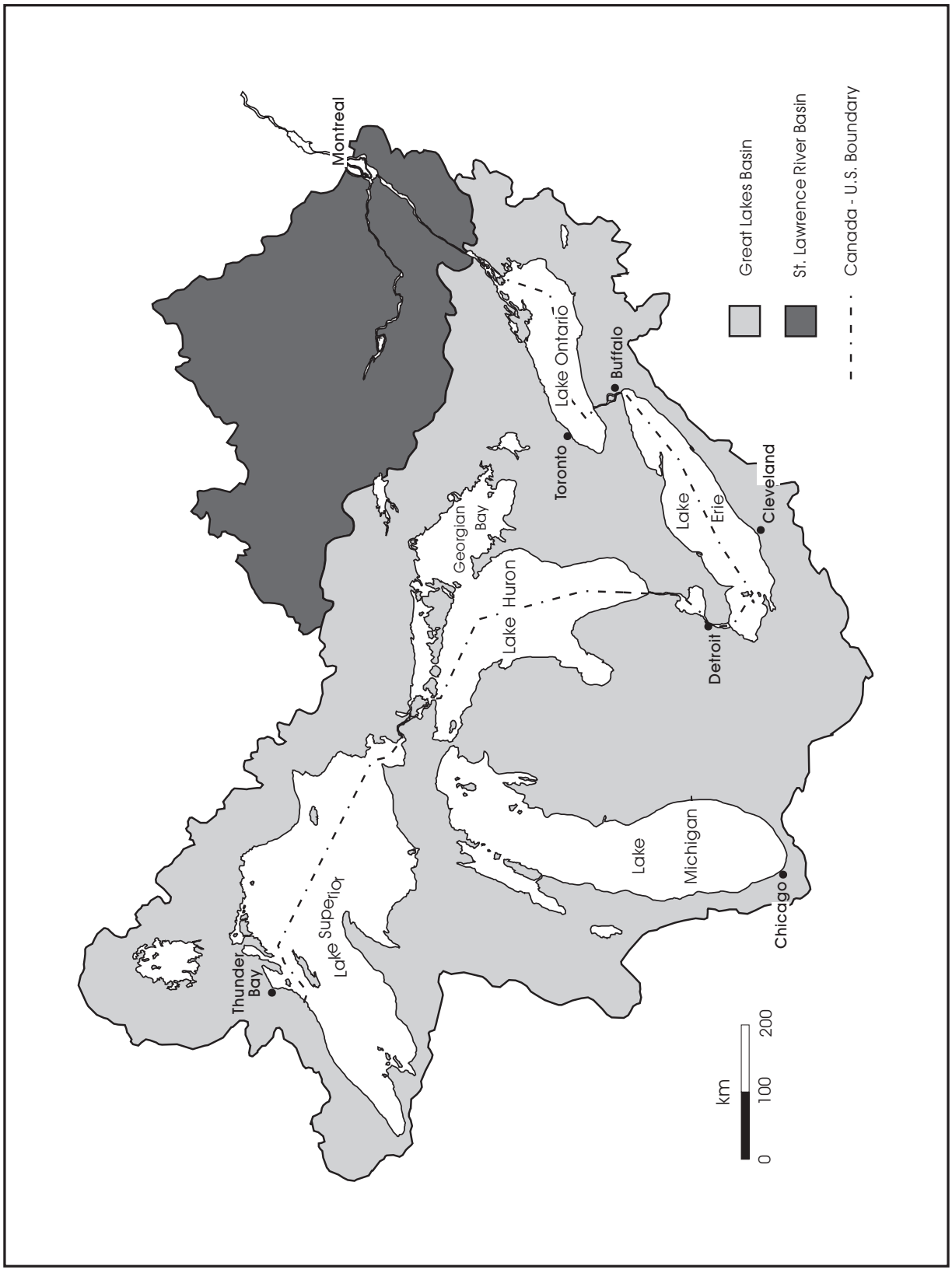
The shoreline of the Great Lakes, roughly 15,700 km in length, is complemented by an additional 4,800 km of shoreline along its connecting channels. The terrestrial, or landside portions of the shoreline consist of a diversity of shore types from erosion-resistant bedrock to highly erodible cohesive bluffs, to beach, dune and wetland complexes.

The Great Lakes, themselves, occupy about 244,000 km^2 or one-third of the 766,000 km^2 of the basin, and range in size from 82,100 km^2, Lake Superior, to 19,000 km^2, Lake Ontario. The lakes contain a variety of aquatic habitats, from deep, cool, oxygen-rich oligotrophic basins to shallow, warm eutrophic embayments. These habitats support numerous fish species and the many organisms upon which fish depend.

More than half of Ontario's population live within the shoreline communities of the Great Lakes - St. Lawrence River basin. Within the lower Great Lakes, the entire population of the basin lives within approximately two hours drive of one or more of the Great Lakes shorelines. This, in addition to the transportation capability, water supply availability, recreational opportunities and aesthetic features of the Great Lakes, attracts a wide variety of shoreline interests. Competition for use of the shoreline, by this diverse and growing range of shoreline interests, has and is continuing to place considerable strain on this limited and fragile resource.

In areas susceptible to flooding, erosion, dynamic beaches and to environmental degradation, the effects of ever increasing development pressures and competing interests have resulted in extensive and mounting property damages, risks to public safety as well as detrimental impacts to the shoreline ecosystem.

Figure 1.1: The Great Lakes - St. Lawrence River Basins



1.3 FLOOD, EROSION AND DYNAMIC BEACH SUSCEPTIBILITY AND HAZARDS

Having been developed and evolved from the naturally occurring processes of glaciation, ice retreat, isostatic rebound, water inundation, surface weathering (i.e., erosion, recession, accretion/deposition) and wind action, much of the *Great Lakes - St. Lawrence River System* shoreline continues to experience and provide evidence of these ongoing, naturally occurring processes.

In determining the appropriate shoreline management strategy for a given shoreline an assessment of these natural processes, the current status or factors impacting on the shoreline, and the intended or proposed use of the shoreline must be examined and balanced.

Evaluations of hazard existence, management and remediation are often based on two distinct and somewhat differing perspectives. These being that:

- flooding, erosion and dynamic beaches are naturally occurring processes which in and of themselves are not hazards, that they only become hazards when humans activities and development encroach within shoreline environments influenced by these natural processes. Activities which in some instances have accelerated the severity of the resulting hazards.

- flooding, erosion and dynamic beaches are hazards which must and can be addressed through various remediation measures (i.e., shore protection, lake regulation, floodproofing), and that the siting of development within shoreline environments is a right and should not be limited by the existence and/or susceptibility of hazards within the defined stretch of shoreline.

The distinct and subtle differences in these positions must be recognized when determining, interpreting and delineating such things as areas of hazard susceptibility, the degree of risk, options to hazard mitigation, and ultimately, in the development of an overall shoreline management strategy.

In general, the inundation of low-lying shorelines (i.e., flooding) and the loss of material from non-lithified shorelines (i.e., erosion) and the continuous adjustment of beach profiles (i.e., dynamic beaches) are considered to be natural processes rather than hazards. Early mapped information for the *Great Lakes - St. Lawrence River System*, has tended to generalize the existence and magnitude of hazards by defining all low-lying shorelines as flood hazards and all shorelines composed of non-lithified sediments as erosion hazards. The degree of hazard susceptibility and severity used in defining these areas has often been very subjective and can depend upon a number of factors including the presence or absence of human occupation.

For discussion purposes, the depiction of flood and erosion susceptible shorelines is provided in Figures 1.2 to 1.7. These depictions of flood and erosion susceptibility along the shorelines of the *Great Lakes - St. Lawrence River System* are based on the synthesis of a number of, often site specific, studies and investigations. These maps should be viewed as general representations of shoreline flood and erosion susceptibility and should not be considered as conclusive.

Flooding, in general, is a phenomenon which is sensitive to and influenced by water level fluctuations. Inundation of low-lying *Great Lakes - St. Lawrence River System* shorelines in and of itself does not necessarily constitute a significant hazard, depending of course, on the type, design, location and density of any development which may exist in or near the flood inundated shorelines. However, where flooded lands are coupled with storm events their cumulative impact can and frequently does pose significant degrees of risk, often over extended periods of time. Of importance in managing a potential flood susceptible shoreline is the need to understand the interrelationship between pre-storm flooding, storm setup, wave height, wave uprush and other water related hazards (i.e., wave spray, ice). If the area of inundation is a wetland or an undeveloped area, the resultant "damage" caused by a storm event may be minimal if measured in terms of human losses (i.e., property and life). Indeed, periodic flooding of wetland complexes have been found to be beneficial for the continued maintenance and enhanced diversity of wetland vegetation itself, by helping to eliminate the invasion of water sensitive upland vegetation into low-lying

Figure 1.2: Flood and Erosion-Prone Areas: Lake Superior

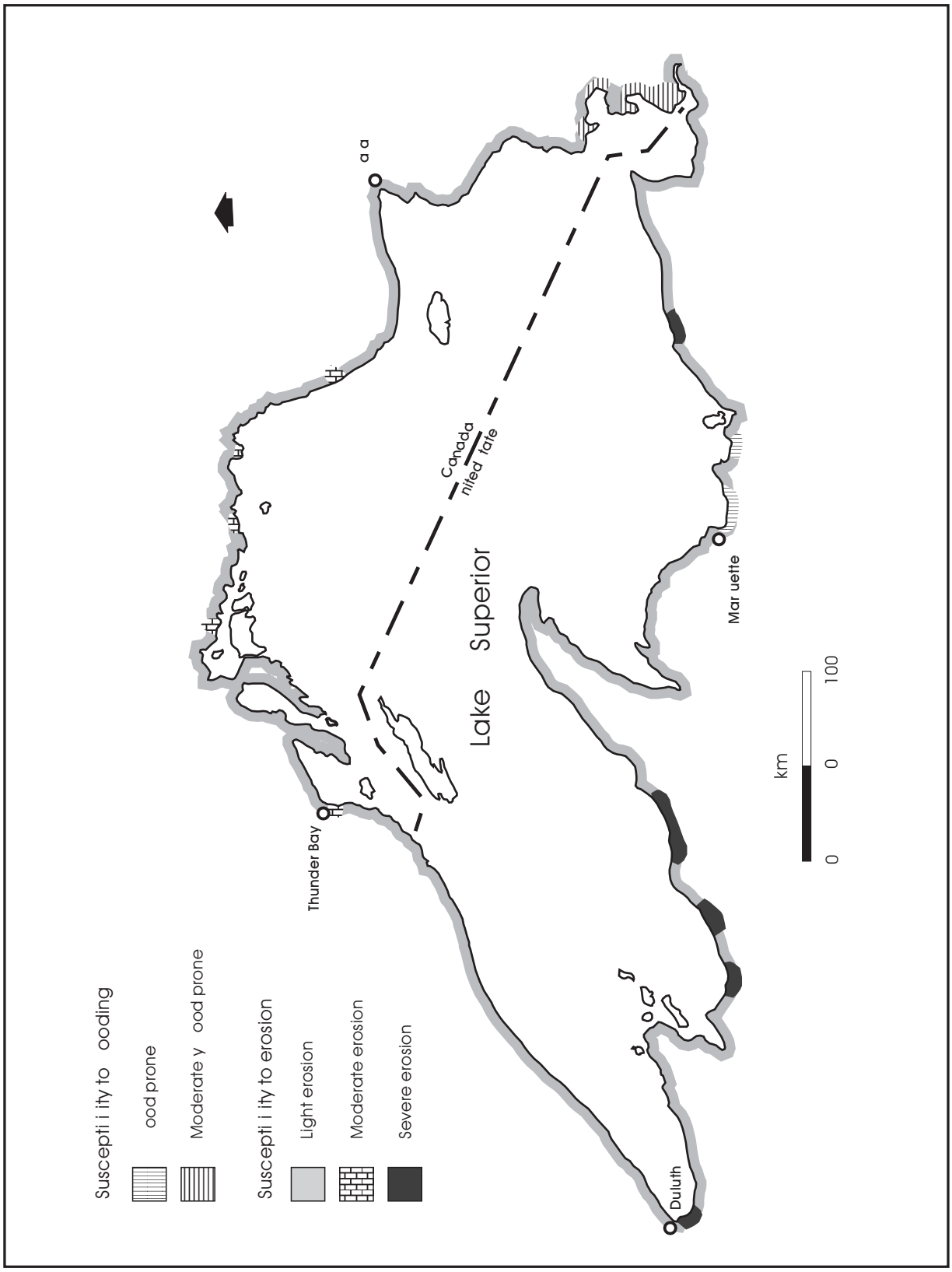


Figure 1.3: Flood and Erosion-Prone Areas: Lake Huron

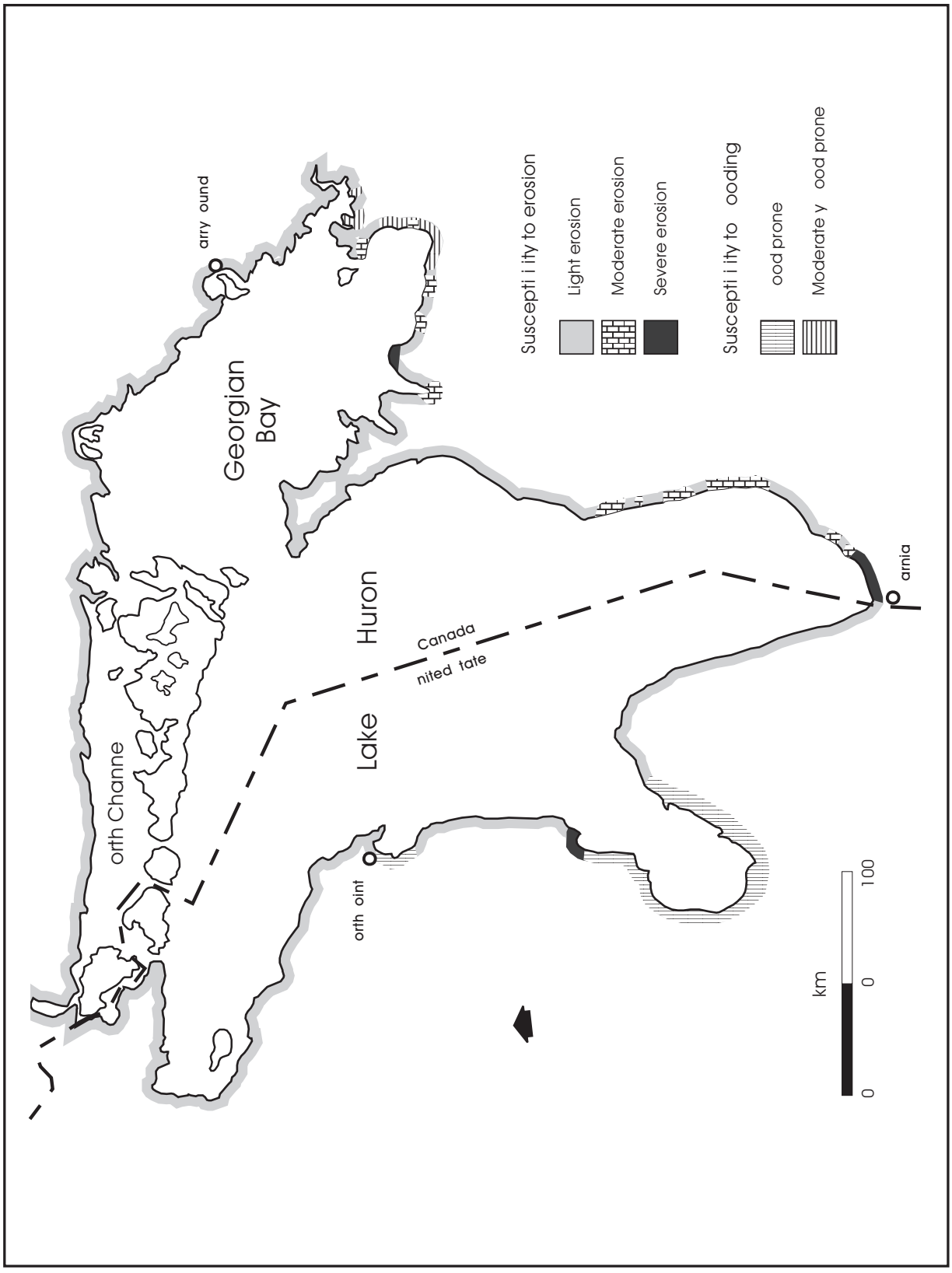


Figure 1.4: Flood and Erosion-Prone Areas: Lake Michigan

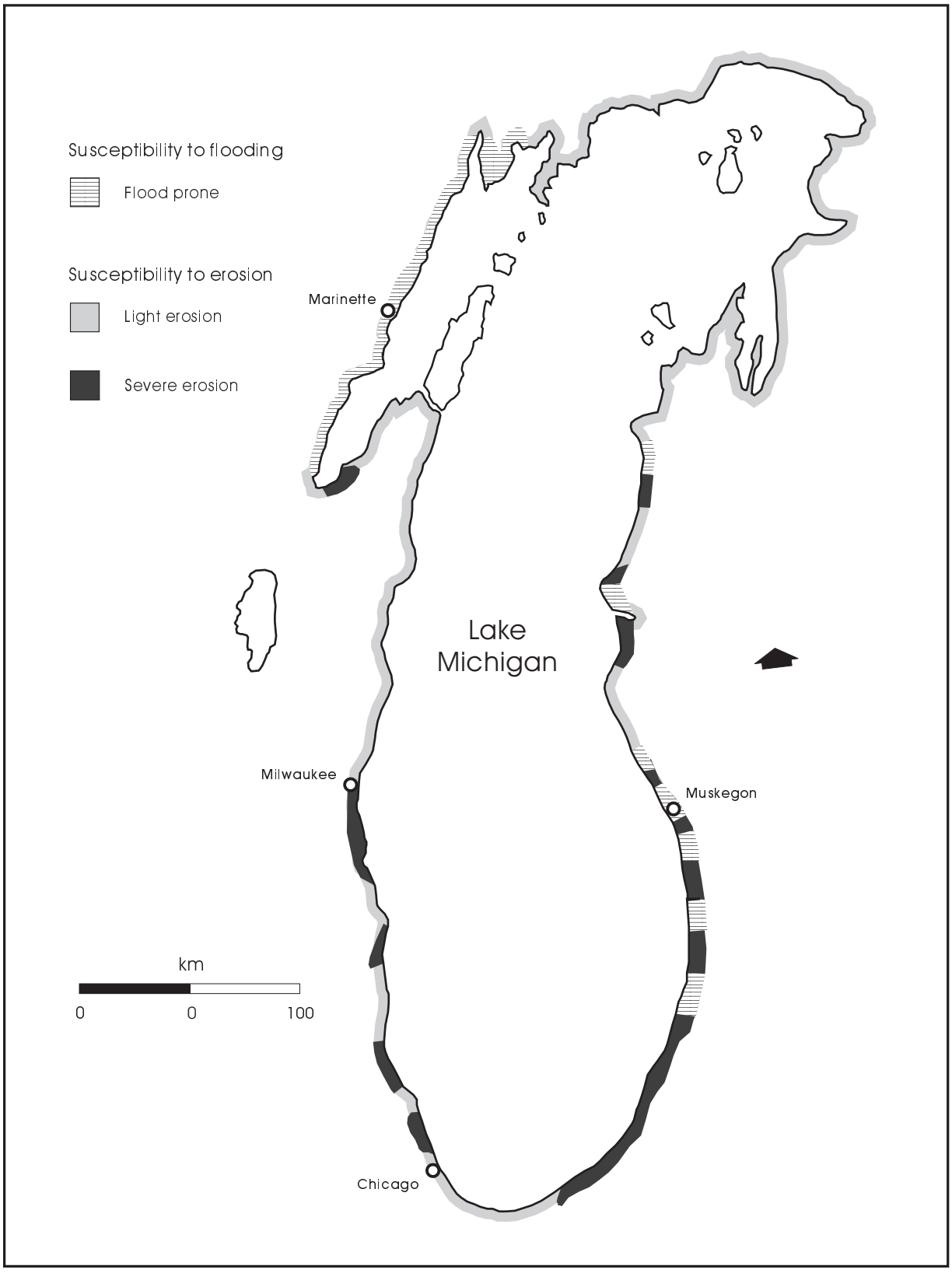


Figure 1.5: Flood and Erosion-Prone Areas: Lake Erie

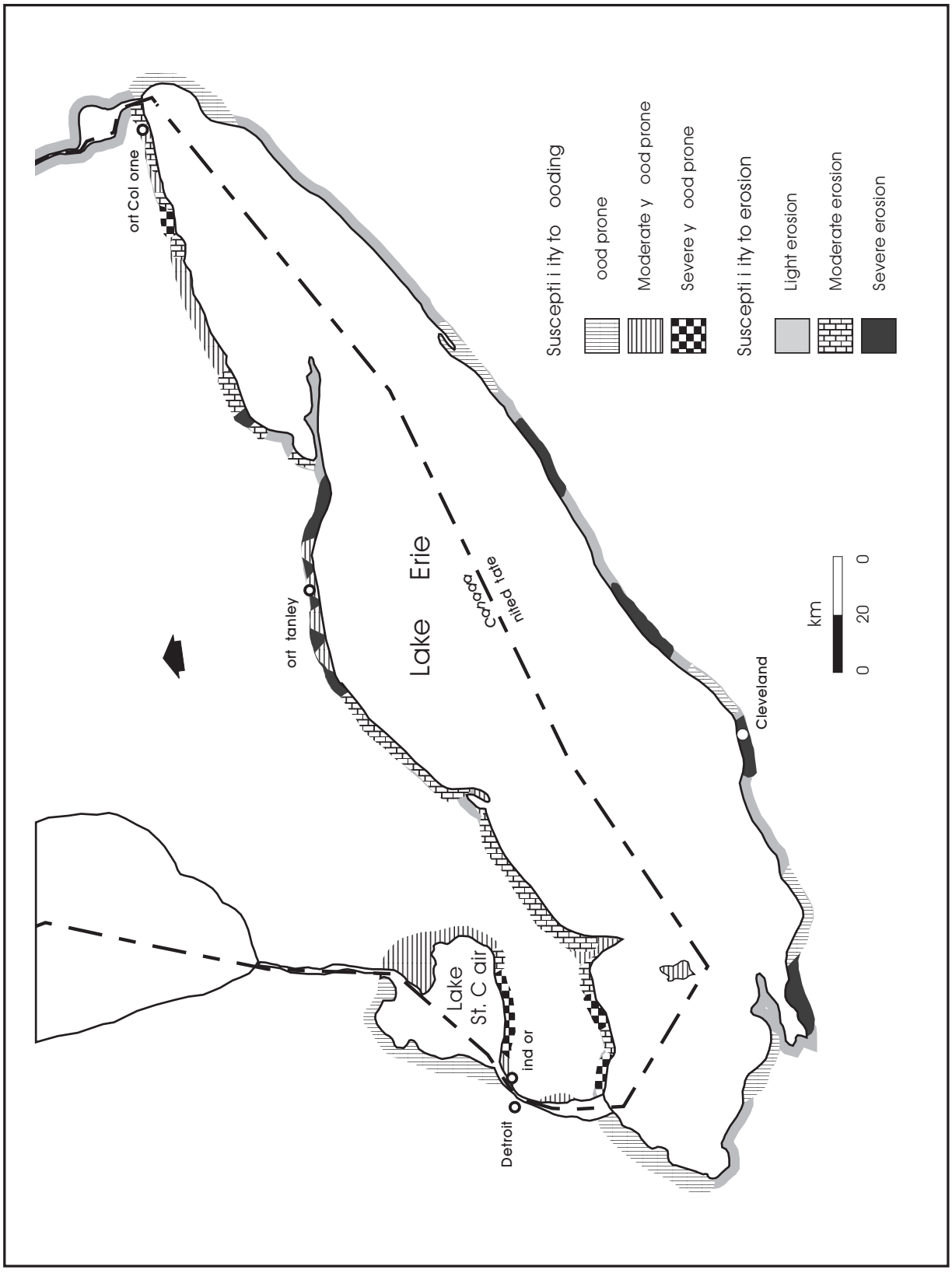


Figure 1.6: Flood and Erosion-Prone Areas: Lake Ontario

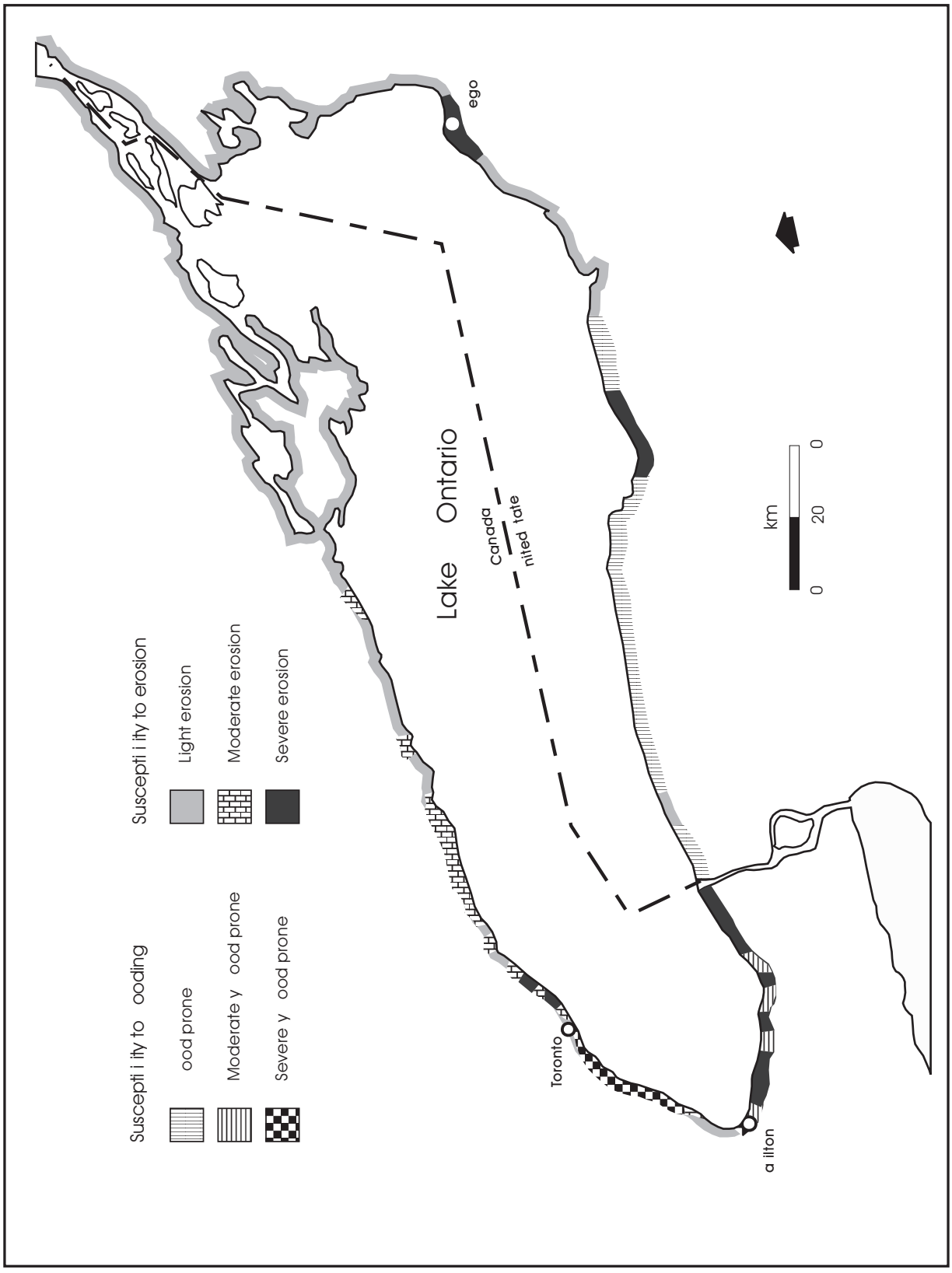
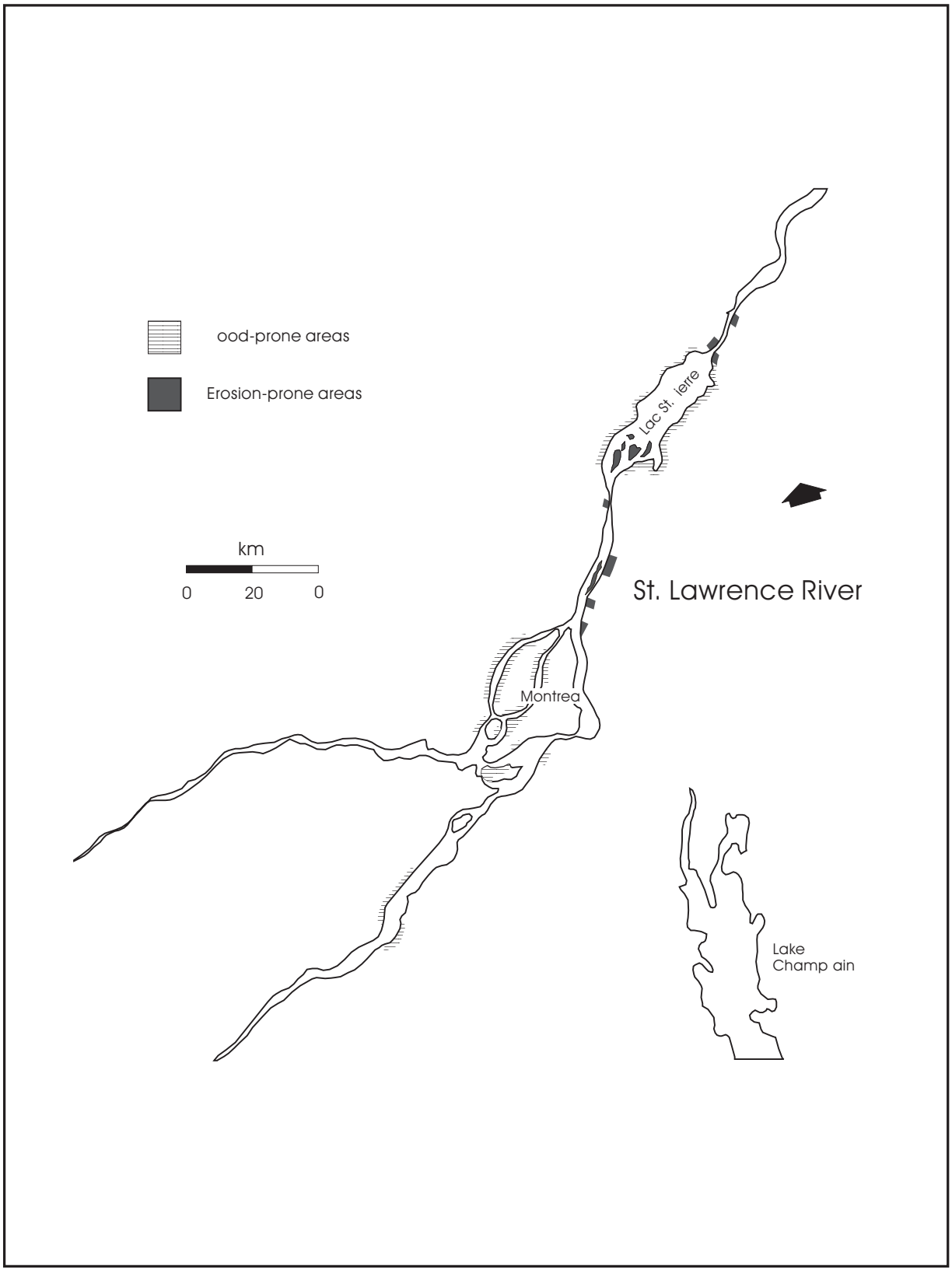


Figure 1.7: Flood and Erosion-Prone Areas: St. Lawrence River



shorelines during periods of low water levels. In terms of human use and occupation of the low-lying *Great Lakes - St. Lawrence River System* shorelines, development decisions based on or during periods of low water levels ironically present the most serious problem. During lower water levels, the potential flood hazard to homes, cottages and other development often goes unrecognized. Consequently, when water levels return to long-term averages or high water levels, flood damages are sustained, damages which are frequently quite significant.

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

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

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