TECHNICAL GUIDE FOR
GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

PART 4

EROSION HAZARD

EROSION HAZARD

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4.1 INTRODUCTION

Many geological, topographical and meteorological factors determine the erodibility of a shoreline. These include soil type, surface and groundwater, bluff height, vegetation cover, shoreline orientation, shoreline processes, wind and wave climate and lake level fluctuations. Erosion over the long-term is a continuous process influenced by these lakeside (i.e. wave action, water levels) and landside factors (i.e., surface/subsurface drainage, loading/weight of buildings, removal of surface vegetation).

The rate of erosion may be heightened during severe storm events, resulting in large losses of land over a very short period of time. These large losses, which are more readily visible immediately following major storm events, at times can obscure the more continuing long-term processes.

To slow the erosion of shorelines, structures such as breakwaters, seawalls and revetments have been used. Often these attempts have proven futile and very expensive. Studies have indicated in numerous locations that they may have caused more problems than they solved. These problems usually occur on updrift and/or downdrift properties, aggravating existing off-site hazards, and/or posing unacceptable detrimental impacts on a wide array of environmental components of the shoreline ecosystem (e.g., fisheries, wetlands, water quality).

A continuously changing shoreline limits the ability of humans to intervene (i.e., due to costs of properly designed/installed structures frequently being too high for individual residents and the long-term maintenance costs/requirements). This reality clearly demonstrates the need for individuals and implementing agencies to better recognize, understand and adapt to these changes rather than attempt to structurally alter or control these naturally occurring phenomena.

When making land management and land use management decisions there is a need for shoreline interests to better understand the natural processes at work along their shoreline and to ensure that selected non-structural or structural protection works are properly designed, installed and maintained to enhance the long-term functionality and benefits.

In examining these issues, the intent of Part 4 of this Technical Guide is to provide an indepth analysis of the *erosion hazard* as defined in the *Provincial Policy Statement (*i.e., Policy 3.1, Public Health and Safety: Natural Hazards). For purposes of clarification, Part 4 will examine the factors influencing the definition, types, controlling parameters, and potential impacts associated with erosion processes in the following manner:

- **Section 4.2** outlines the principle parameters controlling *Great Lakes - St. Lawrence River System* shore erosion, describes erosion and slope stability processes, and discusses the range of visible evidence or indicators of shoreline erosion (supported by the technical support document ***Geotechnical Principles for Stable Slopes*** (Terraprobe 1997))
- **Section 4.3** presents the ***erosion hazard*** defined in accordance with the *Provincial Policy Statement* (1996) and the supporting Natural Hazards Training Manual (1996)
- **Section 4.4** describes in detail the concept of **stable slope** and the **accepted geotechnical principles** (supported by the technical support document *Geotechnical Principles for Stable Slopes* (Terraprobe 1997))
- **Section 4.5** describes in detail the concept of **average annual recession rate** and provides direction on the general data sources, procedures to calculate recession rates and accuracy considerations (supported by Appendices A4.2 to A4.6)
- **Section 4.6** addresses the possible **adjustments to the erosion allowance**

- **Appendix A4.1** provides an overview of the **methods of determining rates of gully development, growth and advancement**
- **Appendix A4.2** provides an overview of the use and utility of **historic recession studies** in determining shoreline recession rates
- **Appendix A4.3** provides an overview of the use, utility and limitations of **historic map and aerial photographs** in determining shoreline recession rates
- **Appendix A4.4** describes the various **methods to create historic-recent shoreline position maps**
- **Appendix A4.5** describes the various **methods to create historic-recent digital shoreline position maps**
- **Appendix A4.6** describes the **methodologies** to **monitor shoreline recession**

4.2 SHORELINE EROSION PROCESSES

There are many processes that lead to erosion and deposition of sediments along the *Great Lakes - St. Lawrence River System* shoreline. Each process is dependent on a number of different factors that operate within different time frames.

As discussed in Part 1: Great Lakes - St. Lawrence River System: Physical Features and Processes (Section 1.1, 1.2), in terms of a geologic timeframe, the lower Great Lakes are evolving into large, oblong, shallow basins, as material is eroded from the shore zone and deposited into the deeper portions of the lakes. Within this same geologic timeframe, the lakes are also tilting slightly due to isostatic rebound of the land mass, the result of glacial ice retreat following the last ice age, which in turn is affecting water levels and relative rates of erosion.

Within the more recent timeframe, measured in terms of hundreds of years, headlands, bays and other features are undergoing continuous change as large parts of the shores of the lower Great Lakes slowly retreat. The rate of erosion or recession is primarily dependent on the strength of the shore materials and the exposure of the shore to wave action. Other contributing factors include long-term changes in water levels, changes in land use patterns, and alterations to surface and subsurface drainage. Although erosion is a naturally occurring and continuous process, the short-term impacts of excessive wave action and heightened water levels, particularly during storm events, tend to cause the more readily visible, short-term destruction and shore losses. Evidence of these losses is typically visible in the undermining and collapse of shore bluffs or through the rapid changes in beach profiles.

4.2.1 Parameters Controlling Shoreline Erosion

The following provides a listing of the principal parameters controlling erosion within the *Great Lakes - St. Lawrence River System*:

- **Shoreline geology** — The largest part of the erodible shoreline consists of bluffs composed of glacial sediments which include silt, clay and granular deposits. The remaining shore consists of wetlands and rock outcrops.

- **Shoreline orientation, and adjacent bathymetry** — The nearshore bathymetry plays an important role in controlling wave action on the shore. The orientation of the shore, relative to the prevailing winds and storm waves, is important in determining rates of erosion and the characteristics of any beaches that may form.

- **Waves** — Waves are the most important force contributing to erosion.

- **Water Levels** — Water levels control the elevation at which waves will impact on the shore and will influence the amount of energy available for erosive processes.

- **Nearshore Currents** — Although nearshore currents are relatively weak and have only a minor direct importance in causing erosion, they are critically important in their influence on shore processes. Nearshore currents are important in shore processes as they carry sediments that has been stirred into suspension by the turbulence of breaking waves, and remove the sediments along the shore or lakebed. This process is fundamental in the formation of many shoreline features.

- **Ice** — Ice cover can in one location, protect the shore and in another location, be the cause of erosion and damage to the shore and to protection works located along the shore.

- Wind — Wind action, or aeolian forces, as a separate process (i.e., beyond their influence in wave generation and wave action) are important forces acting on the shore. In particular, wind has a primary role in the formation of beach sand dunes and the erosion or transport of weathered sub-aerial bluff material.

- Groundwater — The movement and action of groundwater within shore bluffs can saturate the upper, relatively pervious, sediments in the bluff profile. As a result, bluff stability can be seriously impacted to the point where the bluff feature may no longer be able to support the weight of the upper layers of pervious sediments. This leads to the slumpage of large sections of the bluff. The slumped bluff material is then further broken down and transported alongshore or offshore by wave action. Seepage and channelization of groundwater along the bluff can also lead to localized erosion problems (i.e., gulleying).

4.2.2 Erosion and Slope Stability Processes

Erosion and slope instability are two different processes which are often associated together (Figure 4.1). The erosion process affects the soils at the particle level, by dislodging and removing the soil particles from the parent mass. Water movement is often the agent (Figure 4.2), commonly occurring in one of the following manners;

- wave action (i.e., shorelines of lakes, bays);
- rainfall or snowmelt and surface runoff (e.g., sheet or rill or gully erosion);
- internal seepage (e.g., springs) and piping; and
- surface water flow.

Other processes such as wind and frost may assist in the weathering or dislodging and transport of soil particles.

Slope failures (i.e., instability) consist of the movement of a large mass of soil (Figure 4.3). Slope movement or instability can occur in many ways but is generally the result of:

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

One very common event is for "toe erosion" to trigger slope instability, due to steepening or undercutting of the slope. Water seepage or groundwater levels can also affect slope stability since they affect the slope strength. "Piping" on a slope face can be related to "springs" or seepage, where soil erosion occurs in water bearing sands and slopes.

Initial formation of shoreline slopes takes place through cycles of water erosion, followed by stabilization and re-vegetation (Figure 4.4). Stabilization occurs when the slope reaches a stable angle, and soil movement stops. Vegetation then becomes established on the stable slope mass, which provides protection against surface erosion. Sloping surfaces are prone to increased erosion due to the increased flow velocities and to the increased concentration of flow quantity, or duration.

Environmental influences (e.g., climate and heavy rainfall) may interrupt stabilization by causing new erosion that can trigger or re-initiate slope movements. Studies have found that along river valley slopes, low intensity but long duration storms seem to produce more slope failures related to toe erosion (i.e., water flow along toe). Comparatively along lake shoreline slopes, sustained storms or high lake levels tend to produce more slope failures influenced by toe erosion (i.e., wave attack on toe).

Figure 4.1: Erosion and Slope Stability Processes

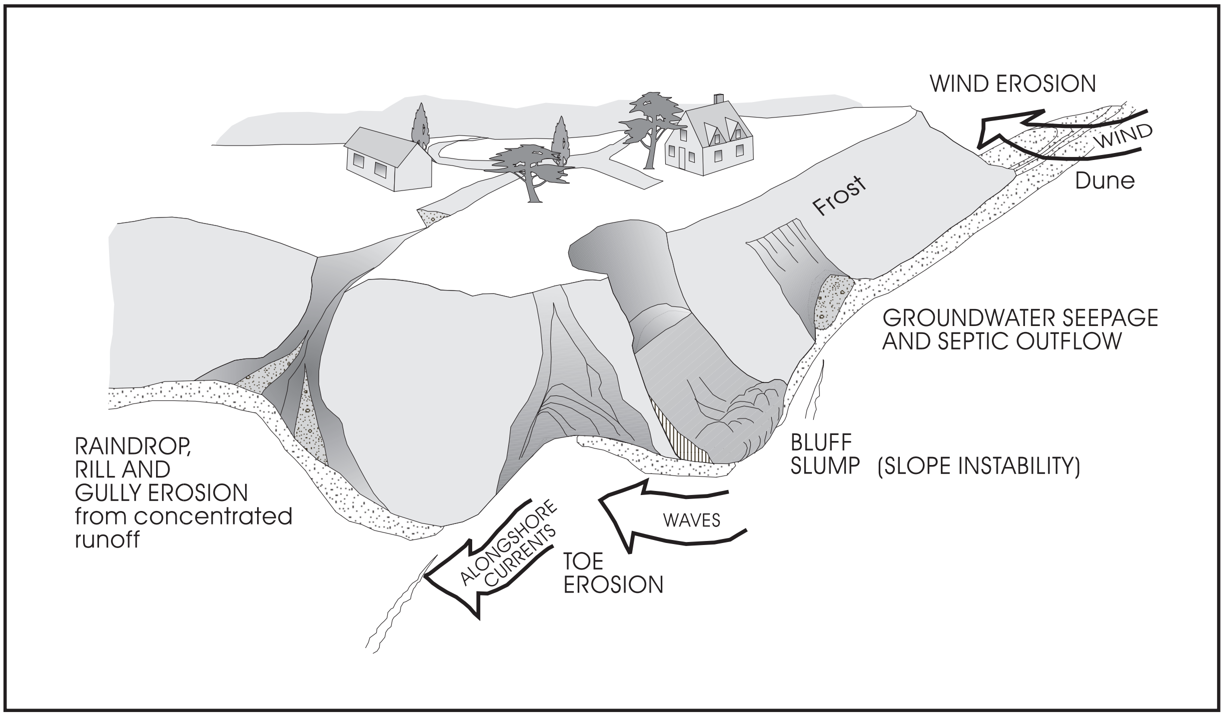


Figure 4.2: Water Action on Soil

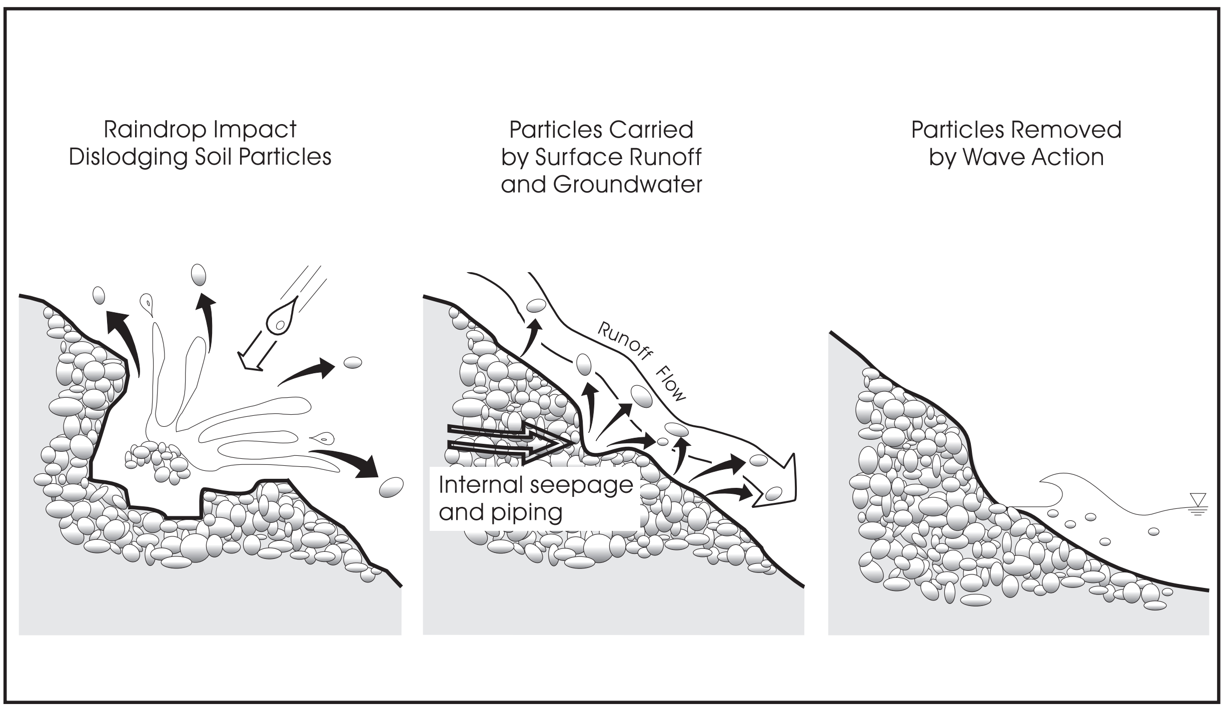


Figure 4.3: Slope Movements

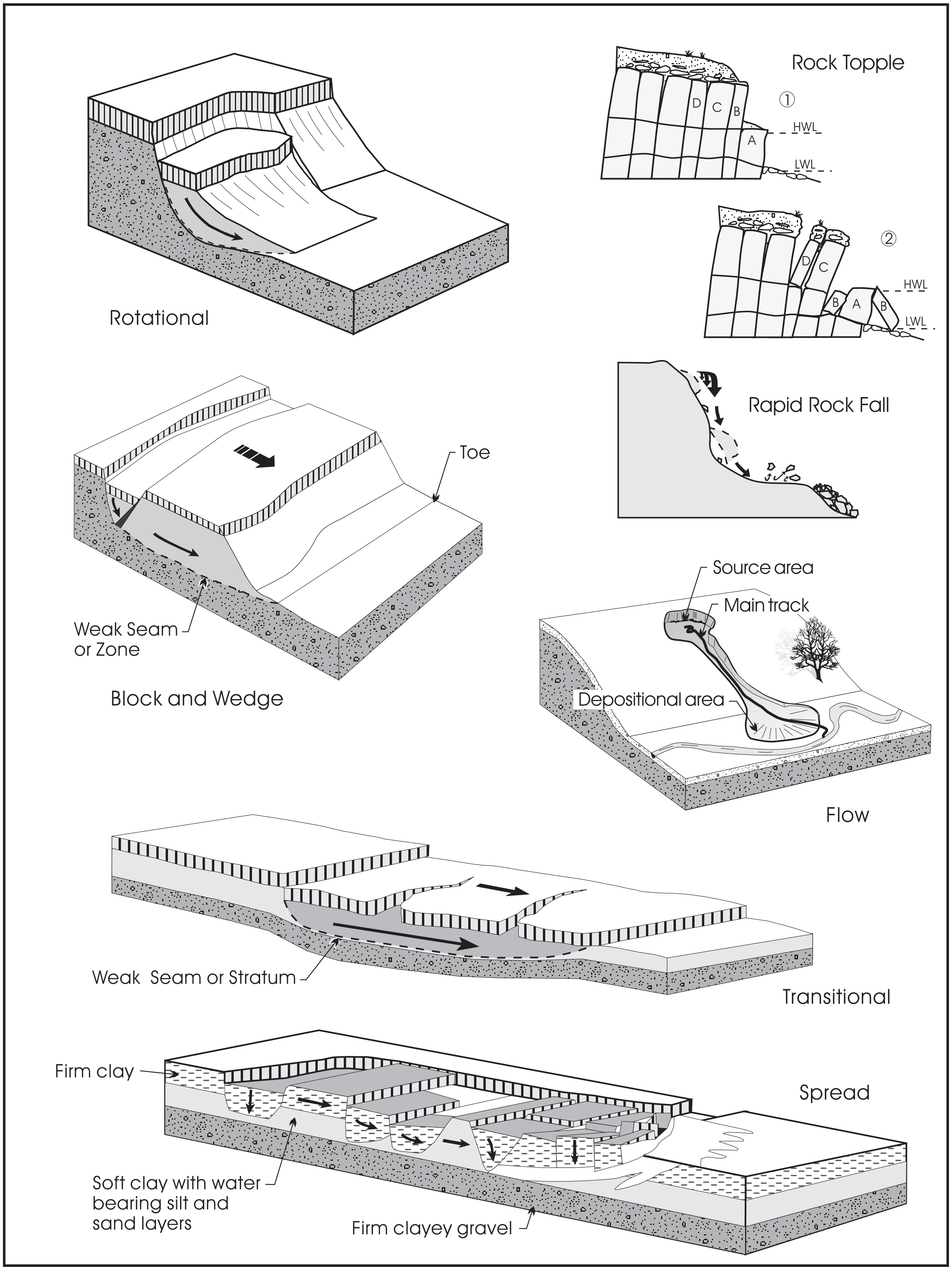
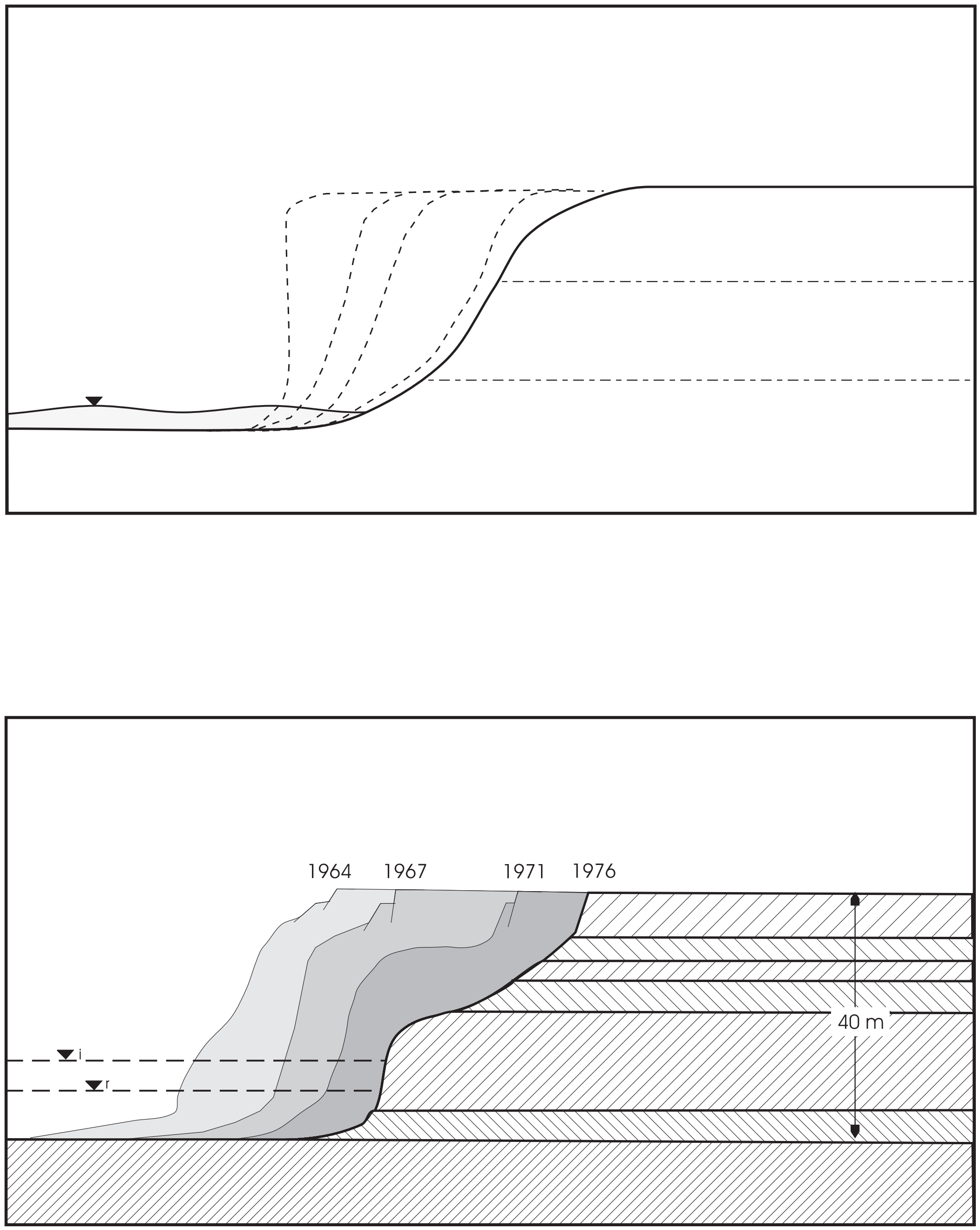


Figure 4.4: Depiction of a Slope Becoming Stable



a) Wave Action

The primary erosional process impacting on cohesive and erodible bedrock profiles, along the open shorelines of the *Great Lakes - St. Lawrence River System*, is direct wave action on the subaqueous nearshore profile, resulting in the erosion, or downcutting, of the lakebed material (Figure 4.5). This ongoing downcutting allows waves to reach the slope toe over the long-term. Nearshore downcutting is described in greater detail in Appendix A1.2 of the Technical Guide. In addition, wave uprush and abrasive effects of entrained coarse sediments which accompany the wave action, cause an additional erosional impact on the subaqueous nearshore profile and toe of a bluff or bluff face. It is this combination of wave action and accompanying abrasive forces that essentially act to dislodge the shore material which is then quite often quickly removed by alongshore currents.

Shoreline bluffs subject to wave action at the slope toe, commonly experience cycles of erosion and slope instability leading to crest recession (i.e., loss of tableland). Erosion may start when lake levels rise and cover previous beach areas along the bluff toe. This allows wave action to undercut (see Figure 4.6) and locally over-steepen the slope toe. Similar to gully and river erosion, this toe undercutting triggers the loss of vegetation cover near the slope toe, which progressively spreads up the slope face. This in turn sets in motion a whole series of subaerial processes (e.g., gravity, groundwater) in an effort to restore an equilibrium slope through bluff or bank failure. These subaerial forces usually tend to include slumps, slides, falls or flows (Figure 4.3). Over the long term, the continued erosion of the bluff and bank toe by wave action and the continued lateral retreat of the entire shoreline profile is perpetuated by the ongoing downcutting of the nearshore profile.

Along shorelines where the downcutting process is limited due to the presence of a rock outcrop, a thick deposit of sand on the nearshore profile, or a rapid decline in water levels, erosion of the shore bluff or low plain will be dominated by subaerial processes. In these situations, the bluff will ultimately establish a stable slope position while the low plain will return to a continuous gentle sloping plain. There may be infrequent episodes of bluff undercutting during periods of extreme high water levels.

The most important initial step in stabilization of bluff erosion is to ensure that the slope toe is protected from wave action, where possible, prior to undertaking slope works. Any protection works should consider the ongoing nearshore downcutting and possible effects on the littoral system and sediment transport.

b) Rainfall, Snowmelt and Surface Runoff (Gully Erosion)

Rainfall, snowmelt and runoff can lead to gully erosion of the bluff. Gully development is common on high bluff shorelines along the Great Lakes where surface drainage becomes concentrated and where erosion goes unchecked. The process begins with the accumulation or concentration of surface runoff in narrow channels, which then experience progressive erosion and the formation of larger channels or gullies. The gully erosion process is attributed to two actions:

- downcutting of the gully base by swiftly flowing water; and
- slumping or failure of the gully banks causing the gully to become wider.

Gully development typically starts at the slope toe and progresses up the slope face to the slope crest and into the tableland (Figure 4.7). It also can be initiated inland by natural drainage processes or by human-made drainage features such as storm sewer outfalls, ditches, and farm field tiles. The typical gully erosion process is summarized as follows:

- sufficient runoff drainage to disrupt natural vegetation cover;
- establishment of a drainage channel and start of downcutting;
- channel banks steepen by continuing base erosion, until slope failure;
- gully widens with slope slides, and debris interrupts downcutting;
- cycle of downcutting and slumping is repeated after debris is washed away and downcutting resumes; and
- gully can mature once stable gradient is achieved by drainage flows.

Figure 4.5: Downcutting of Nearshore Profile

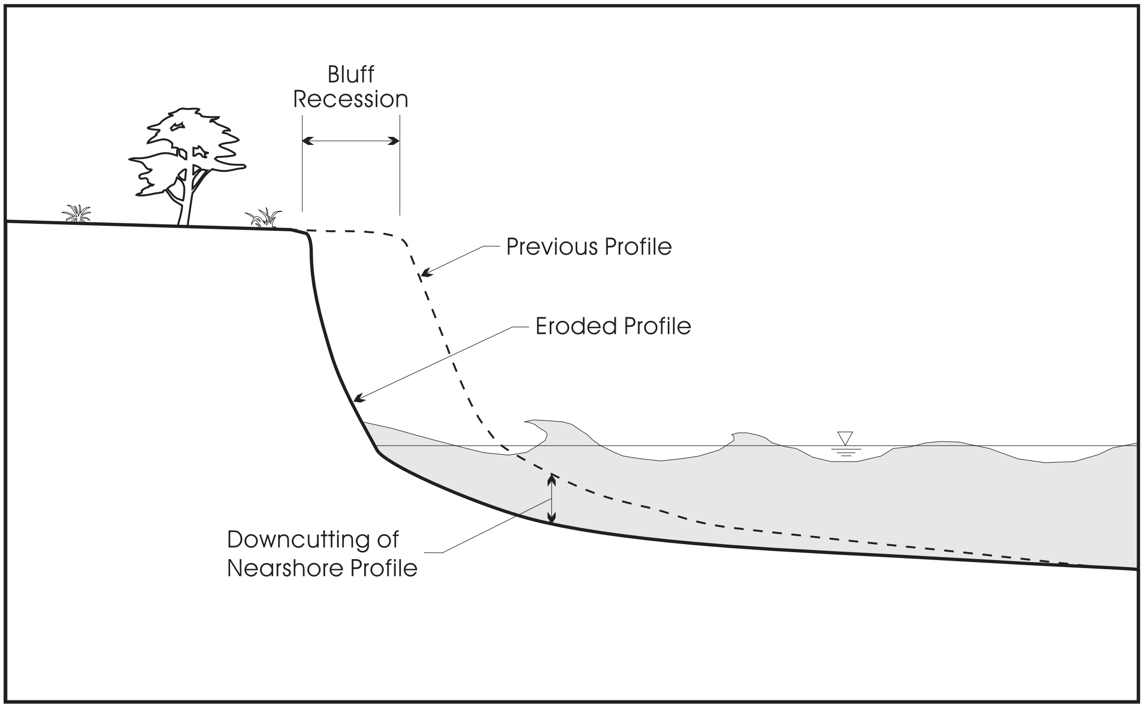


Figure 4.6: Undercutting of Bluff Profile

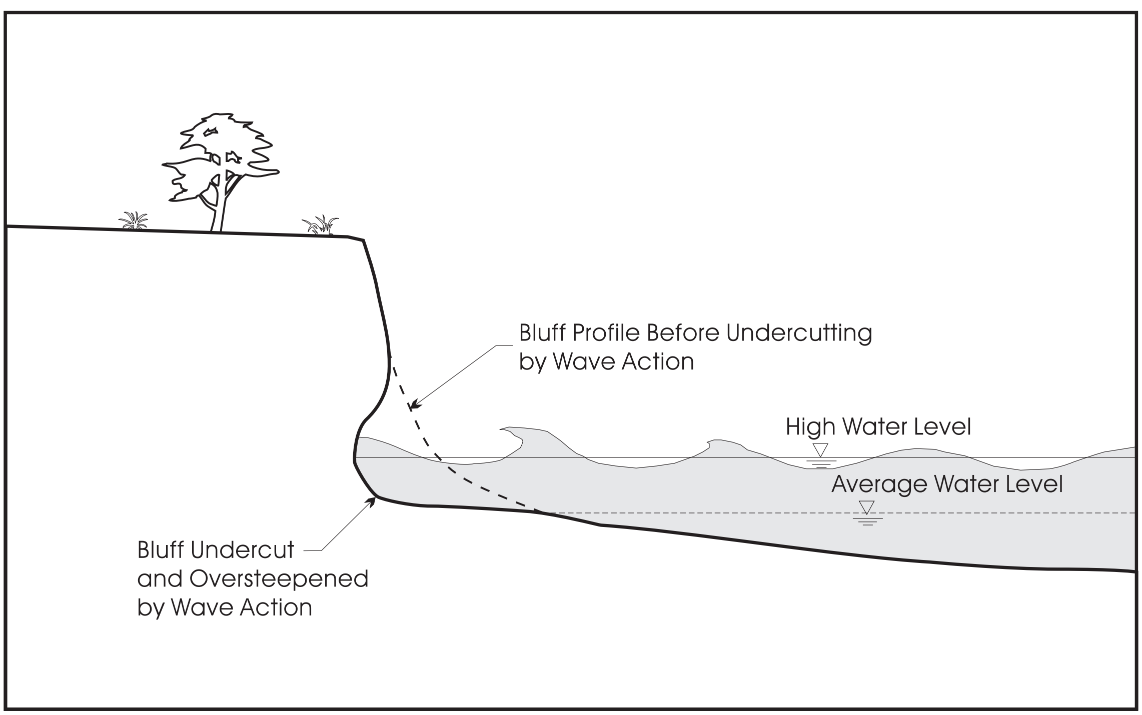
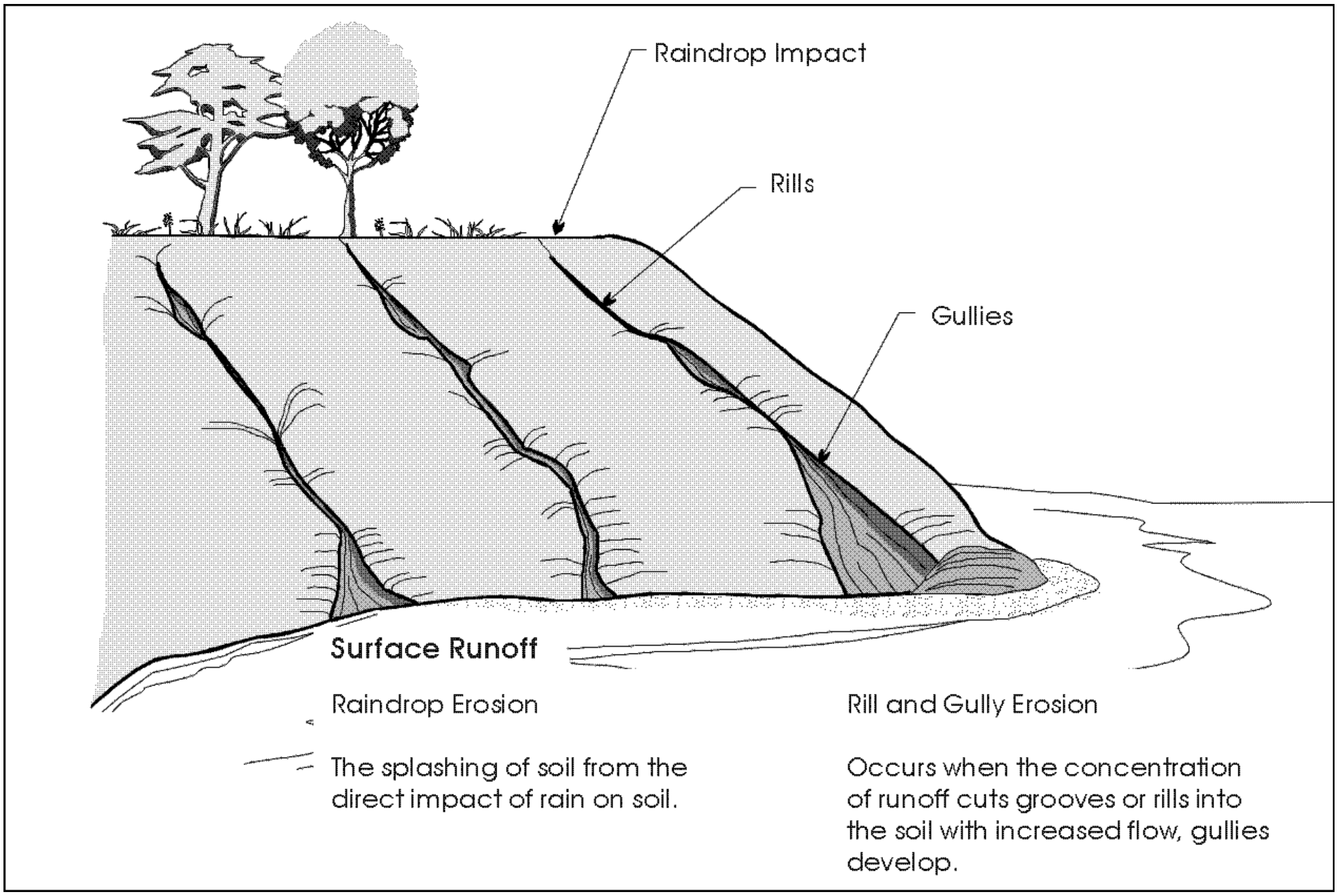


Figure 4.7 Gully Erosion



Erosion of the gully base followed by slumping of the side-slopes, will result in the gully slope crest receding and the loss of tableland. The erodibility is influenced predominantly by the nature of the soil, and by the slope gradient (i.e., steepness). Strongly bonded cohesive soils (e.g., clays, clayey silts, tills) are generally less erodible than cohesionless soils (e.g., sands, silts).

For further information on procedures to predict gully growth and advancement rates, factors contributing to gully advancement, and methods of predicting historic gully erosion rates see Appendix A4.1 of this Technical Guide.

c) Internal Seepage

The cohesive strength within a bluff feature depends on the packing and arrangement of particles in each layer and in the cementing of these particles. In general, the presence of water has a profound influence in determining the cohesive strength of unconsolidated and poorly consolidated materials by acting as a lubricant between particles or between sedimentary layers and as such, decreasing cohesion. In addition, groundwater that is acting under pressure can have the effect of forcing the particles apart and placing them in full or partial suspension, leading to a significant weakening of the cohesive strength of the material.

The sedimentary layering of a bluff influences the movement and location of the groundwater. The interaction of groundwater and sedimentary layers is illustrated in Figure 4.8. The generalized shore profile depicted in Figure 4.8 has a surface till strata underlain by a porous sand strata which is overlying an impervious clay strata. As rain falling on the ground infiltrates the surface and percolates down through the pervious soil, till and sand strata, the downward percolation is halted by the impervious clay layer. The groundwater is then forced to flow over, or parallel to the clay strata until reaching the bluff face. As the groundwater nears the face of the bluff slope, the water flow velocities in this area may increase and lead to erosion at the point of exit or seepage at the bluff face. If the strata above the impervious clay layer is generally composed of weak consolidated or unconsolidated material, an increase in groundwater velocity and localized erosion may also lead to the formation of pipes into the bluff face or cause the formation of gullies as the water seeps out and down the bluff face to the lake below.

Overall, water is generally regarded as the most significant cause or initiator of slope failures. As such, any hydrologic change to either surface or groundwater patterns can pose a direct impact on slope stability. Beyond the lubricating influence of groundwater within a shore profile, the accumulation of groundwater combined with the natural action of gravity and the overall weight of the groundwater itself will lead to a reduction in slope stability.

d) Water Flow

Flowing water in the connecting channels can cause surface erosion of the bank or channel walls. This erosion can affect the toe of a larger slope thereby causing steepening (i.e., undercutting) and likely slope instability (Figure 4.9). The erosion is usually due to increased flow velocities from climatic events such as heavy rains or snowmelt. Locations where there are changes in flow direction such as the outside bends in the connecting channel alignment are particularly susceptible to bank erosion.

The most important initial step in the stabilization of channel erosion is to ensure that the slope toe is suitably protected from the water flow, prior to undertaking slope works.

e) Slope Failure or Instability

Through prolonged natural weathering, most slopes tend to achieve a stable inclination and vegetation cover. Changes or disturbances to the slope conditions can result in slope slides whereby the slope is attempting to assume a more stable flatter inclination (Figure 4.10). Slope failure or instability involves the sudden movement or sliding of a large mass of soil over a failure plane or slope plane. Slope movements or failures tend to occur rapidly compared to erosion processes. The movement often leaves a "scarp" at the top of the slope and a zone or block of slumped ground below.

In comparison to nearshore downcutting (see Figure 4.5) which tends to involve a fairly continuous erosional process, the failure and subsequent erosion of an unstable, over-steepened bluff form tends to be periodic or cyclic in nature. Consequently, over short periods of time the unstable, over-steepened bluff may appear to have little if any erosion occurring, then suddenly a large portion of the bluff top will slide, slump or fall into the nearshore. This will be followed by a subsequent "quiet" period. During this time, the slumped material is broken down and transported alongshore or offshore by waves and currents and the undercutting process at the toe of the bluff recommences leading to the next cycle of bluff failure. Although the rate of erosion over the short-term may appear to vary considerably, over the long-term, with repeated cycles of bluff erosion, the bluff will appear to be retreating landward at an almost orderly rate.

The principal driving force in slope instability is gravity. Therefore, the slope inclination or steepness has the greatest effect on stability. Steep slopes are most susceptible or vulnerable to failure if there are minor changes in the other variables (i.e., loading, undercutting, wet weather). Flatter slopes tend to be less affected by changes in these variables.

The strength of the geological materials opposes the force of gravity. The strength of the bluff material depends on the cohesion of the particles making up a particular layer or section of the bluff. For instance, a loose, unconsolidated sand bluff face will have less cohesion than a firm, compacted bluff material such as glacial till.

Decreases in soil strength can be caused by increases in groundwater levels, weathering, shocks, and vibrations which can trigger instability. A summary of factors leading to slope instability is presented in Table 4.1.

Figure 4.8: Erosion by Waves and Water Flow

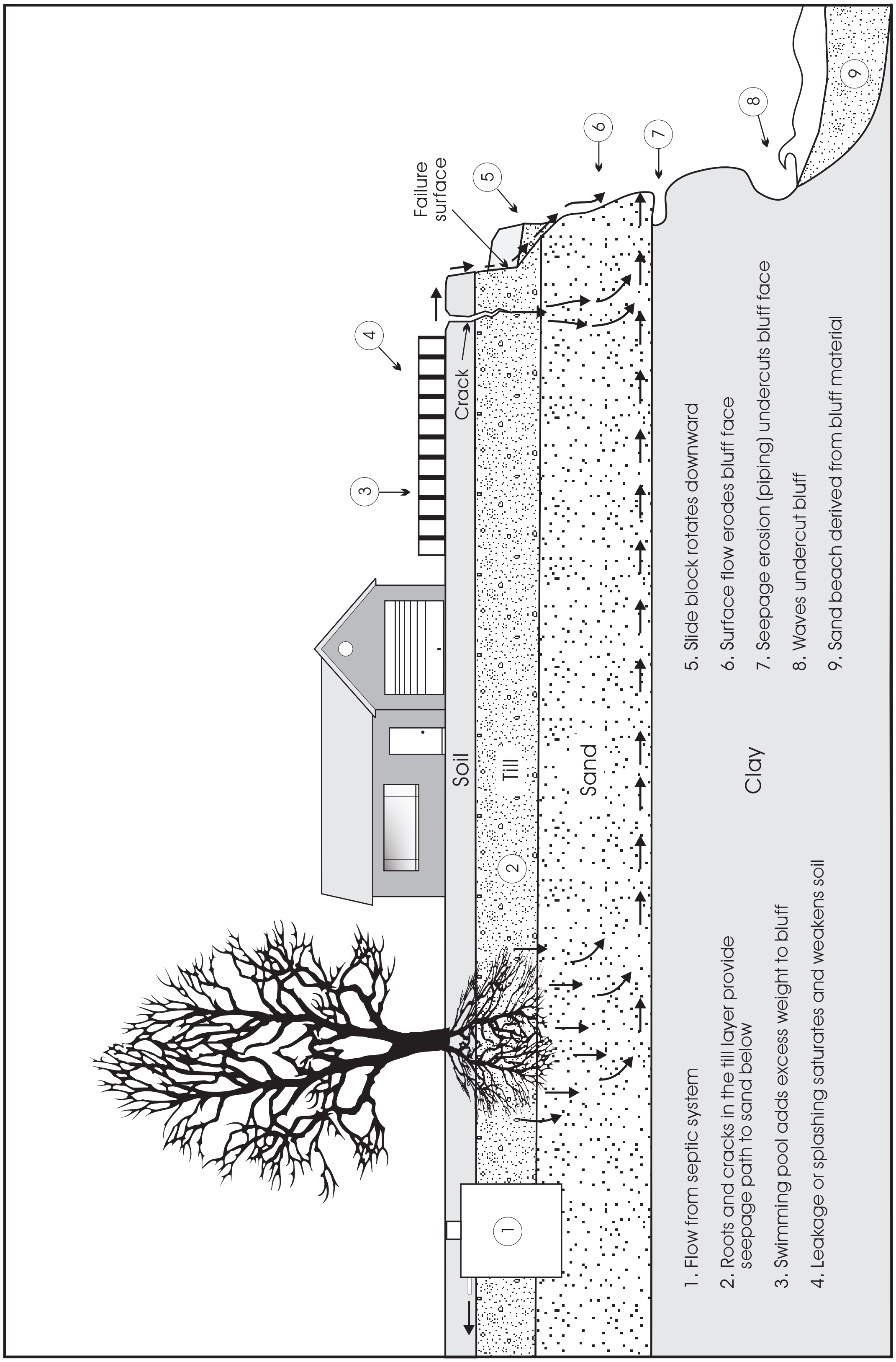


Figure 4.9: River Bank Erosion

Figure 4.10: Slope Steepness and Failures

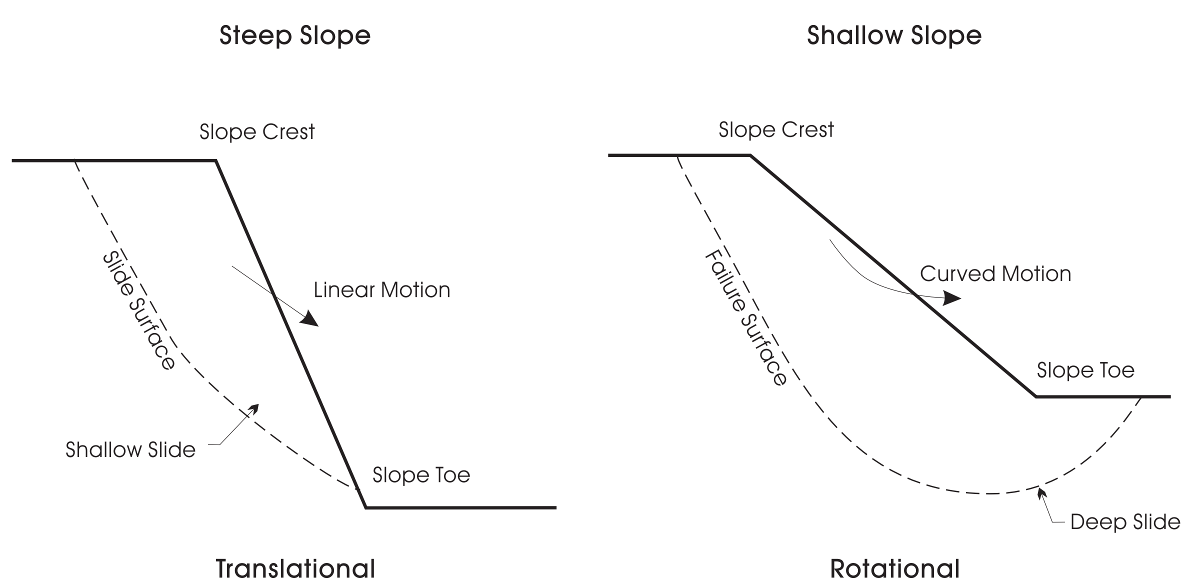


Table 4.1 Factors Leading to Slope Instability

	Natural	Human-made
1. Increased Slope Steepness or Inclination	toe erosion by water	excavation, retaining walls
2. Additional Loading (i.e., weight, load)	trees, snow, and ice	filling, structures, pools
3. Reduced Soil Strength	increased groundwater levels, flooding, drying, frost	changes in drainage, leakage of buried pipes/tanks/pools

Figure 4.11 shows slope failure based on soil type. Slopes composed of cohesionless soils (e.g., silt, sand, gravel) or competent cohesive soils (i.e., soils with a high friction angle), usually experience shallow slides. Failures through cohesive soils such as clays, with low friction angle tend to be deep slides involving much larger masses of soil.

The composition of the bluff strata or layers often dictates the form of bluff failure. For instance, cohesive sediments generally slide along a circular or curved arc leading the sediment to move downward in a rotating motion along the failure plane. Conversely, cohesionless sediments tend to fail as vertically sided blocks or in the form of a flow.

Another important factor is the sequence or position, of a particular layer or section of the shore bluff. This is particularly important since a thin zone of contact between two layers can be very weak and can form what is termed a "slip plane". The term "slip plane" describes the process of failure, in that an upper layer can slip or slide across the lower layer. As a result, the cohesion within the layer and the slippage resistance between layers are often equally important factors.

Another contributing factor to bluff failure is bluff height. In general, the higher the bluff feature the greater the stresses that are likely to occur within the bluff feature and the greater the potential severity of bluff instability.

f) Human Activities

A number of human activities can aggravate or create slope instability. These include the indiscriminate discharge or leakage of water from pools, septic systems, storm runoff control ponds and drains as well as agricultural tile drainage systems. Changes in the shore topography, by cut-and-fill earth moving or land grading, can also alter the strength of any sedimentary layer or add weight to the entire slope. The construction of buildings or protection works on or near these slopes can further weaken the slope which in turn may contribute to an increased instability of the shore feature.

With the activities of urbanization and land development, fill placement near slope crests and excavations into slopes or retaining walls may alter the stability of shorelines. Filling is a common practice in most urban areas as people try to reclaim more usable flat tableland along existing slope crests. Fill placement often occurs in an uncontrolled manner, sometimes over an extended period of time, and may result in an unstable fill mass which eventually experiences movements. Slides within fill materials, placed randomly and not engineered, can be quite unpredictable and extensive. The resulting instability may occur through the fill materials only or, through both the fill and underlying native soil (Figure 4.12).

Filling on slopes can be carried out in a safe and stable manner with suitable control and precautions, and preferably under the responsibility of a qualified geotechnical engineer.

Figure 4.11: Failures and Soils Types

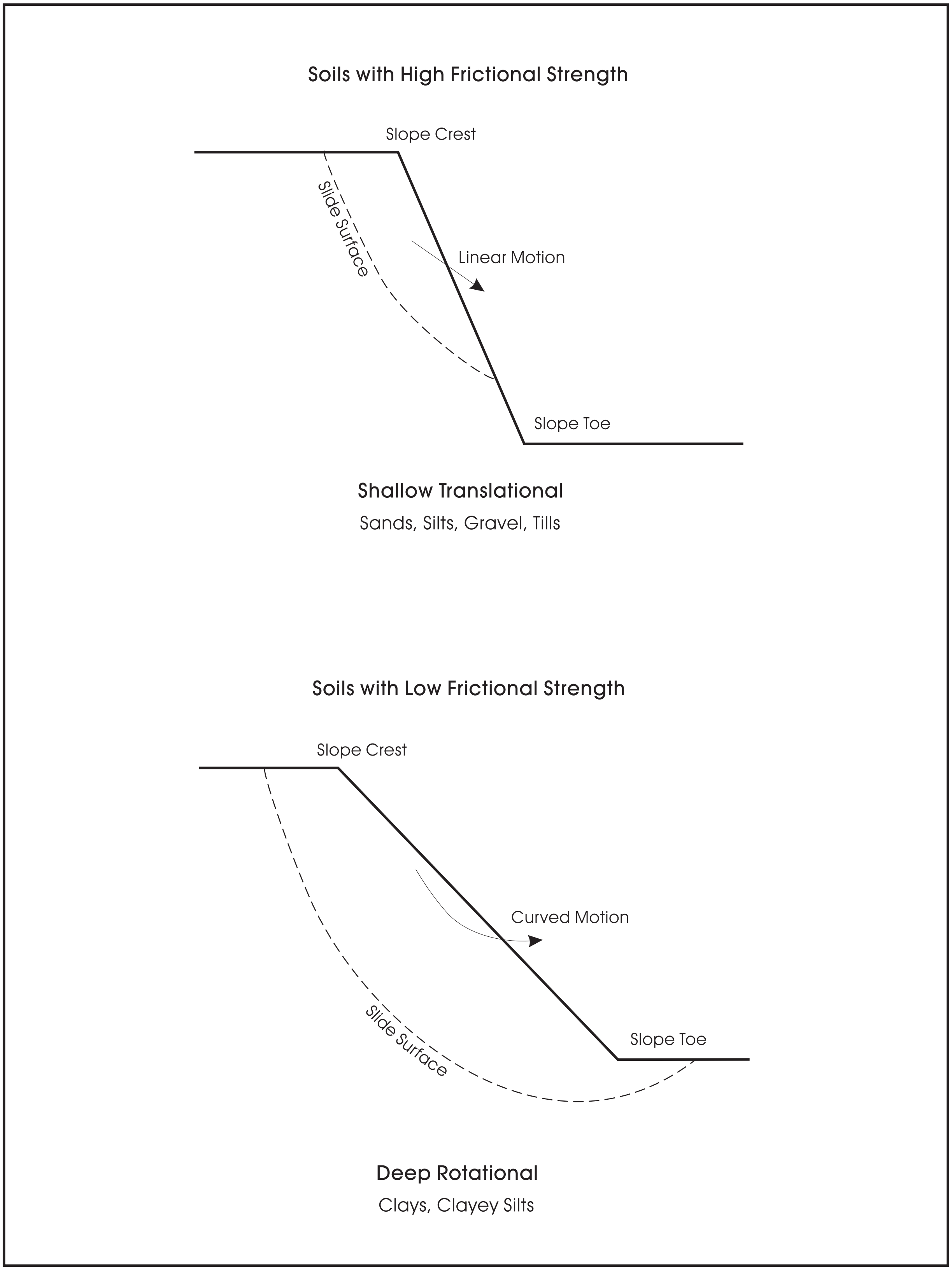
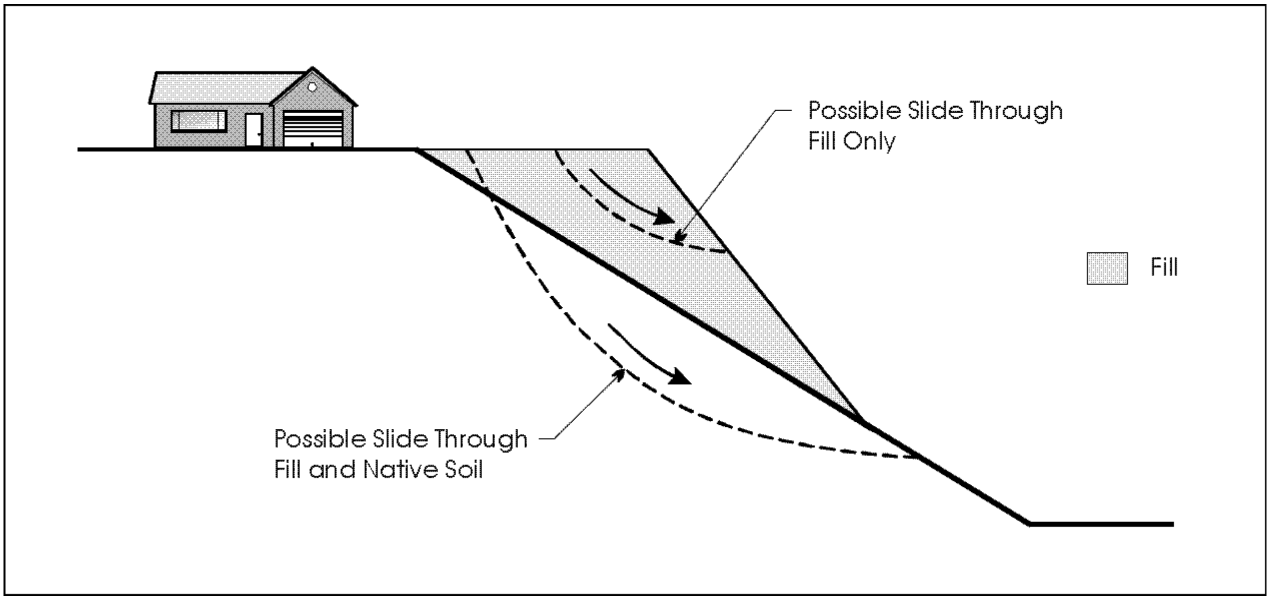


Figure 4.12 Filling on Slopes



g) Vegetation

Vegetation cover on a slope is the primary defence against soil erosion and is very important to long term erosion protection. As indicated on Figure 4.13, vegetation protects against surface erosion and shallow translation slope slides by:

- by holding, binding, or reinforcing the soil with a root system;
- removing water from the soil by uptake and transpiration;
- reducing runoff flow velocity;
- by reducing frost penetration; and/or
- by the buttressing or reinforcing action of large tree roots.

By reducing surface erosion, the likelihood of shallow instability is also decreased.

Vegetation also improves the visual aesthetics of a shoreline slope and is a vital part of the ecosystem.

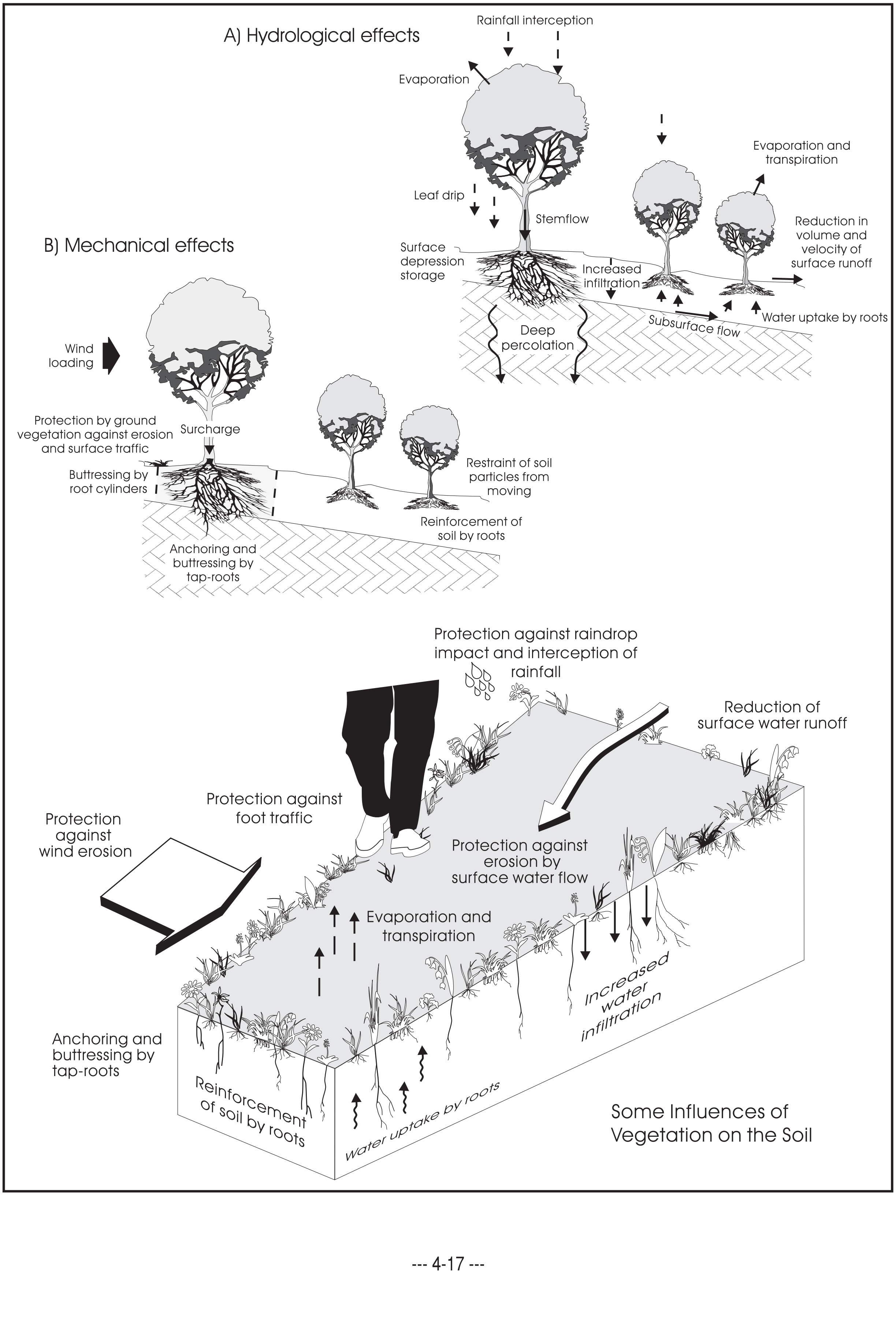
Slope stability can also be decreased by the removal of stabilizing shore vegetation. This may be of particular importance where the removal of tree roots, especially the smaller and more numerous tree roots which provide a binding strength for any sedimentary layers they enter, may have been removed. By the cutting of trees in these areas, the naturally cohesive strength and anchoring force may be lost.

4.2.3 Visible Evidence of Shoreline Erosion and Slope Instability

Evidence of shoreline erosion may be detected in several ways. Aerial photographs can be a great aid in a preliminary investigation, however, the more direct approach would be to undertake a site visit.

Once in the field, a systematic reconnaissance of the entire site and adjacent lands should be conducted. Field notes on pertinent observations should be recorded at the time and place of observation. To further augment and support the field observation, a photographic record can often prove very useful in any subsequent analysis and discussion of management options.

Figure 4.13: Importance of Vegetation in Controlling Surface Erosion

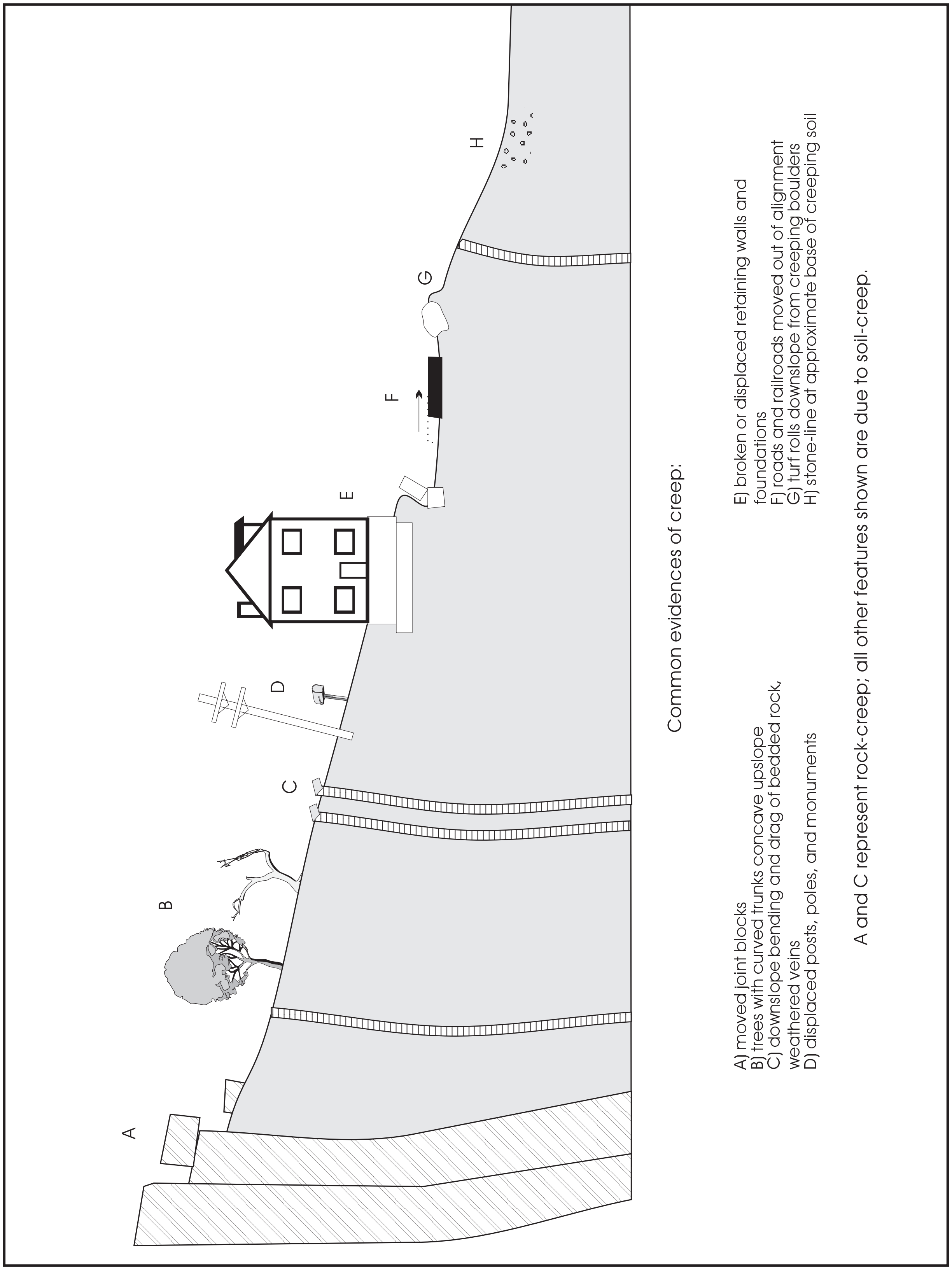


In general, there are a number of visible indicators of erosion which can be determined through a site investigation. A number of the more common visible indicators include:

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

Figure 4.14 shows visible signs of rock and soil creep. In determining the erosion potential of a particular site, consideration must be given to the fact that due to the cyclic nature of shoreline erosion, current potentially hazardous slopes do not always display evidence of past slope failures. In addition, some shoreline locations may not have experienced any recent failures, or conversely, where old failures have occurred they may have been small in magnitude or size and are now disguised by vegetation and surface or toe erosion.

Figure 4.14: Visible Evidence of Shoreline Erosion



4.3 PROVINCIAL POLICY: EROSION HAZARD

The *erosion hazard*, as outlined in the *Provincial Policy Statement*, Policy 3.1, Public Health and Safety: Natural Hazards for the *Great Lakes - St. Lawrence River System*, involves the calculation of the cumulative impact of stable slope, average annual recession rate, and an erosion allowance. To address the variable nature of the *Great Lakes - St. Lawrence River System* shorelines and to provide flexibility and technical support in the application of the Provincial Policy, a two step process to define the *erosion hazard* is recommended.

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

The first step to defining the landward limit of the *erosion hazard* involves selecting one of the following two options:

- the **sum of the stable slope allowance plus 100 times the average annual recession rate** (i.e., 100 year recession) measured landward from the toe of the shoreline cliff, bluff, or bank for shorelines **where a minimum of 35 years of recession information is available** (Figure 4.15)

OR

- the **sum of the stable slope allowance plus a minimum 30 metre erosion allowance** measured landward from the toe of the shoreline cliff, bluff, or bank **where there is insufficient recession rate information** (Figure 4.16)

The second step then involves the comparison of the selected option from the first step with:

- **a minimum 30 metre erosion allowance** measured landward from the top of the shoreline cliff, bluff, or bank or the first lakeward break in slope (Figure 4.17).

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

The *erosion hazard* is applied to all shorelines of the *Great Lakes - St. Lawrence River System* except where dynamic beach shore types exist. Although erosion of cohesionless sediments, such as sands, silts and clays found in beach environments, have a significant influence on the change and configuration of certain shore forms, discussion on this form of erosion is more appropriately and more fully discussed in **Part 5: Dynamic Beach Hazard** of this Technical Guide.

In defining the landward limit of the *erosion hazard*, it is recognized that there are three components to be calculated;

- **stable slope allowance,**
- **average annual recession rate,** and
- **an erosion allowance.**

The following sections of Part 4 explain in more detail how each of the three contributing factors are determined:

- **stable slope allowance** (Section 4.4 describes the 3:1 stable slope allowance standard and situations where a study using accepted geotechnical principles may be acceptable and applied),
- **average annual recession rate** (Section 4.5 describes the use of the minimum 35 years of record, and the various methods for defining recession rates)
- **minimum 30 metre erosion allowance** (Section 4.6 describes shorelines where an adjustment in the minimum 30 metre erosion allowance standard may be considered based on accepted scientific and engineering principles)

Figure 4.15 Erosion Hazard: Stable Slope Allowance plus 100 times the Average Annual Recession Rate

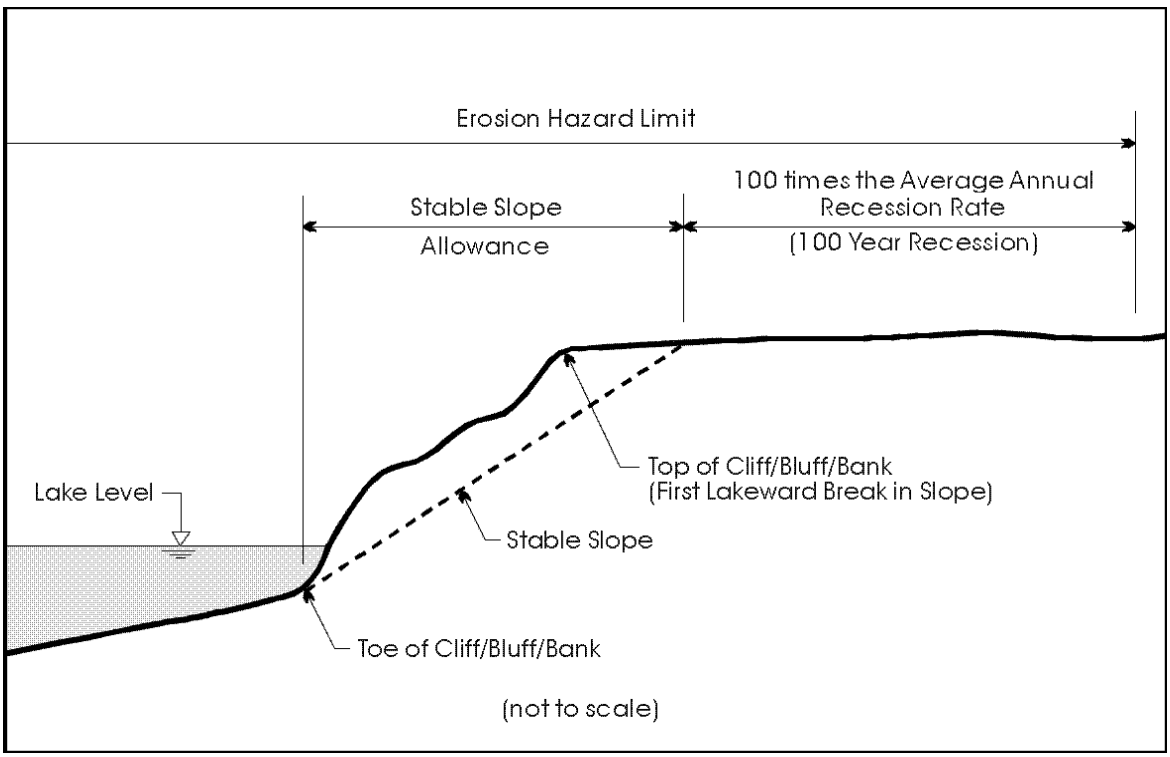


Figure 4.16: Erosion Hazard Limit: Stable Slope Allowance plus 30 metre Erosion Allowance

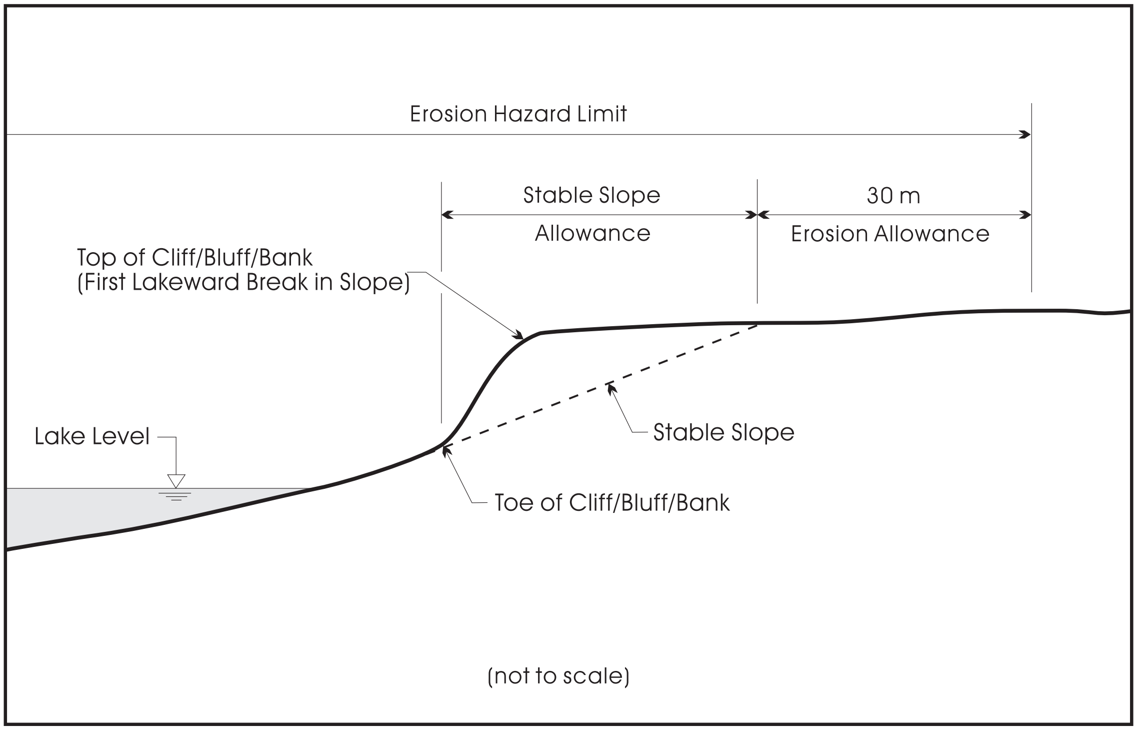
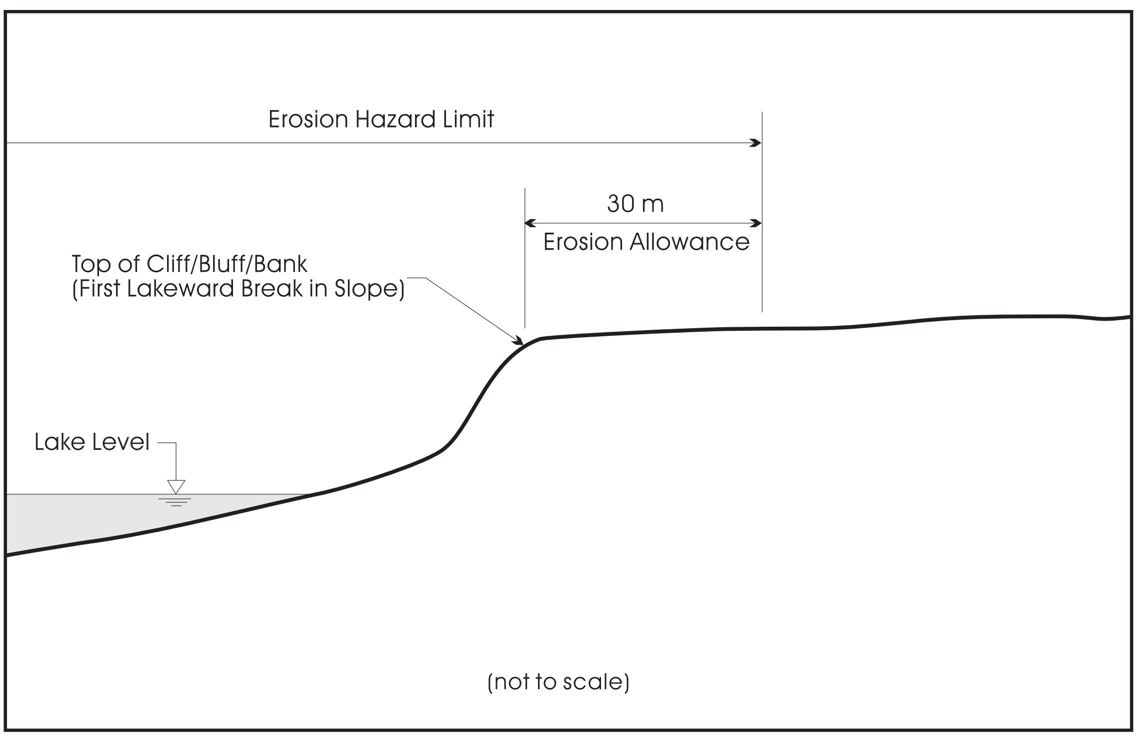


Figure 4.17: Erosion Hazard Limit: 30 metre Erosion Allowance Measured from Top of Cliff/Bluff/Bank or First Lakeward Break in Slope



4.4 STABLE SLOPE

The first step in determining the *erosion hazard* (see Section 4.3) is to identify and calculate the stable slope allowance measured landward from the toe of the shoreline cliff/bluff/bank.

The cyclical process of achieving a stable slope usually begins with the erosion of the toe of the bluff (i.e., over-steepened bluff). The landward retreat of the tablelands then occurs as a result of the force of gravity acting to move material on the unstable slope to a lower position on the shore profile. The slope will reach a stable angle of repose where the stresses acting to move the material down the slope and the resisting strength of the materials in the bluff are in balance.

In achieving or determining the landward extent of the stable slope allowance for any given stretch of shoreline, the influence of human activities and surface and subsurface (i.e., groundwater) must be carefully assessed and addressed.

Recognizing the diverse geotechnical characteristics of the *Great Lakes - St. Lawrence River System* and the limited availability of site specific geotechnical information on slope stability, it is recommended that the stable slope allowance be determined as follows:

- a horizontal allowance, measured landward from the toe of the shoreline cliff, bluff, or bank, equivalent to 3.0 times the height of the cliff, bluff, or bank (i.e., difference in elevation between the top or first lakeward break in slope and the toe of the shoreline cliff, bluff, or bank which may be above or below the water level) (Figure 4.18)

OR

- a stable slope allowance determined through a study using accepted geotechnical principles

A horizontal to vertical ratio of 3:1 is considered to be an acceptable conservative value for most shoreline locations. There are essentially three components to the determination and application of the stable slope allowance which warrant further discussion:

- identification of the toe of the cliff/bluff/bank;
- identification of the first lakeward break in slope (i.e., top of cliff/bluff/bank); and
- measurement or determination of the vertical height of the erosional shore type.

4.4.1 Toe and Top of Cliff/Bluff/Bank Positions

The actual location of the toe of a particular shore type can be either submerged, covered or emerged. The first lakeward break in slope usually corresponds with the lakeward edge of the tablelands commonly referred to as the top of cliff, bluff or bank (Figure 4.19a). In some instances, usually in shorelines which have undergone past slides (Figure 4.19b), the first lakeward break in slope may be some distance landward from the lakeward edge of the tablelands. In these instances, judgement in the determination of the first lakeward break in slope is required.

Figure 4.18: Stable Slope Allowance

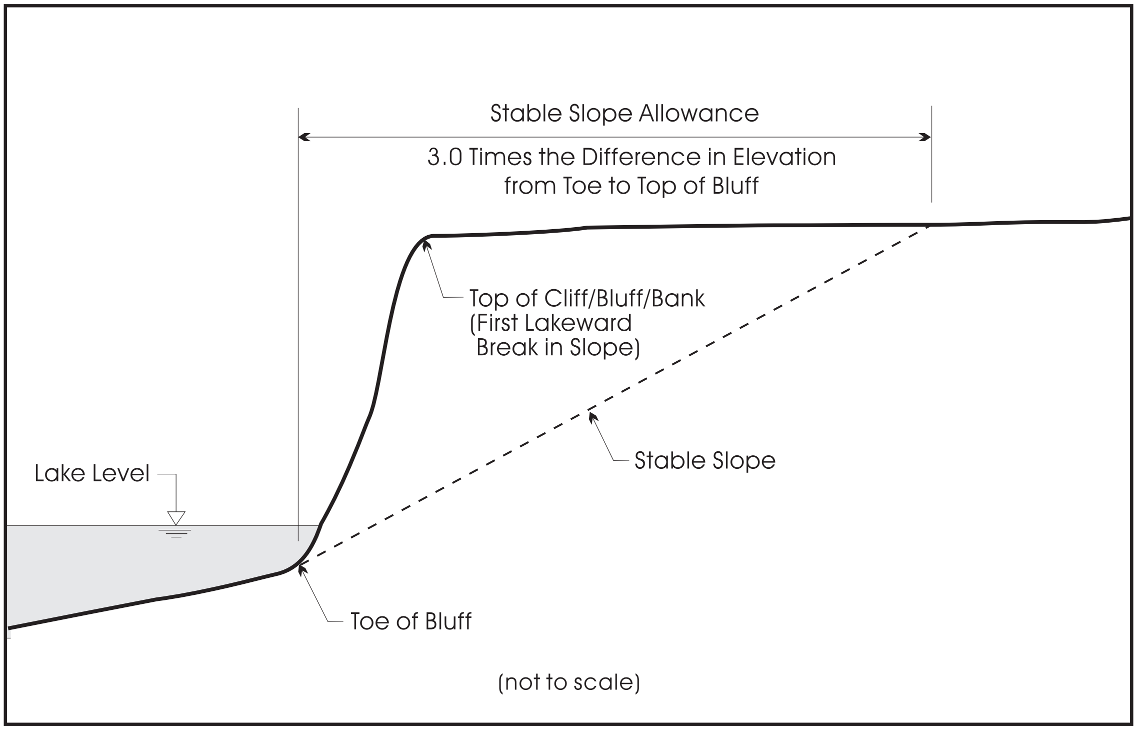
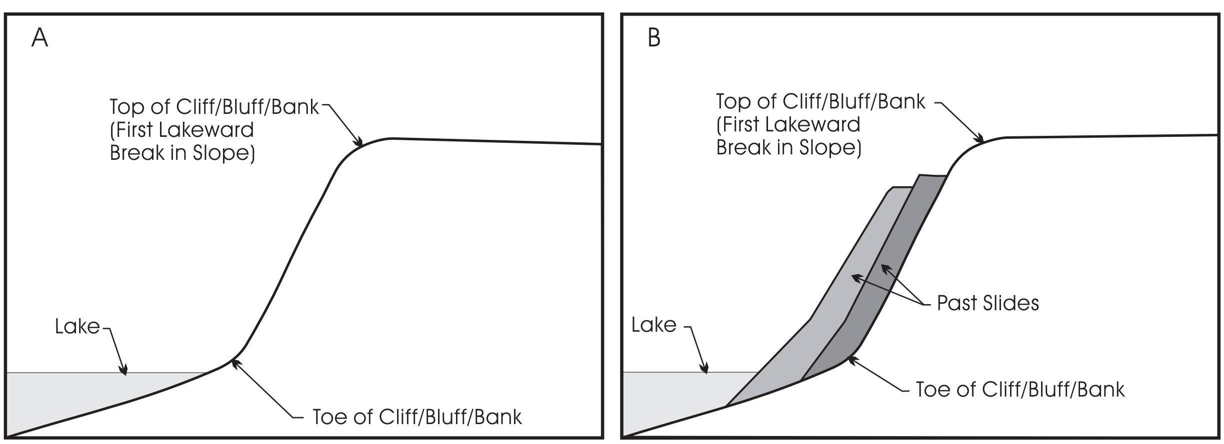


Figure 4.19: Toe and Top of Cliff/Bluff/Bank



Three common sources of information used in defining the location of the toe and top of cliff/bluff/bank positions and the vertical height of the cliff, bluff or bank shore type are:

- topographic maps with one metre contour intervals or less
- detailed aerial photographs, or
- field surveys

Toe and top of the cliff, bluff, or bank positions usually correspond with contour lines on topographic maps, with visible changes, often in slope, on aerial photographs, and in terms of recognized and measured changes in slope as recorded in field surveys.

a) Submerged Toe

For shore forms having a submerged toe, for ease of application, the toe of the cliff, bluff, or bank shall be taken as the waterline. Use of the waterline is considered appropriate in these locations since in many cases the submerged toe of the cliff, bluff, or bank is usually very close to the waterline.

When a more precise definition of the toe of the cliff, bluff, or bank is required, the submerged toe of the bluff can generally be located by simply wading offshore until a rapid change in underwater geometry is detected. This change is then considered to be representative of the transition from the vertical shore form into the nearshore. In situations where the toe of cliff, bluff, or bank is located at a depth that cannot be reached by safely wading, a sounding survey of the nearshore from a boat is recommended.

b) Covered Toe

There are two natural situations when a covered toe can exist. The first is where the toe is covered by a beach, the second is where the toe is covered by slumped material. In the case of a beach covering the toe of a cliff, bluff, or bank, the toe position is to be defined by the intersection point between the top of the beach and the base of the cliff, bluff, or bank (Figure 4.20a).

Where slumped material covers the toe, the toe position of the cliff, bluff, or bank is to be defined by the extrapolation of the toe of the cliff, bluff, or bank from an adjacent uncovered cliff, bluff, or bank location (Figure 4.20b). Where the option of location extrapolation from an adjacent uncovered toe of the cliff, bluff, or bank is not feasible or appropriate, the best option is to core through the slumped material to find the transition point between the slumped and cohesive shore material.

c) Emerged Toe

The easiest situation is when an emerged toe exists. The exact location of an emerged toe is the point where the vertical face of the cliff, bluff, or bank profile changes to a shallow slope (Figure 4.21).

d) Vertical Height

The vertical height of the erosional shore type is taken as the difference in elevation between the toe and the first lakeward break in slope (i.e., top of cliff, bluff or bank). The identification and calculation of this difference in elevation between the toe and the first lakeward break in slope can be obtained through the use of topographic maps, aerial photographs or through field measurement.

The most direct way to determine the vertical height of an erosional shore form is from topographic maps. Vertical heights can simply be obtained by calculating the differences in elevation between the contour lines used to identify the toe and top of the cliff, bluff or bank positions.

Figure 4.20: Covered Toe

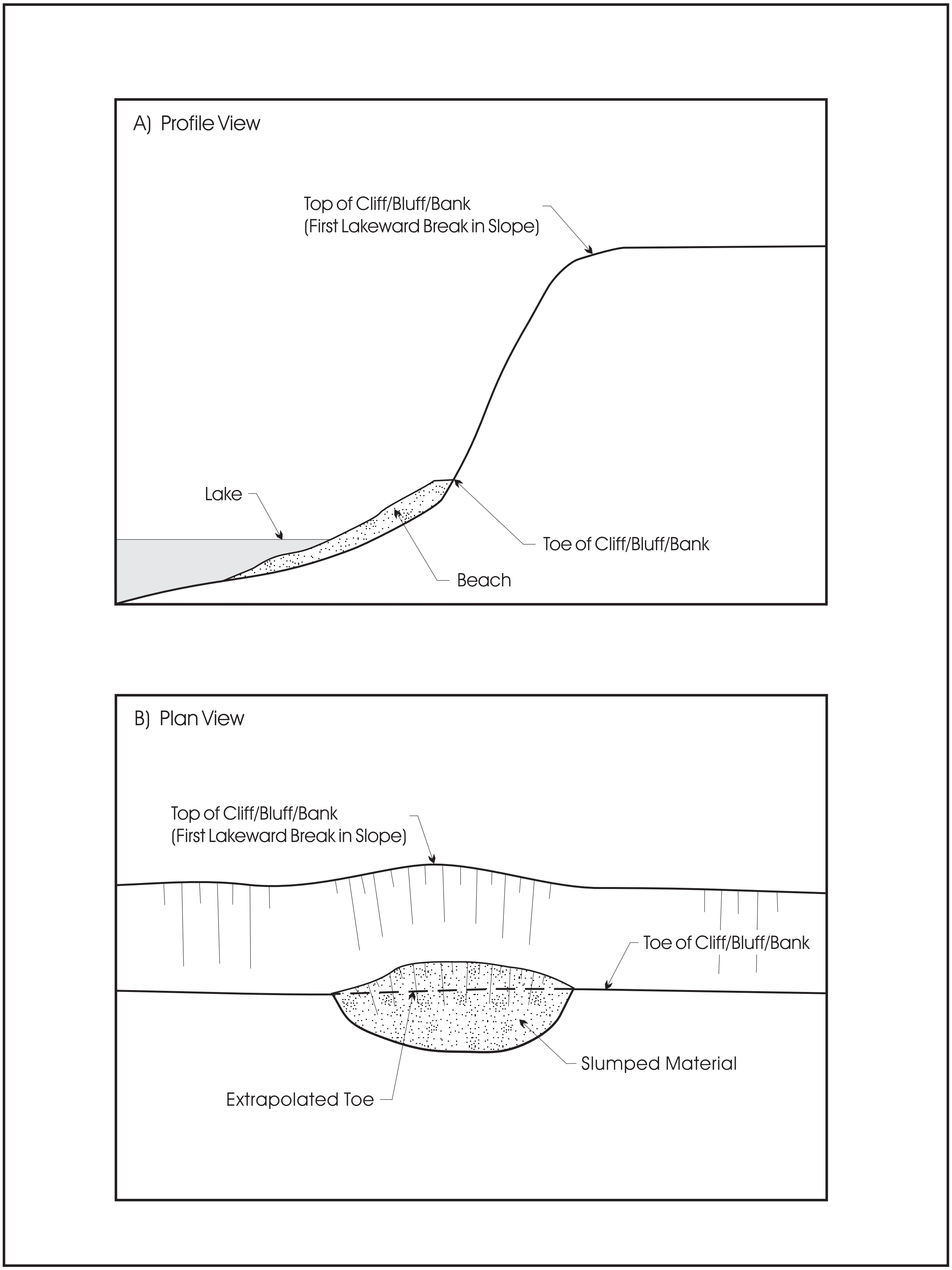
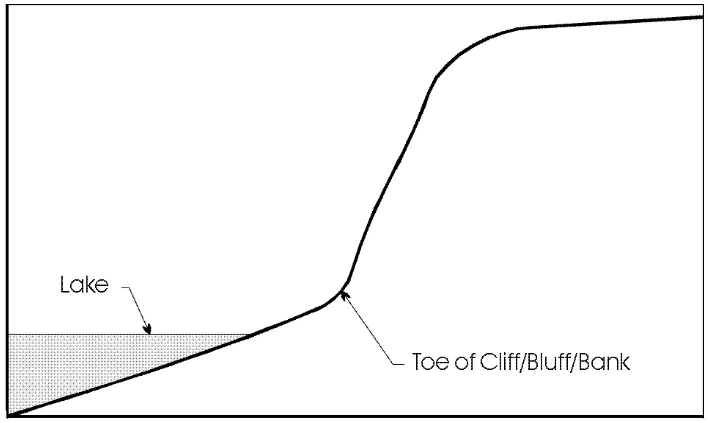


Figure 4.21 Emerged Toe



Vertical heights can be calculated from aerial photographs using the parallax method which requires a stereoscope and a stereo-pair of photographs.

There are several field survey measurement methods used for determining the vertical height of an erosional shore form. All of the methods first require the investigator to find the location of the toe and top of the cliff, bluff, or bank positions. The simplest of the field measurement methods involves measuring the change in vertical height between the toe and top of the cliff, bluff, or bank position using a hand held tape which is lowered from the top of the cliff, bluff or bank. All of the remaining field measurement methods involve some form of field survey requiring more sophisticated equipment and expertise in operation of the equipment. For more detailed information on the various field survey methods most commonly used, Appendix A6.1 of this Technical Guide should be consulted.

4.4.2 Accepted Geotechnical Principles

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

For those situations where a municipality or planning board requires or permits the undertaking of study to determine the stable slope allowance, the study must be undertaken using accepted geotechnical principles.

Where studies using accepted geotechnical principles are approved by the municipalities or planning boards, the landward limit of the *erosion hazard* will be defined by the **engineered stable slope allowance <u>plus either</u> the 100 year recession rate <u>or</u> a 30 metre erosion allowance** and applied only in the area studied.

To assist implementing agencies and development proponents in determining the appropriate study criteria this section of the Technical Guide will provide an overview of the requirements associated with undertaking a study using accepted geotechnical principles, the various slope stability methodologies and the procedures associated with determining slope stability. For more detailed information on each of these three factors, the technical support document (Terraprobe 1997) should be consulted.

(a) Accepted Geotechnical Principles and Slope Stability Methodologies

To undertake any analysis of slope stability first requires an understanding of the basic slope stability and geotechnical principles by the shoreline implementing agencies or the development proponent. To assist in developing this understanding, *Geotechnical Principles of Stable Slopes* (Terraprobe 1997) provides a description of each type and form of slope failure as well as the triggering mechanisms and typical site conditions, followed by a detailed description and assessment of the various models currently being used to assess slope stability.

Several slope stability methods currently being used may be considered as applying accepted geotechnical principles provided that they are used in the same context for which they were originally based and that the required input information is available. The five methods which are currently considered as incorporating "accepted geotechnical principles" include:

- Fellenius
- Bishop
- Janbu
- Morgenstern-Price, and
- Sarma

Implementing agencies should recognize that where the same input information is used within each of the above five methods there is a strong likelihood that each method may produce a different "Factor of Safety". These different results should be carefully considered when reviewing slope stability analysis reports and in determining which study methodology best applies to the particular shoreline location. An example of this variability is provided in the technical support document *Geotechnical Principles for Stable Slopes* (Terraprobe 1997).

In addition to selecting the appropriate model for determining slope stability, a Design Minimum Factor of Safety must also be chosen. The concept, background rationalization and information pertaining to the development, use and importance of the Design Minimum Factor of Safety, as well as examples of how this assessment standard is applied in slope stability analysis is provided in technical support document (Terraprobe 1997).

(b) Procedure for Determining Slope Stability

When determining slope stability, a wide range of factors including the diverse forms of slope profiles, site conditions, and current and intended land uses all contribute to the decision-making process implementing agencies should undertake in identifying the level of study detail required to appropriately evaluate and identify a slope stability allowance for a particular location or stretch of shoreline. To assist implementing agencies in this decision-making process, the range of different study levels and associated geotechnical report formats are presented and discussed in the technical support document (Terraprobe 1997).

Regardless of the method selected, the desired product from these investigations is the determination of the long-term stable slope inclination, usually expressed as a horizontal to vertical ratio, for the particular shoreline site in question.

To undertake and determine the level of slope stability, analysis often requires site information on several key variables including:

- slope height,
- slope inclination (i.e., steepness),
- soil stratification or layering,
- soil type and composition,
- soil density and strength,
- groundwater pressures,
- external loads (e.g., structures, trees, fill),
- toe erosion (e.g., wave action, excavation), and
- surface cover.

To assist in the selection of the appropriate level of study analysis, a **Slope Stability Rating Chart** has been developed which incorporates the site characteristics listed above and the basic geotechnical principles which apply. The Slope Stability Rating Chart (Table 4.2), when completed, provides an indication of the relative stability of the existing slope and the level of investigation required to determine the stable slope allowance for the particular shoreline site in question.

Table 4.2 Slope Stability Rating Chart

Site Location:		File No.	
Property Owner:		Inspection Date:	
Inspected By:		Weather:	

			Rating Value circle one
1. SLOPE INCLINATION			
	degrees	horz. : vert.	
a)	less than 18	3:1 or flatter	0
b)	18 to 27	2:1 to 3:1	6
c)	more than 27	steeper than 2:1	16
2. SOIL STRATIGRAPHY			
a)	Shale, Limestone (Bedrock)		0
b)	Sand Gravel		6
c)	Till		9
d)	Clay, Silt		12
e)	Fill		16
3. SEEPAGE FROM SLOPE FACE			
a)	None or Near bottom only		0
b)	Near mid-slope only		6
c)	Near crest only or, From several levels		12
4. SLOPE HEIGHT			
a)	2 m or less		0
b)	2.1 to 5 m		2
c)	5.1 to 10 m		4
d)	more than 10 m		8
5. VEGETATION COVER ON SLOPE FACE			
a)	Well vegetated; heavy shrubs or forested with mature trees		0
b)	Light vegetation; Mostly grass, weeds, occasional trees, shrubs		4
c)	No vegetation, bare		8
6. TABLELAND DRAINAGE			
a)	Tableland flat, no apparent drainage over slope		0
b)	Minor drainage over slope, no active erosion		2
c)	Drainage over slope, active erosion, gullies		4
7. PREVIOUS LANDSLIDE ACTIVITY			
a)	No		0
b)	Yes		6
			TOTAL

	SLOPE INSTABILITY RATING	RATING VALUES TOTAL	INVESTIGATION REQUIREMENTS
1.	Low potential	< 24	Site Inspection only, confirmation, report letter.
2.	Slight potential	25 - 35	Site Inspection and surveying, preliminary study, detailed report
3.	Moderate potential	> 35	Borehole Investigation, piezometers, lab tests, surveying,detailed report.

Notes:
a) This chart does not apply to rock slopes or to Leda Clay slopes (e.g., Ottawa area)
b) Choose only one from each category by circling rating value; compare total rating value with above requirements.
c) If there is a water body (i.e., stream, creek, river, pond, bay, lake) at the slope toe: the potential for toe erosion and undercutting should be evaluated in detail and, protection provided if required.
d) Refer to Section 2 for information on identifying soil types.

Table 4.2 Slope Stability Rating Chart (Continued)

1. Slope Inclination
   - The angle from the horizontal of the slope face, measured from the toe to the crest. If the slope is comprised of several different inclinations, provide details on each. Estimate visually, or use hand inclinometer, or 'break slope', or survey, as well as referring to available mapping.

2. Soil Stratigraphy
   - Soil layering and soil types composing the slope. Confirm predominant soil type, if visible in bare exposed areas. Refer to previous nearby boreholes or well established local geology. If several soil layers are present, provide details on each.

3. Seepage from Slope Face
   - The quantity and location of groundwater on the slope face. Visually inspect slope for surface seepage (e.g., springs, streams, creeks)

4. Slope Height
   - Measurement of the vertical height between the toe (i.e., bottom) and crest (i.e., top) of the slope. Estimate visually, or measure by surveying, or refer to available mapping.

5. Vegetation Cover on Slope Face
   - Indication of the type and extent of vegetation cover (e.g., trees, grass).

6. Tableland Drainage and Gullies
   - Indication of surface infiltration and runoff over the slope face, which may cause a potential for surface erosion. Describe drainage over slope and whether drainage/erosion features are present.

7. Previous Landslide History
   - Indicates past instability. Visually inspect slope for evidence or indicators of past instability (e.g., scarps, tension cracks, slumped ground bent (bowed, dead, or leaning) trees, leaning structures such as walls etc.).

Toe Erosion
- Recognizes the presence of and potential for continued slope instability. Toe erosion must be eliminated or solved prior to solving slope instability.

The Rating Chart identifies 3 levels of stability and associated investigation requirement. The three levels are:

1. Low Potential/ Site Inspection Only

This should be simply confirmed through a visual site inspection of the slope configuration and slope stratigraphy and drainage. Confirmation if the slope stability should be provided in the form of a letter, signed and sealed with P.E.O. stamp, from an experienced and qualified geotechnical engineer. The letter should include a summary of the site inspection observations (e.g., slope height, inclination, vegetation, toe erosion, structures, drainage). These could be filled out on a Slope Inspection Form.

2. Slight Potential/ Site Inspection, Preliminary Study

The stability of the slope should be confirmed through a visual site inspection of the slope configuration, slope stratigraphy, and drainage. The slope inclination should be determined (i.e., obtained visually with a hand either with a hand inclinometer, or by 'breaking slope', or from mapping, or by survey) and, the slope features should be mapped in detail. A general indication of the shallow soil type could be obtained by hand augering or test pits. Existing available information should be referenced such as historical air photos, geological mapping, previous site investigations, etc. Confirmation of the slope stability should be provided in the form of a detailed report, signed and sealed with an P.E.O. stamp, from an experienced and qualified geotechnical engineer. This report will include a Slope Inspection Record, a site plan and slope profile showing slope crest and toe, slope height and inclination, location of structures relative to the crest, vegetation cover, past slide features (e.g., tension cracks, scarps, slumps, bulges, ridges) and erosion features, and assessment of the stable slope inclination.

3. Moderate Potential/ Borehole Investigation

In addition to a visual inspection, mapping of sites features, and review of previous information; the stability of the slope should be assessed more precisely through topographic survey of the slope configuration, boreholes with piezometers to measure slope stratigraphy, soil penetration resistance, and groundwater levels. Laboratory testing on the borehole samples must be conducted to measure Basic Index Properties (i.e., water content, unit weights, grain size distribution, Atterberg Limits) or other properties as required (i.e., triaxial tests for soft clay).

An analytical stability analysis must be conducted to determine the Factors of Safety for the original slope conditions and the proposed development conditions. The design minimum Factor of Safety should be in accordance with the guidelines provided in the Slope Manual. Confirmation of the slopes stability or instability and the stable slope inclination should be provided in the form of a detailed report, signed and sealed with an P.E.O. stamp, from an experienced and qualified geotechnical engineer. This report will include a site plan and slope profile showing slope crest and toe, slope height and inclination, locations of structures relative to the crest, vegetation cover, past slide features (e.g., tension cracks, scarps, slumps, bulges, ridges) and erosion features, borehole logs, piezometer monitoring data, laboratory test results of the Analytical Stability Analysis showing Factors of Safety, failure surfaces analyzed, assumed slope data, assessment of the stable slope inclination, and stabilized methods.

The relative stability of the slope obtained from this chart should only be used as an indicator of slope stability and should not replace the professional judgement of a qualified geotechnical professional. In addition, one should recognize that the rating obtained for the slope under investigation is applicable only for the time at which the site investigation was conducted. Care should be taken to recognize that slope stability ratings will change with changes in or to site conditions.

Depending on the level of the study required, the slope stability report submitted by a recognized geotechnical professional, to which the implementing agency should ensure that the appropriate signature and P.E.O. stamp has been affixed, will include one or all of the following:

- Slope Inspection Record;
- a Site Plan and Slope Profile indicating the positions of the various measurements taken at the site;
- photographs of the site and slope conditions;
- a discussion of the site inspection measurements taken and a review of previous information;
- borehole logs and piezometer monitoring data;
- laboratory test results; and/or
- the results of the preliminary engineering analysis of slope stability or the detailed engineering Stability Analysis.

To assist in understanding and evaluating each of the above study components, examples and a discussion of each is presented in the technical support document (Terraprobe 1997).

As previously indicated, to undertake a proper stable slope analysis an appropriate Design Minimum Factor of Safety must be chosen. To assist implementing agencies in the proper selection and interpretation of the Design Factors of Safety, Table 4.3 was developed. This table is based on the type of land uses proposed for any given shoreline location and incorporates the current practices, principles and judgement of the professional geotechnical community. The table is intended to provide an indication of the minimum or range of minimum acceptable Design Factors of Safety and should not replace the professional judgement of a geotechnical professional who may recommend a greater factor of safety to properly address local conditions. For further discussion on Design Minimum Factor of Safety see the technical support document (Terraprobe 1997).

Table 4.3 Design Minimum Factors of Safety

LAND-USES		DESIGN MINIMUM FACTOR OF SAFETY
A	PASSIVE: no buildings near slope; farm field, bush, forest, timberland, woods, wasteland, badlands, tundra	1.10
B	LIGHT: no habitable structures near slope; recreational parks, golf courses, buried small utilities, tile beds, barns, garages, swimming pools, sheds, satellite dishes, dog houses	1.20 to 1.30
C	ACTIVE: habitable or occupied structures near slope; residential, commercial, and industrial buildings, retaining walls, storage/warehousing of non-hazardous substances	1.30 to 1.50
D	INFRASTRUCTURE and PUBLIC USE: public use structures or buildings (i.e., hospitals, schools, stadiums), cemeteries, bridges, high voltage power transmission lines, towers, storage/warehousing of hazardous material, waste management areas	1.40 to 1.50

4.5 AVERAGE ANNUAL RECESSION RATE

The second component of the *erosion hazard* (see Section 4.3) is the average annual recession rate which is simply a representative linear measurement of the annual change in the position, or retreat of, the toe or top of cliff, bluff, or bank over time, usually described in metres per year. The average annual recession rate along a given shoreline should be based on the "natural" recession rate (i.e., a rate derived from an unprotected shoreline). This recession rate type of measurement is readily accepted as a form of measuring and expressing the impacts of erosion, or the loss of the usable, shore tablelands. For descriptive purposes the following erosion classification system (Table 4.4) can be used.

Table 4.4
Erosion Classification System

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

In measuring erosion in terms of an average annual recession rate, two specific shore features, the toe and top of the shore cliff/bluff/bank are used. The use of reference points which are generally easily visible or distinguishable on aerial photographs or topographic maps and in the field, is a major contributing factor to the ease and use of this form of measurement.

Where aerial photographs and topographic maps of the *Great Lakes - St. Lawrence River System* shoreline extend over long periods of time, including high and low lake level periods, calculation of the average annual recession rate from these forms of historical records is felt to provide a good indicator of future recession/erosion rates. As storm activity and changes in lake levels cannot be accurately predicted into the future, the calculation of annual average recession rates based on historic information provide the best indicator of what can be reasonably expected in the future providing the material composing the eroding landform does not appreciably change.

Recognizing the complexity and the number of factors that control or influence shoreline erosion referred to earlier in Section 4.2, it is recommended that **at least 35 years** of sound recession information about the unprotected shoreline should exist before an average annual recession rate is adopted for a site. If an average annual recession rate is considered to be inaccurate or questionable, efforts should be made to determine a more accurate average annual recession rate.

4.5.1 Determining an Average Annual Recession Rate

Two general methods are recommended for determining average annual recession rates along the shorelines of the *Great Lakes - St. Lawrence River System*:

- existing historical recession studies, or
- from a comparative analysis of historic and recent shoreline toe and top of the cliff/bluff/bank positions obtained from maps and/or aerial photographs

In determining the recession rate(s) for any shoreline point location, all available information where the shoreline is unprotected should be utilized. The intent in the following subsections of this Technical Guide is to provide direction on procedures to standardize data collection techniques and erosion analysis methodologies to ensure that consistent, accurate, and reliable shoreline recession data and rates for Ontario's *Great Lakes - St. Lawrence River System* shorelines are compiled.

a) Existing Historical Recession Studies

A number of government agencies, academic institutions, non-government organizations as well as individual shoreline owners have undertaken historical recession studies in Ontario. Many of these studies present calculated recession rates derived from either an examination of sequential maps and/or aerial photographs, or a series of topographic or photogrammetric cross-sectional surveys.

The most comprehensive historical recession studies undertaken for the *Great Lakes - St. Lawrence River System* shoreline in Ontario include:

- Canada/Ontario Great Lakes Erosion Monitoring Program as summarized in Boyd (1981);
- 1975 Shore Damage Survey as summarized in the Shore Damage Survey Technical Report (1975); and
- Coastal Zone Atlas (1976) which summarizes the locations of the various recession monitoring stations and associated recession rates.

For additional information on each of these monitoring programs, Appendix A4.2: Historical Recession Studies, of this Technical Guide should be consulted. Additional information can also be found in *Great Lakes Shoreline Classification and Mapping Study: Canadian Side* (Geomatics 1992).

During the 1980's, some of the topographic profile monitoring stations were re-surveyed by a number of shoreline Conservation Authorities. In addition, photogrammetric cross-sections were also re-surveyed during the Great Lakes Shoreline Hazard Mapping initiative conducted through the Canada/Ontario Flood Damage Reduction Program. For further information consult Appendix A4.3: Historical Maps and Aerial Photographs. In each case, the updated survey information resides with the local Conservation Authority.

b) Comparative Analysis of Historic and Recent Shoreline Positions

Comparative analysis of historic and recent shoreline positions involves the creation of a historic-recent position spatial database. Usually this analysis is accomplished through the creation of a map that simply delineates the historic and recent toe and top of the cliff/bluff/bank positions in reference to other current physical and cultural features for the particular shoreline location under review.

Historic-recent shoreline position maps are generated using maps and/or aerial photographs. Once compiled, the total linear distance change in shoreline positions (i.e., toe and top of the cliff/bluff/bank), can be measured directly from the composite spatial maps. Each measurement is then divided by the number of years between data sources (i.e., historic and recent) to obtain an average annual recession rate(s) for any point location along the shoreline.

The average annual recession rates obtained from the comparative analysis can then be compared with historical recession rates obtained from historical recession studies and a final shoreline recession rate determined. This final recession rate is then used in mapping and field staking the *erosion hazard*.

To ensure a high standard of accuracy and reliability in the determination of the average annual recession rate using the comparative analysis process, one of the most important criteria is to ensure that the raw data is as accurate and reliable as possible. The recession rates will only be as accurate as the source material from which they are derived. Maps and aerial photographs used in these studies must be examined carefully to ensure that data containing significant errors or distortions can be either corrected, or if uncorrectable, discarded.

In creating and using a historic-recent shoreline position map to determine the average annual recession rate of a particular shoreline location there are a number of issues requiring identification and consideration. These issues (described in more detail in Appendix A4.4) include:

- identification of the relevant shoreline data required to create a historic-recent shoreline position map;
- evaluation of the availability of pertinent historic-recent information sources and the issues associated with using map and aerial photography in creating historic-recent shoreline position maps;
- recommended procedures to create a historic-recent shoreline position map; and
- development of a step-by-step procedure to determine the average annual recession rate from a historic-recent shoreline position map for natural and altered shorelines.

The utilization of computerized mapping techniques can significantly improve the process of compiling historic-recent shoreline position databases by increasing the speed and efficiency of calculations of shoreline change rates from maps and aerial photographs (see Appendix A4.5 for further detail).

c) Criteria and Accuracy Considerations in Determining Recession Rates from Maps and Aerial Photographs

In using historical and recent maps and aerial photographs to create a historic-recent shoreline position map, a simplified set of criteria for selecting maps (outlined in Appendix A4.4: Methods to Create Historic-Recent Shoreline Position Maps) should be followed to ensure that the most accurate and reliable recession rates are obtained. To assist shoreline managers in determining the appropriateness of various map and aerial photograph materials, Appendix A4.4 outlines the sources of mapping and aerial photographs that are recommended for use in determining average annual recession rates and identifies those sources of information that are not recommended.

Beyond the inherent inaccuracies associated with the scales and mediums of maps and aerial photographs there are several other accuracy considerations that should be addressed. When determining rates of shoreline change derived from an analysis of maps, one must recognize that the resultant average annual recession rate cannot be considered absolute. In general, the level of map accuracy is insufficient to give more than a good estimate of trends in shoreline movement. The reliability of original data sources often is not sufficient enough to discriminate between shorelines measured at short time period intervals or between slowly changing shoreline positions (e.g., bay shorelines).

Therefore, to quantify historical shoreline change rates with some degree of confidence, the absolute magnitude of shoreline movement must be greater than the combined potential map error. Given the available sources of information, methods used and known shoreline recession rates along the *Great Lakes - St. Lawrence River System,* it has been determined that confidence in the reliability of calculated recession rates from maps and aerial photographs can be achieved where recession rates exceed 0.3 metres per year. As such, any recession rate measured from map sources which is equal to or less than 0.3 metres per year should not be automatically adopted for that shoreline location. In these cases the recession rate should only be adopted if the length of record used to determine the average annual recession rate is very long and the source information is very reliable. If possible, alternative methods to determine or verify the recession rate should be pursued. For more information see Appendix A4.3: Historical Maps and Aerial Photographs.

i) Need to Take Measurements at the Toe and Top of the Cliff/Bluff/Bank

To improve the accuracy of the determined average annual recession rate for a point location along the shoreline, measurements should be taken, whenever possible, at the toe and top of the cliff/bluff/bank positions. Comparison of the two measurements can provide some insight on the processes dominating the erosion processes at that location.

At shoreline locations where cliff/bluff/bank erosion is driven predominately by toe erosion (i.e., caused by wave action) the cliffs/bluffs/banks will tend to exhibit a pattern of parallel shoreline retreat. This means that overtime, the toe and top of the cliff/bluff/bank generally recede landward at the same rate. In these types of situations, the average annual recession rate is more easily determined.

ii) When the Toe and Top of the Cliff/Bluff/Bank Recession Rates Vary

Along some stretches of shoreline, it is possible to have the toe and top of the cliff/bluff/bank receding at different rates. For example at locations where the top of the cliff/bluff/bank is receding at a far greater rate than the toe, this could be indicative of less resistant stratigraphy at the top of the cliff/bluff/bank, the existence of toe protection, an alteration of cliff/bluff/bank slope by activities such as grading, dumping or by increased erosion caused by landside drainage features including gullies, watercourses, human activities (e.g., pools, agricultural drainage, sewer/urban drainage outfalls). In each of these situations, the determination of the average annual recession rate is more complex and will involve some experienced judgement. As a general rule, the greater of the two recession rates (i.e., toe or top of the cliff/bluff/bank recession rates) should be used.

As in other locations where the determination of the average annual recession rate may prove complicated, some of the above noted factors can be discounted by conducting successive measurements of information that are separated by long periods (i.e., decades) of time.

iii) When Only the Toe or Top of Bluff can be Measured

Where measurements of only the toe or the top of the cliff/bluff/bank are possible, for the purposes of determining the average annual recession rate, care should be taken to ensure that the identified recession rate actually reflects the long-term retreat of the cliff/bluff/bank at that particular shoreline location.

Average annual recession rates determined from the toe of the cliff/bluff/bank measurements alone should be checked to ensure that temporary landside erosional processes do not skew the identified recession rate. These factors can be addressed through a site visit and are generally smoothed or averaged out if the time period between data sets is adequate.

d) Complicating Factors

There are three factors which may further complicate the determination of the average annual recession rate within a given stretch of shoreline. These include:

- the presence of landside drainage with gully features being the most significant;
- protection works; and
- fill.

The procedures for addressing each of these factors are outlined below.

As discussed in Section 4.2.2, gullies are erosional landforms that frequently occur along shoreline bluffs and banks, particularly within the lower Great Lakes. Typically, gully features are characterized by steep, sloping, V-shaped channels with permanent or ephemeral water flow. Gullies are formed, maintained and enlarged by continuous erosional forces associated with the collection, channelization and transport of landside drainage from the shore tablelands to the lake or river at the base of the bluff.

In determining local shoreline bluff or bank recession rates, shoreline managers must recognize and give consideration to the location and size of shoreline gullies and make appropriate estimates of their growth rates and potential impacts on the surrounding landscape. Procedures to predict gully growth and advancement rates, factors contributing to gully advancement, and methods of predicting historic gully erosion rates are discussed in Appendix A4.1.

There are many varieties of protection works which have been installed along the shores of the *Great Lakes - St. Lawrence River System*. The impact of these protection works ranges from temporarily arresting erosion, to having no impact, and to accelerating the local recession. For mapping purposes, if the adjacent shorelines are unprotected and the bluff or bank composition is the same, the average annual recession rates for the adjacent unprotected shoreline should be used for the individual parcel of shoreline where protection works have been installed.

In some locations fill material may have been placed on top of and down the face of the cliff/bluff/bank landform. In these locations, if the native bluff composition is the same, the adjacent shoreline average annual recession rates should be used for determining the recession rate for the area in which fill has been placed.

4.5.2 Monitoring Shoreline Recession

Where there is a lack or absence of recession or erosion information at a particular stretch of eroding shoreline, it may be advantageous to establish an erosion monitoring program. The need for a program will depend on the rate or variability of erosion, the type of existing development and the level of current and future development pressure identified for the subject stretch of shoreline.

There are two recommended types of erosion/recession monitoring programs, these include:

- a field monitoring program involving topographic cross-section profile measurements, and
- a photogrammetric monitoring program involving cross-section profile measurements obtained from aerial photographs.

For further information on each of these types of erosion monitoring programs, Appendix A4.6 of this Technical Guide should be consulted.

4.6 EROSION ALLOWANCE

The **minimum 30 metre erosion allowance,** measured horizontally at the top of the cliff/bluff/bank is considered to be an appropriate minimum distance:

- to address **safety issues** associated with **risks to life and property**;

- to account for the **uncertainties** associated with calculating or not knowing the local recession rates, the science associated with determining recession rates, and the simple and current inability to accurately predict the final form and extent of any surface failure; and

- the potential yet **incalculable impact on the local recession rates** from changes in land use.

In defining the *erosion hazard* an erosion allowance standard of 30 metres has been identified. The intent is that this 30 metre erosion allowance be considered a minimum value. There is, however, flexibility to address local conditions. Recognizing the variability in the erosion potential throughout the *Great Lakes - St. Lawrence River System*, the uncertainties associated with predicting recession rates in the absence of sound historical records, and the complexities associated with determining rates of recession where a wide range of surface, subsurface and lakeside erosive forces are simultaneously acting on a particular shoreline, and in the interest of providing the added flexibility to address this variability, two options are provided to assist managers in accommodating situations where the 30 metre erosion allowance is considered to be:

- too onerous in addressing the local erosion potential; or

- insufficient to address the local erosion potential.

Regardless of the option selected, any deviation from the 30 metre erosion allowance standard is to be undertaken only in accordance with accepted scientific and engineering principles.

4.6.1 Reduction of the 30 Metre Minimum Erosion Allowance

An evaluation of the general physiography, post-glacial composition and range of erosion forces impacting on shorelines throughout the *Great Lakes - St. Lawrence River System* suggests that there are four general shoreline types or locations where the 30 metre erosion allowance standard may be considered too onerous. These include:

- bedrock shorelines;
- shorelines along the connecting channels;
- naturally, well sheltered shorelines; and
- shorelines along Lake St. Clair.

Given the potentially inherent stability associated with bedrock shorelines, and the generally lower wave action along connecting channels, Lake St. Clair, and shorelines which are naturally, well sheltered, it is recommended that additional flexibility be provided through the municipal planning process to permit the reduction in the 30 metre erosion allowance standard through the undertaking of a study using accepted scientific and engineering principles.

Conversely, recognizing that there are uncertainties associated with less stable shoreline features (e.g., cohesive or non-cohesive bluffs and banks) on open lake environments, the flexibility to undertake studies to reduce the erosion allowance should <u>not</u> be considered. In fact, in highly unstable shorelines (e.g., fine-grained cohesive materials) an increase in the erosion allowance may be warranted.

To determine whether a reduction in the 30 metre erosion allowance standard should be considered, one must first evaluate the specific site conditions, the potential for erosion, and the risks associated with permitting development to be located within the 30 metre erosion allowance standard.

a) Bedrock Shorelines

Bedrock shorelines are defined as those composed of predominantly metamorphic or igneous rock that are not currently being undermined by shoreline processes. Although it is recognized that bedrock environments do erode over time, most do so at a very slow rate compared to cohesive shorelines.

Where studies are undertaken, using accepted scientific and engineering principles, to determine the erosion allowance in bedrock environments, the scientific/engineered erosion allowance is to be based on a sound knowledge and understanding of the stability of the local bedrock formation.

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

Where development is proposed in low plain bedrock shorelines composed of metamorphic or igneous rock, the erosion allowance determined for the site must also give due consideration to the flood hazard and the potential magnitude and impact of wave action and ice effects (i.e., erosion may not be the governing standard in determining the *hazardous lands*). Where development is proposed in areas consisting primarily of bedrock cliffs, recognizing the uncertainties associated with identifying a definitive measure of bedrock stability, the erosion allowance standard determined for the site should be related to cliff height.

Additional care must be taken in the determination of a reduction in the erosion allowance for bedrock shorelines composed of predominantly shale or sedimentary rock formations, given that these formations can be undermined by shoreline processes and that they are considerably weaker than the massive metamorphic and igneous bedrock formations. Any reduction in the erosion allowance standard should give due consideration to the relative stability and composition of the bedrock formation and outcrops and to the potential impacts associated with the flood hazard, the potential magnitude of wave action, ice impacts and cliff height where warranted.

b) Connecting Channels, Lake St. Clair and Naturally Well Sheltered Shorelines

For the purposes of the *Provincial Policy Statement*, Policy 3.1, Public Health and Safety: Natural Hazards governing the *Great Lakes - St. Lawrence River System*, the term connecting channels refers to the rivers which convey flows between Lakes Superior, Huron, St. Clair, Erie and Ontario. These include the St. Mary's, St. Clair, Detroit, Niagara and St. Lawrence Rivers. As a general guideline, the boundary between the lake and the connecting channel is essentially identified as the point along the shoreline where lake influences on the hydraulic functions of the connecting channel or river are considered to be negligible.

In determining the erosion allowance along a particular stretch of connecting channel, Lake St. Clair or naturally well sheltered shoreline, consideration must be given to the erosive potential of the shoreline sediments, the impact of wind and ship generated waves, and ice effects. It should be noted that in some areas, the shoreline has been filled and often the fill material is easily eroded. These areas should be examined carefully and treated with caution.

Any reduction in the 30 metre minimum erosion allowance does not alleviate the policy requirement to address the other hazards (i.e., flooding and dynamic beach). In addition, it must be remembered that the policy does not permit development within defined portions of the 100 year flood level along connecting channels.

4.6.2 Increase in the 30 metre Minimum Erosion Allowance

Where a 30 metre erosion allowance standard is deemed to be insufficient to address the rate of recession along a given shoreline, local municipalities and planning boards have the option of enlarging the erosion allowance requirements in accordance with accepted scientific and engineering principles.

An increase in the 30 metre erosion allowance may be appropriate, but not limited to, actively eroding cohesive bluff shorelines where the average annual recession rate is unknown or not fully documented but is reasonably considered to be potentially greater than 0.3 metres per year. In these situations, determination of an appropriate erosion allowance standard should be based on a sound understanding of the local wave climate and on the erosive potential of the materials which compose the shore profile.

In addition to an evaluation of the erosive potential of the shore materials, a determination of the local sediment budget is recommended to determine if the particular stretch of shoreline under assessment is considered a source or sink area. This information is particularly important if the site is determined to be a source area. For example, in situations where the local sediment budget is negative and where the site is considered to be a source area for sediment supply to other areas, the recession rates, depending on the composition of the shore profile, can be as high as 1.0 metre per year. By comparison, sites that have only marginally negative sediment budgets may be indicative of transition zones between source and sink areas. A general indication of whether the site is a source or sink area can be derived from the *Littoral Cell Study Report* (MNR 1988).

In shoreline locations consisting of predominantly low-lying cohesive materials, an erosion allowance standard of greater than 30 metres may be warranted. For example, an increase in the erosion allowance standard may be desired near the outlet of a river where the outlet has historically and consistently migrated up and down the shoreline. A second example may include the mouth of a connecting channel where the combined hydraulic forces of the river and the lake have the potential to accelerate episodic erosion of the connecting channel banks or lake shoreline profile.

In those locations where protection works have temporarily arrested erosion for all of the years of available and reliable recession rate records, yet the shoreline is composed of erodible sediments, care should be taken to ensure that the erosion allowance standard proposed gives due consideration to the erosion potential of the materials at the site (i.e., natural soil composition). The erosion potential can be determined by an examination of nearby unprotected shorelines composed of the same materials, or possibly from an examination of similar materials located elsewhere on the *Great Lakes - St. Lawrence River System* which are exposed to similar site characteristics and shoreline processes (i.e., fetch, wave height, alongshore sediment transport, etc.).

4.7 EROSION HAZARDS LIMITS AT JUNCTIONS OF THE GREAT LAKES - ST. LAWRENCE RIVER SYSTEM AND RIVER AND STREAM SYSTEMS

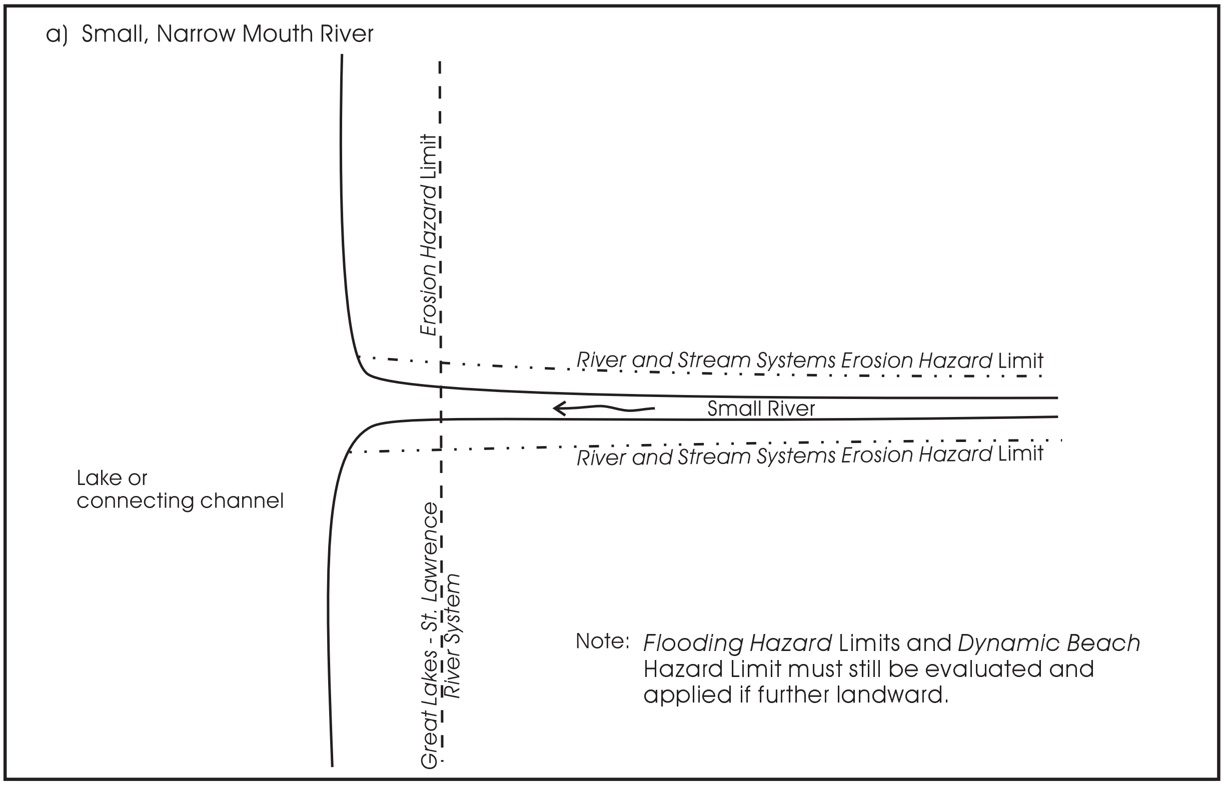
Policies addressing natural hazards can in some situations overlap. This is often the case where rivers empty into a lake or shoreline area. Determination of which policy supersedes the other is determined by which hazard(s) have the greater or controlling impact on the subject area.

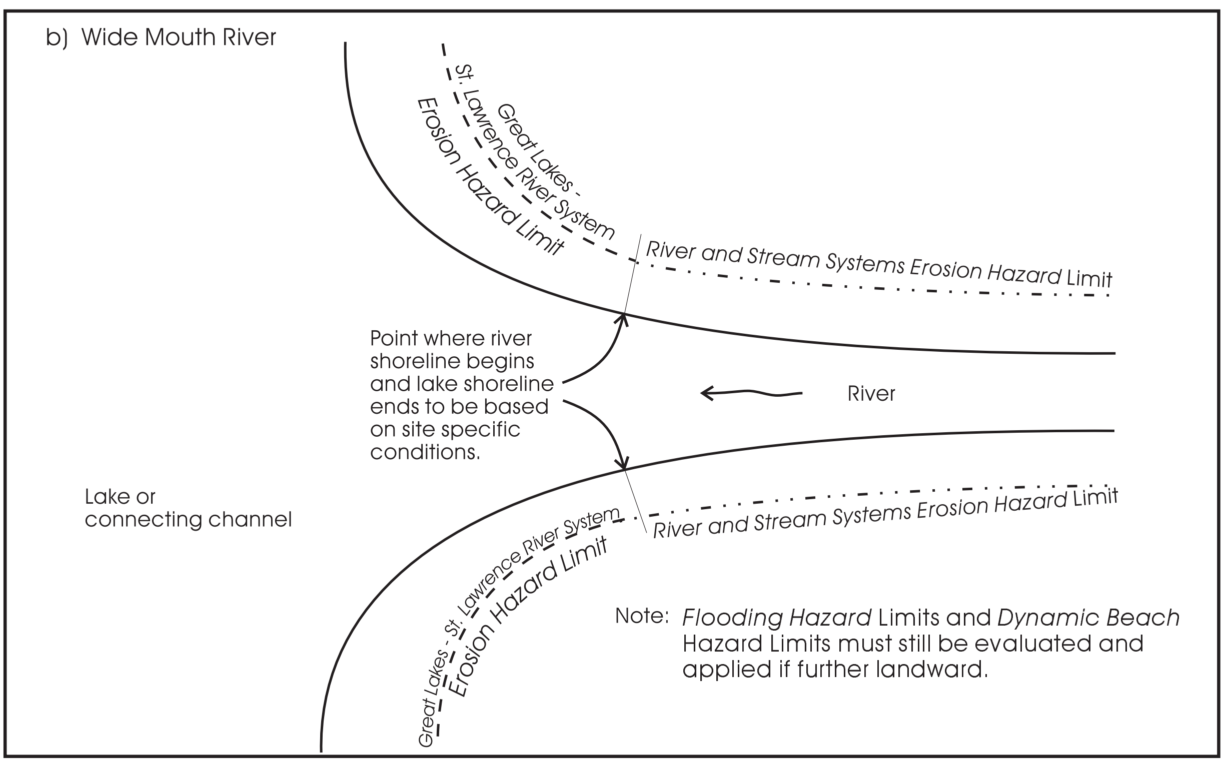
Determining the *erosion hazard* limit at the junction of a lake and a river involves comparing the *erosion hazard* for the *Great Lakes - St. Lawrence River System*, for example Lake Huron, with the *erosion hazard* limit for a river emptying into Lake Huron as defined by the *erosion hazard* standards for *river and stream systems.*

To determine which "standard" takes precedence for the given site, one must determine at which point the erosion forces governed by lake processes are less than the erosion forces within the riverine system. For example, Figure 4.22a shows the location of the *erosion hazard* limits for both the lake and river when the rivermouth is narrow. In these situations, the erosion forces governed by lake processes (e.g., wave action) extend a very short distance upstream of the river mouth. As such, the transition point between the *erosion hazard* standard for the lake and the river is close to the river mouth. Conversely, where the river mouth is wide, and the erosion forces impacting on the lake shoreline extend upstream and impact on the river valley walls upstream of the river mouth, the transition point between the two *erosion hazard* standards is further upstream (Figure 4.22b).

The location of this "transition point" between the *erosion hazard* standards for the *Great Lakes - St. Lawrence River System* and those for *river and stream systems* (see MNR Technical Guide for River and Stream Systems, 1996 for more details on the riverine erosion standards) often requires field investigation as it is driven by site specific conditions.

Figure 4.22: Erosion Hazard Limit at Junction of River and Lake





4.8 REFERENCES

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Ministry of Natural Resources (MNR), 1988. Littoral cell definition and sediment budget for Ontario's Great Lakes. Report prepared for Ministry of Natural Resources Conservation Authorities and Water Management Branch by F.J. Reinders and Associates Canada Limited.

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Geomatics International Inc., 1992. Great Lakes Shoreline Classification and Mapping Study: Canadian Side. Report submitted to Environment Canada, Water Planning and Management Branch.

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APPENDIX A4.1

GULLIES

GULLIES

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A4.1 GULLIES

The purpose of Appendix A4.1 is to provide direction on the determination, measurement, prediction and factors controlling gully growth, recession and advancement.

The need to predict and determine the impact that gully growth rates may have on a particular shoreline is essential to the proper determination of local bluff and/or bank erosion and recession rates.

Several past efforts have endeavoured to develop a method of predicting the growth or extent of gully erosion. One such method involves using the drainage basin area and slope of the gully feature.

Of all of the current methods for estimating gully growth, the simplest is the aerial photogrammetric method. This method essentially involves the measuring of changes in gully size and shape from successive aerial photographs. The growth rate is then determined by dividing the measured changes by the difference in aerial photograph time periods. Comparison of the size of gullies between different years provides a growth rate which can be projected into the future to aid in management decision-making processes.

Although this is the simplest method, it assumes that gully growth rates remain constant over time. This is not always the case, in fact, most gullies tend to erode rapidly during the immature stage of development and then slow down as they reach maturity. The growth rate may also be a function of changes in weather patterns, soil properties or land use. Consequently, once a gully recession rate is determined it should be assessed and, if necessary, adjusted to reflect the current and future life stage of the gully form.

A4.1.1 Determining Gully Advancement

The actual amount of gully erosion expected to occur in any given shoreline location may be a function of a number of natural and physical processes including heavy rainfall, sediment erodibility, and extent of the vegetation cover.

In general, the annual rate of gully advancement is variable, being more rapid at some stages in its life cycle than in others. Observations indicate that the rate of advancement progressively decreases through to the final stages of development. The factors that influence the rate of gully advancement at any period in the life of the gully are varied and complex. Consequently, adequate prediction of the rate of advancement depends largely upon the experience and judgement of the geologist in recognizing the factors which are controlling gully erosion.

One analytical equation used to predict the rate of advancement was developed based on the relationship between headward advancement and primary causal factors.

$$R = 1.5\,(W)^{.46}\,(P_{0.5})^{.20}$$

where

R = rate of headward advancement, in feet per year
W = average drainage area above headcut, in acres
$P_{0.5}$ = the summation of 24-hour rainfalls of 0.5 inches or greater occurring during the life of a gully, converted to an average annual basis, in inches.

A4.1.2 Factors Determining Gully Advancement

There are at least four other factors, not included in the above noted equation, which are known to influence the rate of headward advancement of gullies. These are:

- changes in the erodibility of soil material through which the gully advances,
- the slope of the approach channel above the headcut,
- changes in runoff due to changes in land use and practices in watershed, and
- the influence of groundwater.

Judgement must be used in adjusting for the effect of these factors when determining the future rate of gully head advancement. These factors could be accommodated through the use of the procedure outlined below.

$$R_f = R_p\,(A)^{.46}\,(P)^{.20}$$

where:

- R_f is the computed future average annual rate of gully head advance for a given reach, in feet per year
- R_p is the past average annual rate of gully head advance, in feet per year
- A is equal to the ratio of the average drainage area of a given upstream reach (W_f) to the average drainage area of the reach through which the gully has moved (W_p)
- P is the ratio of the expected long term average annual inches of rain from 24-hour rainfalls of 0.5 inches or greater (P_f) to the average annual inches of rain from 24-hour rainfalls of 0.5 inches or greater for the period, if less than 10 years, in which the gully head has moved (P_p)

Adjustments must also be made for precipitation, the type of surficial materials, and groundwater.

In the case of precipitation, the precipitation factor is a ratio that relates the expected future long-term average precipitation with the average annual precipitation that occurred during the advance of the present gully.

Should a gully advance through materials similar to those in which it advanced in the past, there will be no change in the rate of advancement, therefore no adjustment is needed. The value may be greater or less than 1.0 if a significant change in the soil materials exists upstream from the present gully.

If the composition of the materials in the upstream reaches has a smaller proportion of clay material, it is generally more erodible and a factor of greater than 1 should be used. However, if the material becomes more cohesive further inland, it is generally more resistant to erosion and the adjustment of future advancement would be less than 1.0. Adjustments can be made by multiplying the computed rate of advance and the adjustment factor.

The rate of gully head advancement may change if the gully head intersects a water table or a gully channel emerges above a water table. The rate of gully head movement may be accelerated in zones where groundwater seepage exists at the foot of the overfall or may slow down when progressing above a water table. Where no change in groundwater conditions are anticipated, no adjustment should be made. However, where a gully head intercepts a water table, or where the water table is expected to rise due to land treatment measures, the rate may require an increased adjustment. Conversely, as a gully advances it may rise above the water table and require a decreased adjustment in the rate.

A4.1.3 Determining the Past Rate of Gully Erosion

To properly assess the current or future rates of gully advancement, the past rate of gully erosion should be determined. In the use of this procedure, the past annual rate of gully advance, or R_p is the value which must be determined. This is the reach of existing gully indicated or that which is to be analyzed. The length of gully advancement is determined by use of aerial photographs, maps, field inspection or other methods. The gully age is established primarily by interview, and inspection of old aerial photographs. R_p the average annual rate of headward advance in metres per year can be determined as follows:

$$R_p = \frac{Gully\ length\ (\ metres\ )}{Age\ of\ gully\ (\ years\ )} = metres/year$$

There must be an adjustment made for change in the contributing drainage area. Analysis of a large number of gullies has shown that the rate of advance is related to the approximate square root of the drainage area (U.S. Department of Agriculture, 1966).

In addition to the gully length recession rate, the gully side recession rates should also be determined. This can be accomplished by making perpendicular measurements of the top of gully position changes every 50 metres along the transect for the entire length of the gully (Figure A4.1.1). These measurements are then divided by the number of years between the historic and recent information used to obtain an average annual gully side recession rates at those measurement points.

The toe of bluff average annual recession rate should also be determined along the same gully length transect at the outlet of the gully.

A4.1.4 References

U.S. Department of Agriculture, 1966. Procedure for determining rates of land damage, land depreciation and volume of sediment produced by gully erosion. USDA Soil Conservation Service Technical Release No. 32, 18p.

Other non-cited sources of information on gullies include:

Burkard, Mary-Lou, 1996. Gully erosion along the eastern shoreline of Lake Huron. Ph. D. Thesis, University of Guelph, 203pp.

Burkard, M. and Kostaschuk, R.A., 1997. Patterns and controls of gully growth along the shoreline of Lake Huron. Earth Surface Processes and Landforms.

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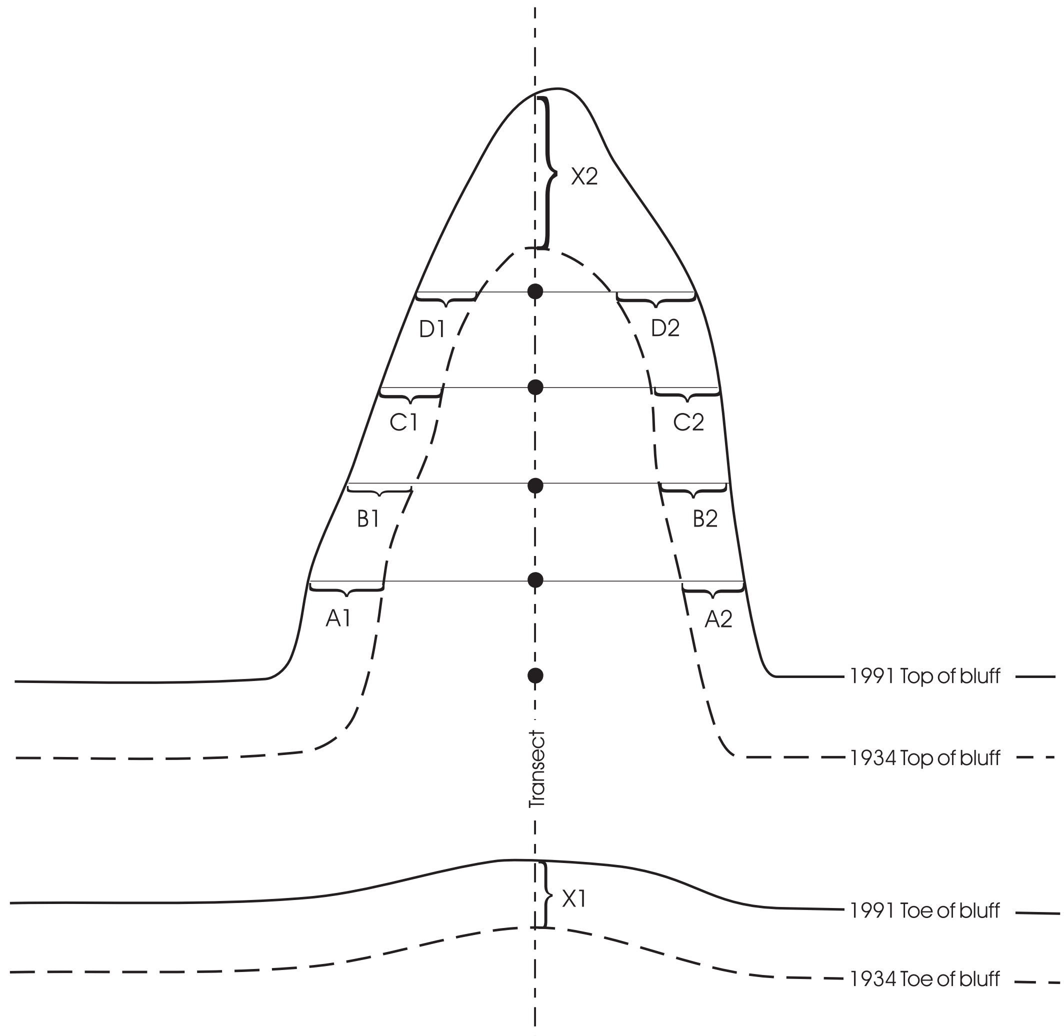
Figure A4.1.1: Procedure to Determine Gully Average Annual Recession Rates



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APPENDIX A4.2

HISTORICAL RECESSION STUDIES

HISTORICAL RECESSION STUDIES

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A4.2 HISTORICAL RECESSION STUDIES

The purpose of Appendix A4.2 is to provide an overview of the various historical recession studies completed for the *Great Lakes - St. Lawrence River System* shoreline in Ontario. This listing is not intended to be all-inclusive as it concentrates on the extensive studies of several lakes as opposed to more site-specific or regional studies.

A4.2.1 Canada/Ontario Great Lakes Erosion Monitoring Programme Final Report: 1973 -1980

a) Objectives of the Study

An erosion measurement programme was undertaken from 1973 to 1980 to measure and monitor bluff and beach changes at 162 selected sites intended to represent the erodible portion of the Great Lakes from Port Severn on Georgian Bay to Kingston on Lake Ontario. The study area encompasses all shoreline types from beaches to high bluff areas for the 2000 km of erodible shoreline found on the lower Great Lakes as well as nearshore and offshore zones.

Two somewhat distinct aspects of shoreline change were evaluated:

- the relatively straightforward one-way processes associated with lakeshore bluff erosion; and
- the dynamic two-way processes of beach erosion and accretion.

The objective was to provide specific data concerning bluff erosion and beach change on the Great Lakes. These results would then be combined with other available information to provide a geomorphological synthesis of the shoreline landforms and patterns present on the erodible Great Lakes shore on both a local and regional scale.

b) Field Surveys

The purpose of the field survey was to measure cross-sections of the shoreline that would extend down a bluff, across the beach and offshore along the lake bottom. The survey was extended offshore to a depth of 18 m or a distance of 3000 m (whichever occurred first) through the use of acoustic sounding. The comparison of annual profiles taken at the same site revealed net changes that occurred between surveys. In total, 162 profile sites or erosion stations were studied.

c) Location of Survey Sites

Preliminary analysis identified both historical and general locations for the erosion stations. In the field, sites which compromised accessibility, erosion extent, permanency of tie-ins and long term surveying feasibility were chosen as survey locations. Over the years some sites lost applicability due to local shore protection efforts, erosion or large scale industrial development. Additional erosion stations were added to either replace lost stations or extend coverage if shown necessary by the results of the first few surveys.

The locations of the erosion stations were shown in the report and a list of geographic coordinates was presented in their Appendix B, Table B-1, and a plan drawing of each site was contained with the master plan of each station which accompanied the final report.

d) Dates of Surveys

Each erosion station was surveyed annually between 1973 and 1980 during the calm summer months. Additional surveys were done for special areas, such as Point Pelee, or following extraordinary events, such as after a major storm, to allow a correlation between annual rates and shorter episodes of erosion. The exact date and time of each survey are listed on the appropriate log sheet.

e) Data Reduction and Methodology

The onshore field notes were reduced using the original bench mark elevation so that all profiles could be compared directly. The offshore sounding rolls were digitized and the information was corrected for water level elevation and scale but the final plots have some vertical exaggeration. The selection of survey points was based on the premise that the land surface profile between two survey points could be represented by a straight line. The assumption being that the variation above and below this straight line should tend toward the mean for each survey and for all years.

f) Products

The basic outputs from data compilation included:

- A master plan showing each site, the measurements used to establish the profile lines, the original onshore profile with soil stratigraphy and composition indicated, and an offshore profile to a depth of 9 m and 18 m at different scales;

- Plots of all onshore surveys;

- Plots of all onshore/offshore surveys;

- Log sheets numerically indicating date and time of survey, linear top of bank recession, volumetric change and water level/water's edge information; and

- Histograms graphically showing volumetric change for the survey period, water level variation, the change at water's edge, and the top of bank change.

g) Checks of Accuracy

A list of specifications for the equipment used during the survey is provided in the body of the report, however, accuracy cannot be fully assessed by simply computing instrument specifications. Additional inaccuracies are introduced into the database because of different operators, changes inherent in surveying a location over a seven-year span, and errors introduced during reduction and plotting of the field data. To circumvent many of these incalculable parameters, an alternative method to test for accuracy used by the investigators was to test repeatability by surveying the same location a number of times (5) on the same day, both onshore and offshore, then run this data through the reduction procedures and ultimately test the variability.

Each year repeatability tests were run by different operators at various locations for the bluff, beach and offshore zones. It was found that the surveying of the bluffs was quite accurate, with a standard deviation on the order of a few cubic metres. For example, the results indicate that on one of the longer profiles of a high bluff (i.e., a "worst-case" example) the standard deviation of the 299.3 m^3 mean was 1.82 m^3. The representative erosion rate at this site (E-2-13) is 1.2 m^3/m/m/yr. Since the volume of material lost is divided by the height of bluff to establish the erosion rate, the standard deviation of the volume can also be divided by the bluff height (e.g., $1.82 \div 21.2 = 0.09$) which means that for general purposes the rate of 1.2 could vary from 1.1 to 1.3 m^3/m/m/yr. Even greater accuracy is probable on the simpler, smaller bluffs. However, this example is valid only for a same day repeatability test since it does not account for all possible errors involved in the methodology and encountered when measuring dynamic natural systems through time.

The repeatability technique may not be as valid for the offshore survey since it does not account for the various wave conditions which affect the accuracy of sounding and the ability to run a straight profile line. Although the tests vary, it is suggested that the typical standard deviation of 95 m^3 for a mean of 12000 m^3 is reasonable. This means that the changes recorded in the far offshore are often not significant; while for the beach zone, changes on the order of 10 m^3 or less may not be conclusive.

h) Top of Bank Change

The top of bank is the point where the flatter tableland abruptly changes slope and drops toward lake level. For eroding bluffs, it is usually quite evident but the exact measurement to this point is subject to some minor surveyor discretion when overhanging matted vegetation obscures the area.

The measurement of the retreat of the top of bluff/bank over time provides information solely on the linear recession rate of the top of the bluff/bank. Its utility lies in the fact that it is a simple, straightforward measurement and concept that directly relates to the loss of the flatter, usable land surface important to local land owners. Since the top of the bluff/bank is generally visible on aerial photographs and available from some past regional and property surveys, it can provide information about long-term historical recession not otherwise available.

The top of bluff/bank recession rate, however, tends to be highly variable in the short term. Although a great deal of material may be eroded at mid-slope or at the toe of bluff/bank, the corresponding changes at top of the bluff/bank may be temporarily slow or non-existent, especially in high bluff areas. Over time, the bluff over-steepens and the upper portion ultimately fails, returning the bluff to its previous shape either by increased yearly increments or by one or more major failures. Since this measurement is highly dependent on the time of survey, care is taken not to reflect the quiescent period nor the catastrophic period but rather the entire cycle when the bluff has the same form. However, for bluffs exhibiting parallel retreat whereby the toe and top of bank are receding at much the same rate, these problems are not as significant.

A4.2.2 Canada/Ontario Great Lakes Shore Damage Survey Technical Report: October 1975

a) Background

During the fall of 1972 and spring of 1973, severe storm action superimposed upon record and near record high water levels caused extensive damage to riparian property on the Great Lakes and connecting channels. Subsequently, a cost-shared agreement was entered into between the Ontario Ministry of Natural Resources and Environment Canada to survey the nature and extent of these damages and to make preliminary recommendations aimed at more effective shoreline management.

The Canada/Ontario Great Lakes Shore Damage Survey was confined to the erodible portion of the Great Lakes from Port Severn on Georgian Bay to Gananoque on the eastern end of Lake Ontario, excluding the Niagara River. The period of survey was November 1972 to November 1973. The results were presented graphically within the Coastal Zone Atlas (see section A4.2.3 for description) and discussed in detail in a Technical Report of the Survey which is summarized below.

b) Methods and Criteria of Survey

The methodologies of the survey may be grouped under four major headings. These are: photography and mapping procedures; determination of erosion rates; shore property inventory; and stage damage survey.

The Canada/Ontario Great Lakes Shore Damage Survey utilized two sets of aerial photography. Coverage flown from 1952-1955 was utilized along with aerial photography from 1973. Profiles were extracted and compared to determine rates of recession/accession for the period between 1952-1955 and 1973. Recession rate histograms were also derived from historical land survey records and from data obtained from ground controlled erosion stations.

Thus, the erosion rates described in the report can be classified into three groups:

- Historical recession and accession rates based on land survey data from 1900 to the time of study;
- Photogrammetrically extracted recession and accession rates based on aerial photography from 1952-1955 and 1973; and
- Ground survey erosion and accretion rates based on erosion station data, 1971 to 1973.

The shore property inventory was gathered from 25 Regional Assessment Offices with the cooperation of the Ontario Ministry of Revenue. The data on land use, land ownership, and land value is stored in a mass data program (SAFRAS) at the Canada Centre for Inland Waters in Burlington.

The stage damage survey provided information as to the nature and extent of shore damage along the Great Lakes. Reconnaissance of the entire erodible shoreline was completed during the 1973 field season while the compilation and analysis of data was carried out during the winter months of 1973-74. Damages were documented by interviewing shore property owners, taking photographs, and preparing sketches showing the overall layout of properties. A total of 8,439 damaged properties were identified along the shoreline and subsequently evaluated in detail.

c) Determination of Erosion Rates

The erosion rates described in the report can be classified into three groups, each bearing its own characteristics and dealing with a different time period. These three groupings are:

- Historical recession and accession rates based on land survey data from 1900 to the time of study;
- Photogrammetrically extracted recession and accession rates based on aerial photography from 1952 and 1973; and
- Ground survey erosion and accretion rates based on erosion station data from 1971 to 1973.

The inclusion of these methodologies helped to create a time perspective for analyzing the erosion process on the Great Lakes and a basis for interpreting the correlations between erosion intensity, time and lake stage.

d) Photogrammetrically Extracted Recession/Accession Rates

The province-wide aerial photographic coverage flown in 1952-1955 by the Ontario Ministry of Natural Resources provided a means of quantitatively comparing the shoreline on the Great Lakes at that time with the shoreline photographed in 1973. An added benefit in comparing these periods was the fact that they both represented periods of peak lake levels over most of the lakes, and thus documented shoreline changes occurring over a complete high-low-high water level cycle. In many respects, the data obtained by this technique were relatively reliable, and allowing for the standard errors inherent in using aerial photographs, provided continuous values for recession along the shoreline.

The techniques used for data extraction from this source were conventional photogrammetric mapping techniques and comprised the following:

- Traces of the edge of bluff were delineated from both series of aerial photographs and superimposed in a horizontally rectified manner. This served to illustrate graphically the changes in edge of bluff position for the ± 20 year interval.
- In areas of non-bluff shoreline, the water's edge (1973) was shown.

- In order to show changes in the shore profile itself, digitized cross-sections were extracted at similar locations for both photographic series and were superimposed to show the changes that had occurred. Spacing of these cross-sections averaged 1 km along the shoreline.

By utilizing these techniques, an accurate assessment of recession/accession rates for the period was obtained which served both to complement historical rates, and to highlight the interactions of water level variations with the recession/accession process.

e) Ground Survey Erosion/Accretion Rates

In order to record the immediate effects of the peak high water stage of the Great Lakes, a ground survey was conducted to re-profile a network of shoreline cross-sections which had been established in 1971-1972 along the shores of Lake Huron, Lake Erie and Lake Ontario (e.g., southern shore). For those stretches of shoreline having no recently recorded profile data (e.g., north shore of Lake Ontario), cross-sections were established which were then resurveyed at 10-12 month intervals.

Each erosion station was selected to represent a typical reach of shoreline having similar physical characteristics of bluff height and composition, beach material, width of beach, angle of wave approach, or any other phenomena associated with the erosion process which could be characterized to a particular stretch of shoreline. An example would be an area subject to rotational arc sliding.

Profile lines were established with their reference points at permanent or semi-permanent land marks such as the intersection of road centre lines or limits, buildings, existing survey monuments and property boundaries. Points along the profile line were then selected and their elevations (IGLD 1955) established from the current water level using conventional levelling techniques.

By comparing earlier profile data with that of 1973, annual net volumes of erosion and accretion were calculated in m^3 by applying the planimetric values to the corresponding reach length.

A computer program was written to facilitate volume calculations in both Metric and English units whereby mean, net, and sub-total erosion/accretion figures are given for each of the reaches along with a grand total for each lake. The calculated volumes represent quantitative changes in the shoreline material of beaches and bluffs from the top of bank to low water datum.

In addition to resurveying and establishing onshore profiles, the 1973 survey undertook offshore profiling to a 20 m depth using a Raytheon echo-sounder. Directional guidance was provided by a Tellurometer Hydrodist system and a Wild T1 Transit. In comparing subsequent offshore profiles, sediment transport patterns of eroded material can be determined. A master plan layout for an erosion station included the location plan of the station, two offshore profiles, one to a 10 m depth, the other to 20 m, and an onshore profile at a scale of 1:1.

To aid in a comparative analysis of recession rates, values of recession/accession were calculated from these profiles of short-term changes and the rates included in histograms on the Coastal Zone Atlas.

f) Erosion on the Great Lakes: Magnitude

As previously discussed, erosion along the *Great Lakes - St. Lawrence River System* shorelines has been quantified using three different classifications: historical recession/accession, 1900 to present; photogrammetric recession/accession, 1952 to 1973; erosion/accretion rates 1971 to November, 1973. Since it is generally accepted that high water levels and storms accelerate the erosion process, rates which are based on the period 1971 to present would appear significantly higher in a comparative analysis. It should be noted that all three methods outlined give recession/accession rates while the third method introduces a volumetric parameter to establish rates of erosion/accretion. The correlations and anomalies of each of the methods are discussed in a comparative analysis which follows the individual analyses.

g) Historical Recession/Accession Rates

Historical rates of shoreline recession were based on land surveys carried out at intervals over several decades. They should be interpreted bearing in mind the following considerations:

- The values represent average rates only, and although they are the closest to the true rates, spanning as they do many oscillations of lake levels and periods of abnormal erosion intensity, they cannot be expected to reflect the shorter-term erosion events.

- A total of 723 erosion measurements were obtained from International Great Lakes Levels Board files and from fill-in data from local land surveyors. After screening, a total of only 410 samples (Table A4.2.1) met the criteria for use in determining historical erosion rates. Aerial coverage varied widely from lake to lake with a greater extent of coverage in Lakes Ontario and Erie than in Lake Huron and Georgian Bay.

Table A4.2.1
Distribution of Historic Recession Measurements

	TOTAL	SELECTED FOR ANALYSIS	REFERENCED TO EDGE OF BLUFF
Lake Ontario	161	72	72
Lake Erie	217	117	59
Lake St. Clair	52	21	1
Lake Huron	293	200	49
	723	410	181

- Where possible, "edge of bluff" was used as the standard reference feature. However, in some areas, there was no definable bluff and recession had to be referenced to the high water mark or the water's edge. Measurements referenced to edge of bluff were preferable in that they represented a permanent reduction of usable property. Changes in high water mark, as in beach area, are not necessarily permanent and may represent temporary property gain in low water periods.

- Average recession/accession rates were determined by a weighted average technique. Each erosion measurement represents a reach of shoreline of similar physical characteristics and orientation. These reaches were assumed to be receding or acceding at the same rate. Weighted average rates were determined as follows: for each reach in a county, the product of the measured recession/accession rate times the reach length was determined; the total length of the reaches considered was added; the weighted average recession/accession rate was determined by dividing the sum of the reach length - recession rate products by the total length of reaches considered; percentage coverage was determined by dividing the length of the considered reaches by the total shoreline length.

Many areas were not covered because the shore was considered to be non-erodible. For example, some areas along the shore were primarily bedrock while other areas were protected by breakwaters or piers. Therefore, the average erosion rates cited should be considered representative only of the erodible shorelines within the lake or county.

h) Comparative Analysis of Results

In Appendices 3.4.1 through 3.4.4 of the technical report supporting the Canada/Ontario Great Lakes Shore Damage Survey, recession/accession data are listed for the Great Lakes erodible shoreline. An analysis of the three distinct groups of recession rates was made a part of the study. The recession rates obtained photogrammetrically were based on a shorter time interval than the historical rates. Thus, the historical rates were the best representation of long-term average recession rates. Data obtained from erosion stations established from 1971 to 1973 represented short term changes in the shoreline during a period of abnormally high water levels and frequent storms. Thus, these figures are relatively high when compared to the historical and photogrammetric rates.

When looking for a method of standardizing recession rate data, the photogrammetrically extracted recession rates from 1955-1973 are preferable. The coverage proved to be more continuous than in the historical analysis and all of the data referred to the approximate same time interval.

In analyzing the recession rates obtained by any of the three methods, the reference mark should be carefully noted. "Edge of bluff" is considered the best reference since changes in its position can be readily identified. Where "water's edge" was used as a reference, the accession or recession of beach areas becomes dominant in establishing average rates. Beach areas are in a constant state of change so that average net accessions were quite common in certain areas of the Great Lakes. It was concluded that stations referenced to "edge of bluff" give the actual recession of the bluff while those referenced to "water's edge" illustrate the relative movement of beach areas.

The third method of erosion analysis referred to a series of erosion stations established in 1971 and resurveyed during the period of survey of the Canada/Ontario Agreement. Volumetric data were derived to give a representation of erosion/accretion rates rather than recession/accession rates. Since the unit derived (m^3/m/m/yr) was based on volumetric data, one should not attempt to draw any distinct parallels between this data and the recession/accession data.

Through these varied methodologies, it is concluded that erosion intensity during the period of survey, November 1972 to November 1973, was significantly higher than that observed in a long-term analysis. It also becomes obvious that to obtain an accurate assessment of the erosion taking place in a particular area, individual stations must be analyzed separately rather than assuming that weighted average rates are effectively representative.

A4.2.3 Coastal Zone Atlas

The fundamental aim of the Coastal Zone Atlas was to provide easily interpreted base maps, compiled from the latest available survey information and as accurately represented as the scale would allow. There was a 50% reduction of scale between the master copy and the final printing size.

Each of the 637 map sheets in the Atlas are large enough to accommodate approximately 9 kilometres or 6 miles of shoreline at a scale of 1:20,000 when drawn on a 1,000 metre grid superimposed on a 6° Universal Transverse Mercator Projection.

Erosion and/or recession rates were gathered according to three distinct methodologies which were discussed previously in Section A4.2.2 and are:

- Historical recession and accession rates based on land survey data from 1900 to present;
- Photogrammetrically extracted recession and accession rates based on aerial photography from 1952 to 1973; and
- Ground survey erosion and accretion rates based on erosion station data from 1971 to 1973.

The Atlas is composed of two map sheets with several accompanying strips of information. The content of each sheet and associated strip is as follows:

a) Contents of Sheet 1

Sheet 1 consists of three strips: photomosaic, township lot lines with 1973 shoreline and histograms of recession or accession rates. There were some notable exceptions to the format of sheet 1. In certain areas, the extraction of topographic information was excluded (i.e., 3 metre contours) the 1973 water's edge, relative position of bluff edge and profiles. These areas were:

- Bruce Peninsula from Owen Sound to Oliphant;
- St. Clair River from Sarnia to Port Lambton;
- Inner Toronto and Hamilton Harbours;
- Bay of Quinte, Adolphus Reach and North Channel; and
- Amherstview to Gananoque, north shores of Amherst and Wolfe Island and Howe Island.

The reason for the above exclusions is that the areas were either not susceptible to erosion or inundation, or were subject to comparatively minor effects due to their physical characteristics and geographical orientation.

Where the shoreline configuration in these areas is such that the photomosaic is best shown on the full size of sheet 1, strips 2 and 3 are omitted, and the space is thus utilized. In these cases, the township lot lines are directly superimposed on the photomosaic.

i) 1st Strip

The first strip is a photomosaic produced from black and white infrared aerial photographs, flown between March and June 1973 at an altitude of 10,000 feet. Horizontal control was established using road patterns on enlargements of the 1:25,000 scale map sheets of the National Topographic Series. Where the 1:25,000 scale maps were not available, the 1:50,000 scale series were used. The minimum width of land shown on the photomosaic is about 1.6 kilometres (1 mile). In addition to the standard nomenclature, the daily mean water level was shown for the date of the aerial photography and 3 metre contours were plotted extending 200 metres inland from the shoreline. The locations and identification numbers for the profiles extracted photogrammetrically and from ground erosion stations were also shown on the photomosaic.

Water levels and contour lines were referenced to International Great Lakes Datum (IGLD 1955) with the first contour being 3 metres above datum for each lake. These contours, which were extracted photogrammetrically from the 1973 aerial photographs, serve to illustrate the general topography of the shoreline and to identify areas susceptible to inundation. The profiles for the determination of erosion rates were extracted from both the 1952-56 and 1973 aerial photographs at approximate intervals of 1.6 kilometres along the erodible shoreline. The 1952-56 black and white Ontario Forestry Resources Inventory aerial photography was flown at a scale of 1:15,800. Locations of profiles were chosen to coincide on both the 1952-56 and 1973 aerial photographs in such a way that they could be readily identified. An additional criterion in selecting profile locations was to have them coincide with ground erosion station profiles wherever the latter existed.

As with the map sheets, the numbering system of the profiles increases with the general direction of gradient flow for each lake. For example, the profile number of Lake Erie starts with E-1 at the west end and ends with E-211 at the east end of the lake. In order to distinguish between photogrammetrically extracted profiles and ground erosion station profiles, the numbers for the latter are in parenthesis.

ii) 2nd Strip

The second strip shows township lot lines, the water's edge at the time of the 1973 aerial photography and changes in the position of the edge of bluff between 1952-1956 and 1973. The water's edge and relative positions of the edge of bluff were extracted photogrammetrically and superimposed with horizontal control. This serves to illustrate graphically the changes in the position of the edge of bluff for the 20 year interval. Where no significant change took place, the edge of bluff for 1952-1956 and 1973 were shown intermittently. Township lot lines were extracted from county maps and township plans, and serve as a cross-reference to the land title base.

iii) 3rd Strip

Histograms of rates of recession and accession form the third strip. The abscissa and ordinate of the histograms represent the rate and time span respectively. These histograms show both long and short term recession and/or accession rates at profile locations shown on the photomosaic. Also shown on this strip is a graph indicating the fluctuations of lake levels during the time period to which the rates are referred.

In determining the rates of recession, the edge of bluff was used as a reference point wherever possible. Otherwise, the histograms were calculated and annotated with reference to water's edge. When rates were calculated with respect to water's edge, adjustments were made to compensate for changes in lake level. In order to distinguish between rates extracted photogrammetrically and those based on ground measurements, dashed and solid lines were used respectively. Where two horizontal lines appear, with no vertical connection, recession or accession rate records exist but no significant change in the edge of bluff or water's edge has taken place during the time period indicated. Where only the zero rate line appears for a profile, records exist but were deemed unreliable and were not shown.

b) Contents of Sheet 2

Sheet 2 consists of five data strips depicting shoreline damage, ownership, value, land use, physical characteristics and existing protective works in damaged areas.

The information depicted by the strips 1 and 5B was compiled from a damage survey which examined the entire erodible shoreline.

The data depicted on strips 2, 3 and 4 were extracted from the shore property inventory which included all the Great Lakes mainland and island shoreline from Port Severn on Georgian Bay to the Ontario/Quebec boundary on the St. Lawrence River. The inventory is based on a 100% sampling of riparian property.

The data on the strip 5A were extracted from International Great Lakes Levels Board (IGLLB) maps prepared by Public Works Canada with updating from sequential oblique colour slides taken from the air in 1973 and field observations.

A detailed breakdown of the classifications for the five strips appears in the legend on each sheet 2 of the Atlas. The format of presentation is briefly described as follows:

i) Strip 1: Shoreline Damage

The structural damage value was based upon the degree of damage sustained and the subsequent replacement value or cost of remedial work required. Inundation damage dealt not only with loss of use due to flooding, but also with the obsolescence of protective or marine structures as a result of high water levels. In this case, the damage evaluation was based on the cost of rendering the structure useable. The values derived in this damage survey were based upon identification of all damaged properties (8,349) and subsequent evaluation in detail using a costing schedule which was developed through the cooperation of Central Mortgage and Housing Corporation and local industries. The extent of damage presented relates to the period of survey, November 1972 to November 1973. Where blank spaces appear on this strip, no shoreline damage occurred.

ii) Strip 2: Shoreline Ownership

Shoreline ownership is designated on the Atlas as public (i.e., federal, provincial, municipal) or private. The information is shown on the landward side of the strip. Where blank spaces appear, information was not available for that area.

iii) Strip 3: Land Value

Land value represents the total value of the land plus its improvements. At the time of the survey, many of the regional assessment offices were in the process of converting their assessed values to market values. The land data as they appear in the Atlas are based upon the following regional classification (Table A4.2.2).

Table A4.2.2
Land Data Regional Classification

COUNTY OR REGIONAL MUNICIPALITY	ASSESSED (A) AND/OR MARKET (M)	COUNTY OR REGIONAL MUNICIPALITY	ASSESSED(A) AND/OR MARKET(M)
Simcoe	A	Peel	A
Grey	M	Metro Toronto	A & M
Bruce	M	Durham	A & M
Huron	M	Northumberland	A & M
Lambton	M	Hastings	A & M
Kent (Lake St. Clair)	M	Prince Edward	A & M
Essex	M	Lennox & Addington	A
Kent (Lake Erie)	M	Frontenac	M
Elgin	M	Leeds	A
Haldimand-Norfolk	A	Grenville	A
Niagara	M	Dundas	A
Hamilton-Wentworth	M	Stormont	A
Halton	M	Glengarry	A

As is the case on strip 2, the information is shown on the landward side of the strip and data were not available wherever blank spaces appear.

iv) Strip 4: Land Use

This strip designates the use of the shoreline (e.g., residential, industrial, commercial, etc.) as presently classified by the Ontario Ministry of Revenue. The information is shown on the landward side of the strip. The distribution of wildlife habitat areas was provided by the Ontario Ministry of Natural Resources. In areas were wildlife habitat co-exists with other land uses, the strip is divided in half to depict both uses.

v) Strip 5A: Shoreline Physical Characteristics

Information on physical characteristics of the shoreline are shown on the landward side of strip 5. The three main categories are beaches, bluffs and plains, definitions of which are given in the Glossary of Terms.

vi) Strip 5B: Existing Protective Works in Damaged Areas

This information is shown on the lakeward side of strip 5. The protective works were divided into six main groups according to their intended function. Where blank spaces appear, protective structures may exist but were not damaged during the period of survey and therefore are not shown.

vii) Special Notes: Sheet 2

Where the configuration of strips created a space problem on Sheet 2, special notes were used to replace strips 1 to 4, in parts or in their entirety, in order to reduce the total number of sheets. These special notes were used for strip 1 where no damage occurred and for strips 2 to 4 where no information was available.

c) Limitations

The information on shore damage and property inventory is applicable to riparian property only. In most cases the scale of the Atlas did not permit the information to be shown on an individual property basis but rather in an aggregated and generalized manner.

Other information (i.e., contours, relative positions of edge of bluff, 1973 shoreline, township lot lines and other geographical boundaries) was presented as accurately as the scale of the Atlas permitted.

TECHNICAL GUIDE FOR
GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

APPENDIX A4.3

HISTORICAL MAPS AND AERIAL PHOTOGRAPHS

HISTORICAL MAPS AND AERIAL PHOTOGRAPHS

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A4.3 HISTORICAL MAPS AND AERIAL PHOTOGRAPHS

The primary purpose of Appendix A4.3 is to provide an overview of the factors effecting the use and comparison of historical maps and aerial photographs and to provide an inventory of potential federal, provincial and public programs offering access to map and aerial photograph information. In addition to identifying map and aerial photograph programs, the inventory provides a program overview, identifies map content, discusses the coverage(s) and scale(s) available, outlines the procedures for conversion to digital files and/or availability of digital information where available and provides direction on ordering procedures for each respective program.

A4.3.1 Factors Affecting the Use and Comparison of Historical Maps

There are a number of issues and factors that must be considered when using and comparing maps including:

- scale;
- datum changes;
- uneven map shrinkage;
- map defects (e.g., tears, folds, creases);
- publication standards; and
- projection.

To assist in determining the implications of each of these factors, a discussion of each factor is provided below.

a) Scale

Every map has a scale which should be expressed as the representative fraction, or ratio between a given distance on the ground and on the map (e.g., 1:2,000). Usefulness of these maps for quantifying shoreline change depends on their accuracy standards and scale.

The question of accuracy becomes even more important when dealing with maps that are not generated using provincial mapping standards or compiled by a qualified Ontario Land Surveyor. Older non-standard maps are useful for describing the long-term history of shoreline change, but their reliability must be carefully evaluated.

For the purpose of quantifying shoreline changes large-scale mapping (i.e., 1:5,000 or larger) should be used. Older regional maps can, at best, be used only for qualitative assessment of shoreline changes.

The rationale for using 1:5,000 or better large-scale mapping is based on what is referred to as the "smallest field distance measurable" from the map source which is best explained by the following:

Scale	Field Distance Distance on Map - 0.5 mm	Field Distance Distance on Map - 0.2 mm
1:125,000	62.5 m	25.0 m
1:62,000	31.0 m	12.4 m
1:50,000	25.0 m	10.0 m
1:25,000	12.5 m	5.0 m
1:20,000	10.0 m	2.0 m
1:10,000	5.0 m	2.0 m
1:5,000	2.5 m	1.0 m
1:2,000	1.0 m	0.4 m
1:1,000	0.5 m	0.2 m

The distance given in the two right-hand columns now must be divided by the number of years of study, to yield the "smallest measurable change per year". Any measurement smaller than this limit must be taken to mean "no detectable change". For example, two maps, each at a scale close to 1:5,000 were published 20 years apart. Using the "strict" limit of 0.2 mm, we note that this translates into a “smallest field distance measurable” of 1 m, which is 0.05 m/yr. Erosion or accretion smaller than this cannot be detected, nor can a statement be made as to whether the changes, if there have been any, were erosion or accretion.

When using maps the scale should be verified by measuring known distances between objects which appear on both maps, and which can be located today. This is especially important for older maps, and for maps not compiled by the official mapping agencies.

b) Datum Changes

An additional error is made if the data source for one date differs from another data source. Datum changes often occur when using two different sources of maps such as comparing topographic mapping with nautical charts.

c) Uneven Map Shrinkage

Maps that were originally printed on paper are subjected to varying degrees of shrinkage. Typical map paper can expand over 1 percent with a 60 percent increase in humidity, and expansion varies in different directions on the same sheet. This generally is not a problem if the amount of shrinkage is equivalent in all directions because many computer mapping programs have the ability to uniformly increase or decrease map scale. Unfortunately, shrinkage can be problematical in that paper tends to shrink more along the grain so that scale change introduced by shrinkage is not the same in both directions. Uneven shrinkage can be determined by calculating distortion factors, either manually or by computer so that overly distorted maps can be identified, then rectified or discarded. If possible use only mylar copies of maps. Mylar resists further shrinkage and does not pucker or crease easily as paper or bromide prints.

d) Map Defects

Many older historical maps are plagued with major and minor tears, folds, and creases. The magnitude of distortion caused by defects can be determined by digitizing at least four control points spanning both sides of the defect. If the distortion is excessive, then each segment of the defect-divided map must be digitized separately. Accuracy assessments must again be conducted within the individual defect-bound segments. Again this is a strong argument to use mylars whenever possible.

e) Publication Standards

Shoreline measurements obtained from historical maps can only be as reliable as the standards to which each original map was made and on changes which may have occurred to a map since its initial publication. It should be noted that not every measurable distance on a published map is correct, even within the limits set by scale.

f) Projection

A variety of projections have been used to represent earth surface features on maps. All maps contain distortions in their particular projections. The problem for shoreline mapping occurs when data from different projections are compared.

A4.3.2 Factors Affecting the Use and Comparison of Aerial Photographs

Similar to the use and comparison of historical map information, there are factors and issues which must be considered when using and comparing aerial photographs including:

- location and quality of control points;
- tilt (i.e., scale differences within the photo);
- scale differences between photos;
- scale verification;
- relief displacement;
- radial lens distortion; and
- film and print buckling.

To assist in determining the implications of each of these factors, a discussion of each factor is provided below.

a) Location and Quality of Control Points

With respect to reference points, a concentrated effort should be made to insure that only permanent type objects that are close to the ground and lend themselves to identification from the air are used.

b) Tilt (Scale Differences Within Photo)

Aerial photographs taken where the optical axis of the camera is approximately perpendicular to the ground surface are called vertical photographs. However, virtually all vertical air photos are slightly tilted with a 1° tilt being common and up to a 3° tilt not unusual (Lillesand and Keifer 1979). Unfortunately, the scale across tilted air photos is non-orthogonal. This can result in gross displacements of features depending upon the degree of tilt. For example, on 1:20,000 scale air photos, a 1° tilt can result in about 20 metres of displacement between a point on an air photo and its actual ground location; a 3° tilt may yield a horizontal displacement that exceeds 60 metres (Leatherman 1983).

The relationship between a tilted and exactly vertical air photos is illustrated in Figure A4.3.1. On the upper side of the air photo, images appear displaced radially toward the isocenter, and radially away from the isocenter on the lower side of the image.

Displacement of a point on an air photo due to tilt (*D*) from its actual ground position can be calculated using the following relationship:

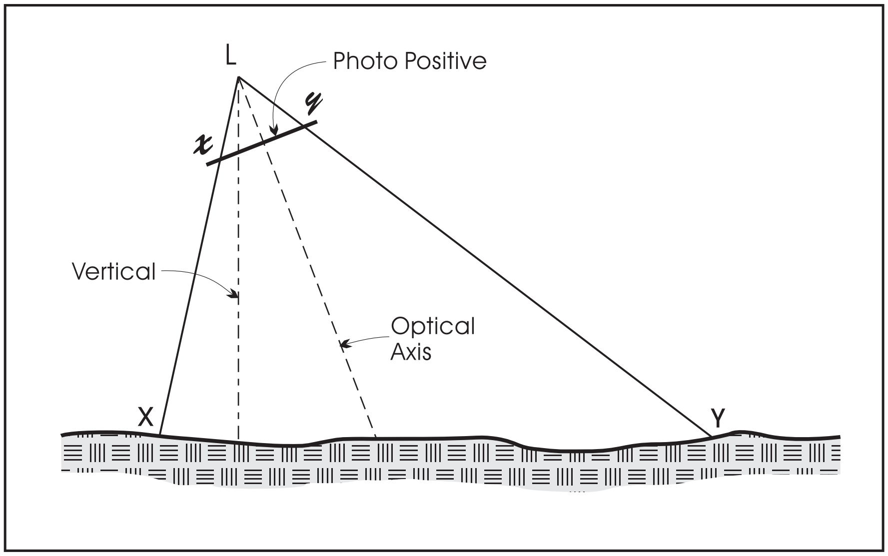
$$D = \frac{[\, r^2 (\sin t)(\cos^2 P)]}{[\, f - (r \sin t)(\cos P)]}$$

where:

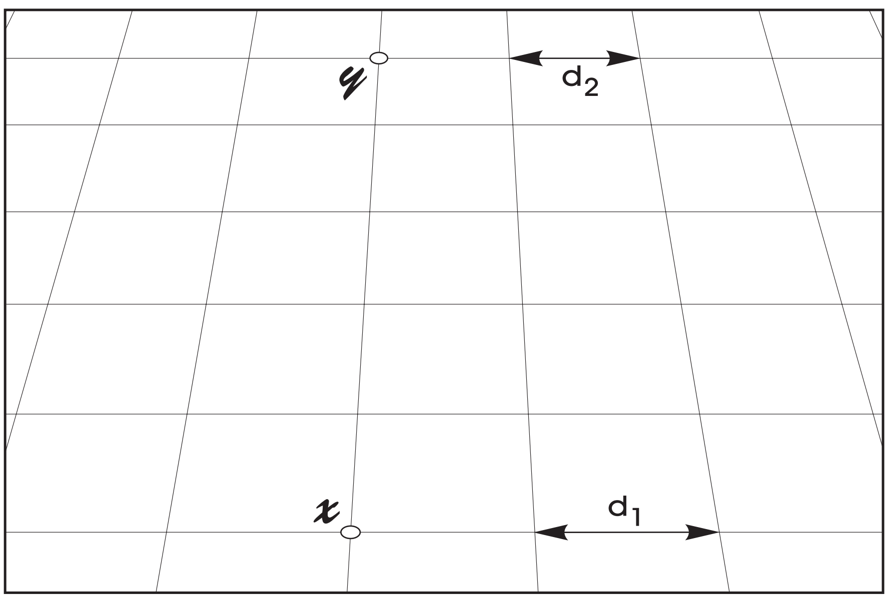
r = the distance from the point to the isocenter
f = the focal length of the lens
t = the angle of tilt of the photograph
P = the angle measured clockwise from the principal line to the radial line between the isocenter and the point within the plane of the photograph

As is apparent from this equation, the amount of displacement increases with distance from the isocenter and with increasing tilt. For example, with a tilt angle of only 1 degree, a control point 10.0 cm from the isocenter and 40 degrees from the principal line on a 1:20,000 air photo would be in error by 13.6 m relative to its true ground location. Under similar conditions, a point on an air photo with 3 degrees of tilt would yield an error of 41 m in its

Figure A4.3.1: Tilt



a) Principal Plane of a Tilted Photo Taken Over Flat Ground



b) Image on the Tilted Photo of a Square Ground Grid

Due to tilt, object distance LX in figure a) is less than object distance LY and hence a grid line near *x* would appear larger (at a bigger scale) than a grid line near *y*. This is illustrated in figure b) where photo distance d_1 appears longer than photo distance d_2, yet both are the same on the ground.

ground location. Using air photos with minimal tilt and working only at the centre portion of the air photo minimize point displacement (*Accuracy of Shoreline Change Rates as Determined from Maps and Aerial Photographs,* 1991).

Air photo tilt must be corrected prior to or concurrent with air photo interpretation. Tilt correction is a process of projecting a tilted photograph on to a horizontal datum plane and can be done manually by using a Zoom Transfer Scope, or analytically by using stereoplotters or computerized space resection programs (*Historical Shoreline Change: Error Analysis and Mapping Accuracy,* 1991).

c) Scale Differences Between Photos

Another problem with aerial photography arises from the inability of an airplane to fly a constant altitude. Changes in altitude cause the scale to vary from one photograph to the next.

Exact scale for each air photo should be determined so appropriate factors are used when digitizing or scaling data from an air photo. Photographic scale (S) can be calculated by:

$$S = \left(\frac{H}{f} \right)^{-1}$$

where:

f = the focal length of the camera lens
H = the height of the camera above the mean elevation of the terrain (in similar units).

The result is a representative fraction corresponding to map scale. Scale may also be determined if the distance between two points or the size of an object is known in the field or on an accompanying map.

To illustrate the effect of scale variation, the following example is presented. At the start of an air photo mission, the elevation of the plane is 3,048 m (10,000 ft) and a 152.4 mm (6 in) focal length lens is used, for a scale of 1:20,000. During the mission, if the elevation of the aircraft decreases by 10 m (15 m is not uncommon in small light planes), at the moment of exposure, the scale of that photo will be 1:19,934. If this air photo were used to measure distance between a stable point and a shoreline position (e.g., 10 cm), ground distance would be calculated at 2,000 m, assuming a 1:20,000 scale. However, if the scale were actually 1:19,934, the distance between the points is 1,993.4 m. This would produce about 6.6 m difference in location of the shoreline point (*Accuracy of Shoreline Change Rates as Determined from Maps and Aerial Photographs,* 1991).

A Zoom Transfer Scope is very efficient in removing scale differences between photos. However, because of the likelihood of inherent tilt distortion, the use of space resection programs or analytical stereoplotters may provide better results (Leatherman 1983; Clow and Leatherman 1984; *Historical Shoreline Change: Error Analysis and Mapping Accuracy,* 1991).

d) Scale Verification

On photos, the problem of scale verification has two facets. For unfavourable scale photography (e.g., 1:80,000), measurement of distances between key points is a straightforward procedure, which permits a single-photo scale to be determined. The published scale is only an average, in some general sense, and cannot be used for shoreline change calculations. Because of scale changes from one part of the photo to another, due to tilt, differential shrinkage of the paper, such measurements must be made in several different places, along lines having different orientations, producing in some instances north-south scales which are different from the east-west scales. Once the scale has been determined, or the scale difficulty has been stated clearly, the investigator faces the problem of lack of detail. Enlargements do not solve the basic problems of unfavourable-scale photography.

The other facet deals with favourable scale photography such as 1:1,000 or 1:2,000. Here the detail is sharp and rich, and measurements are easy to make, but scale verification is extremely difficult to achieve, for the simple reason that the necessary key points are scattered across several photos, thereby introducing a scale ambiguity of a new kind (i.e., scale variability from one photo to the next). The best way to handle this problem, if it arises, is to make high-precision ground measurements at enough points to establish the scales of the individual photos. Such verification can be undertaken for photos of any age, provided that enough key points appear both on the photos and on the ground at the time of measurement. In this work, it should be kept in mind that houses and fence corners may have been moved; that the middle stripe of a highway, after three-, four-, or five-laning, is not necessarily located where it was prior to widening or relocation; and that highways may have been moved *(Standards for Measuring Shoreline Changes,*1978).

e) Relief Displacement

Differences in elevation or relief of land surfaces introduce a type of distortion called relief displacement, where surfaces rising above the average land elevation are displaced outward from the photo isocenter. Distortion due to relief displacement can easily be seen when viewing air photos taken above towns or cities with tall buildings or high shoreline bluffs. In the centre of the photos, tall structures appear to point straight up. Relative displacement of the top of the structure relative to the structure foundation is minimal. However, as one moves farther away from the photo isocenter, summits of buildings become progressively displace (Stafford 1971).

Low-lying beach environments are relatively flat so that distortion due to relief displacement is usually negligible. However, in high relief areas, such as bluff shorelines care should be taken in selecting primary control points that are about the same elevation as the feature (Stafford 1971). Otherwise, such distortion of air photos must be removed mechanically by stereoplotters or analytically as part of the space resection subroutine. Note that distortion due to relief displacement can be minimized if only the centre portion of the air photo is digitized (*Historical Shoreline Change: Error Analysis and Mapping Accuracy,* 1991).

Displacement of an image due to radial distortion resulting from elevation changes (D_c) can be calculated as:

$$D_c = \frac{r\,h}{H}$$

where:

r = the distance on the photograph from the centre of the image to the top of the object
h = the ground elevation of the object
H = the flight altitude of the camera relative to the same datum as h.

On the water plane, which is, on the average, essentially flat within the distance of interest in mapping, there is typically no radial distortion. Therefore one might deduce that relief problems do not enter into making measurements on air photos.

The position of the shoreline must be identified however, relative to a reference point of some kind, and such reference points are almost invariably located on the landward side of the shoreline. The reference point, for any given measurement, may be elevated considerably above the water plane.

All of the points on the air photo image were photographed from a single position in space: the camera lens. A lighthouse, standing 10 m high, on top of a 30 m vertical cliff, does not point toward the camera lens, with the single exception of the instant when the airplane is directly overhead, and perfectly horizontal. Instead, the camera, at almost all moments, sees a side of the lighthouse, and in 50% of the moments, the face of the cliff. This means that the vertical line, from the top of the lighthouse to the water level, is laid out on the photo as if it were a horizontal line; the fact that this horizontal line has length is evidence for relief distortion, and the length of the line is, in fact, a direct measure of the amount of relief distortion.

Lattman and Ray (1965, p. 42) cite the well-known formula:

$$m = \frac{r\,h}{H}$$

where:

- m = radial displacement of the top, relative to the base.
- r = radial distance, on the photo, from photo centre to base of object (i.e., water plane, in our example).
- h = height of object (i.e., altitude above water plane, in this case).
- H = altitude of camera (i.e., above the water plane).

(Consistent units, such as S.I. units, should be employed.)

For example, a control point on a 10 m cliff, 10 cm (0.1 m) from the photo centre, is displaced 0.333 mm. At a scale of 1:20,000, this is a horizontal error of 6.667 m, which might be interpreted by the unwary as erosion or accretion, depending on the relative positions of land and sea (*Standards for Measuring Shoreline Changes,* 1978).

f) Radial Lens Distortion

A problem which may be a factor in older air photos is that of radial lens distortion. Lens distortion varies as a function of radial distance from the photo isocenter. As such the centre of the image is relatively distortion free, but as the angle of view increases, distortions become more pronounced. While a significant source of error in earlier photography, it has become less of a problem with refinements in lens manufacturing technology (Clow and Leatherman 1984).

Apparently, it is impossible to correct this problem without knowing the make and model of the lens that was used. However, if overlapping air photos are used in the study, one can digitize the centre (i.e., non-overlapping and relatively distortion-free) portions of the air photos (*Historical Shoreline Change: Error Analysis and Mapping Accuracy,* 1991).

g) Film and Print Buckling

This is an individual problem, commonly due to rapid transport of the film within the camera, especially in “shutterless” cameras, for which no firm rules can be stated, except one: do not make measurements on such photos. Buckling should be obvious where the water plane can be seen; it shows clear sine-wave relief in the 3-D image. Streams on the adjacent land may also indicate buckling, by flowing uphill along part of the stream course.

Buckling almost never extends entirely across any one picture frame, hence the error due to this cause varies from place to place on one picture. Print buckling and shrinkage can be minimized by using aluminized or mylar paper (*Standards for Measuring Shoreline Changes,* 1978).

A4.3.3 Programs and Sources of Mapped Information

The following sections identify various data sources available for use in determining **average annual recession rates** along the *Great Lakes - St. Lawrence River System* shoreline in Ontario. This listing is not intended to be comprehensive.

a) Canada/Ontario Flood Damage Reduction Program: Shoreline/Riverine Mapping Program

i) Overview of the Program

In 1978, Environment Canada and the Ontario Ministry of Natural Resources (MNR) entered into the Canada/Ontario Flood Damage Reduction Program (FDRP). The program has, as its prime objectives, the reduction of potential damage in flood and erosion risk areas along the rivers and lakes of Ontario, and the reduction of risk of loss of life. These objectives are pursued by discouraging new development in flood and erosion risk areas.

The program involves mapping and hydrologic and hydraulic analyses within floodplains and along the shorelines of the lower Great Lakes and the St. Lawrence River. Individual conservation authorities prioritize and arrange for the production of conventional (i.e., paper) and digital (i.e., computerized) technical flood risk maps at a scale of 1:2,000 to 1:5,000 for their respective shorelines and rivers. Public Information Maps are then prepared at a scale of 1:5,000 to 1:25,000, and are distributed free of charge to the public.

ii) Overview of Map Content

Large scale (i.e., 1:2,000 - 1:5,000) FDRP maps are possibly the most ideal source for recession rate data. Few other sources provide equally adequate, accessible topographic information for as much of the *Great Lakes - St. Lawrence River System* shoreline.

An overview of the information portrayed on 1:2,000 and 1:5,000 scale FDRP maps is provided below, along with a sample section of a 1:2,000 scale FDRP topographic map.

- topographic contour lines (i.e., 1 metre interval with 0.5 m auxiliary, North American Datum (NAD) 1927),
- 100 year flood line,
- numerous point elevations,
- UTM georeferencing,
- Transverse Mercator projection,
- vertical/horizontal control points, and
- the outline of roadways including street names, significant stands of vegetation, and structures such as houses.

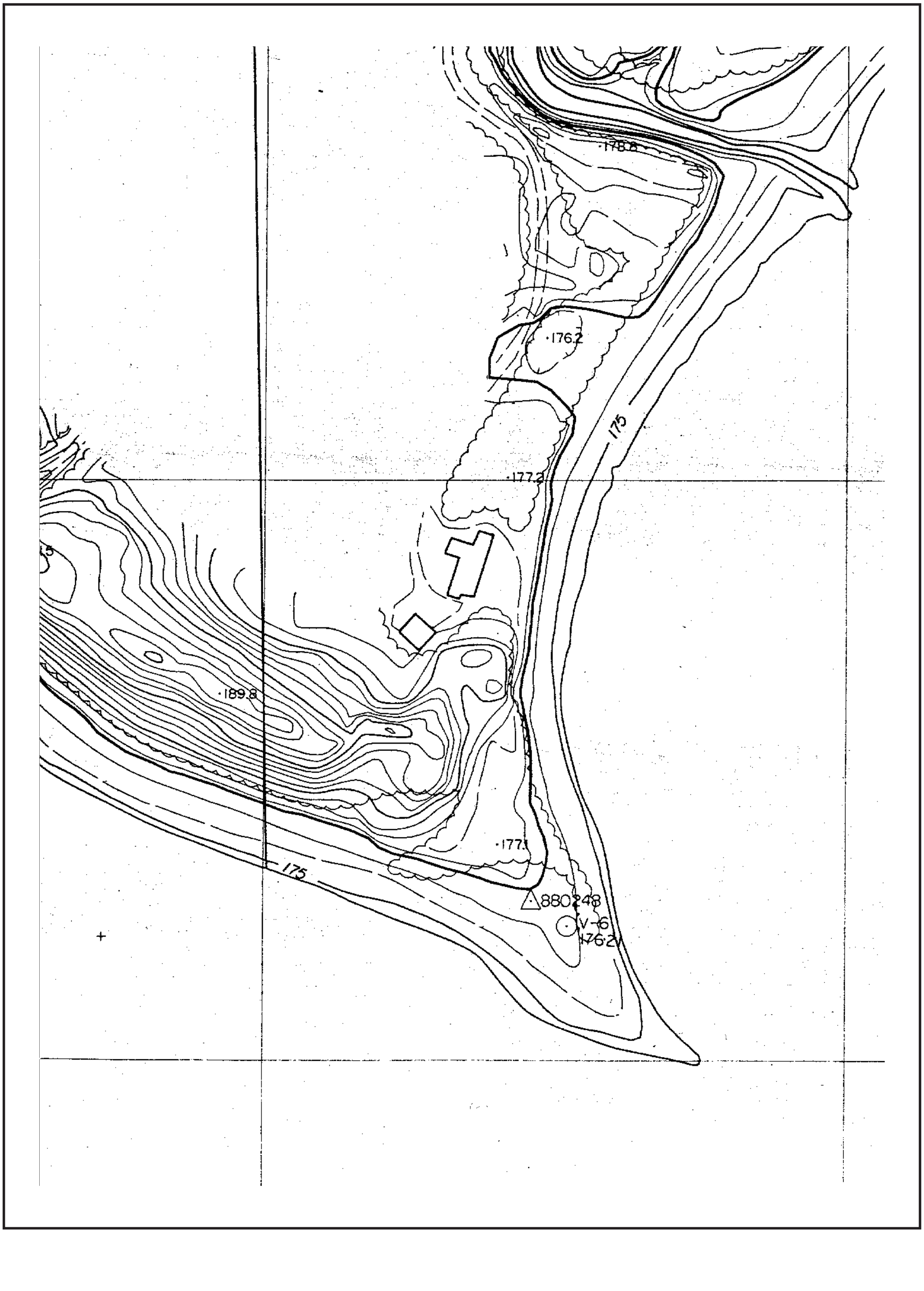
The accuracy of FDRP mapping is specified in the Canada/Ontario Flood Damage Reduction Program, Survey and Mapping Guidelines, Schedule C. FDRP mapping meets Class A NATO standards whereby 90% of the well-defined features measured from the map will fall within 0.5 millimetre, at map scale, of their actual planimetric location. Vertical control is based on the mean elevation above sea level as established by the Geodetic Survey of Canada. The vertical accuracy as defined in the Class A NATO standards is such that 90% of the elevations of contours will fall within one-half of the contour interval relative to their true elevation.

iii) Coverage and Scales Available

All shoreline FDRP mapping is completed at a scale of 1:2,000 (Figure A4.3.2). Some conservation authorities including Metro Toronto and Region, Maitland, Ganaraska and Raisin Region have opted to produce their own shoreline maps without the assistance of the FDR Program and as a result may have mapping of a different scale (e.g., Raisin Region - 1:5,000). Conservation authorities which are participating in the program may not have mapped and may not intend to map the entire length of shoreline under their jurisdiction.

Great Lakes 1:2,000 and 1:5,000 scale FDRP mapping is currently available for portions of the Great Lakes that are prone to flooding and/or erosion and are currently experiencing or are expected to experience development pressures. Approximately 50% of the lower Great Lakes shorelines have been mapped under this program. Ultimately, mapping will exist for portions of Lakes Huron, Erie and Ontario. No mapping, at the writing of this document, was underway north of the Severn River on Georgian Bay nor on Lake Superior.

Figure A4.3.2: FDRP Map



Natural hazards at river mouths are to be defined under the *Provincial Policy Statement* (Policy 3.1), meaning that mapping coverage of these features is required. FDRP shoreline mapping typically extends inland far enough, 250 metres on average, to include river mouths. However, in areas where shorelines with steep banks exist it may be necessary to consult both shoreline and riverine mapping in order to have complete coverage of the river mouth.

Figures A4.3.3 and A4.3.4 indicate the current status of conventional and digital (i.e., ASCII code, ISIF format) FDRP shoreline mapping. Some municipalities have only produced conventional maps, others only digital maps. Some municipalities have produced or intend to produce both.

Aerial photographs (1:8,000) also exist for each area which has been mapped. Refer to the section of this appendix entitled **Federal Photo Sources** for more information on FDRP photography.

iv) Ordering of Maps

Public Information Maps and 1:2,000 scale topographic maps may be available from the conservation authority and municipal offices in your area of interest as well as from the Ministry of Natural Resources and Environment Canada. The Public Information Maps, which are free, contain additional information concerning the FDR Program and the watershed to which the maps pertain. A printing charge may apply to orders for large (1:2,000) scale maps.

Inland Waters Directorate
Environment Canada
Canada Centre for Inland Waters
Box 5050, 867 Lakeshore Rd.
Burlington, On.
L7R 4A6

TEL: (905) 336-4999
FAX: (905) 336-6230 - Technical Operations
FAX: (905) 336-4989 - Water Navigation

b) Historic Ontario Land Survey (OLS) Surveys

i) Overview of the Program

In the mid 1930's, a number of Ontario Land Surveyors (OLS) were contracted by the Ministry of Lands and Forests to prepare a survey of the shores of Lakes Huron, St. Clair and Erie along with the connecting channels, St. Clair and Detroit, between these lakes. Water levels on the lakes were at or near historic record lows during the mid 1930's which provided a unique opportunity to collect this information when accessibility to the shore was high. The index of these historic shore surveys suggests that a number of islands in northern Lake Huron/Georgian Bay and the St. Joseph channel were also surveyed although the extent of this coverage is not evident. The shore surveys were conducted by county on a per township basis, usually divided into manageable amounts between surveyors or spread over a period of years if all of the county was surveyed by the same surveyor. In the case of major harbours, a more detailed survey was often provided in addition to the one for the township.

The general instructions to the surveyors, as conveyed by letters sent by the Surveyor General, were to make a survey of the shoreline along the front of assigned Townships, and to renew by permanent monuments, all original survey posts which can be found in their original positions or which can be ascertained by satisfactory evidence.

The surveyors were also instructed to verify adjustments of their surveying equipment prior to commencing the survey and frequently during the work and to pay particular attention to the accuracy of their measurements and methods.

An astronomical observation was to be taken for azimuth prior to and often during the survey as all boundaries shown on the final shore survey plans filed with the Ministry of Lands and Forests were to contain astronomical bearings.

Figure A4.3.3: FDRP Shoreline Conventional and Digital Mapping

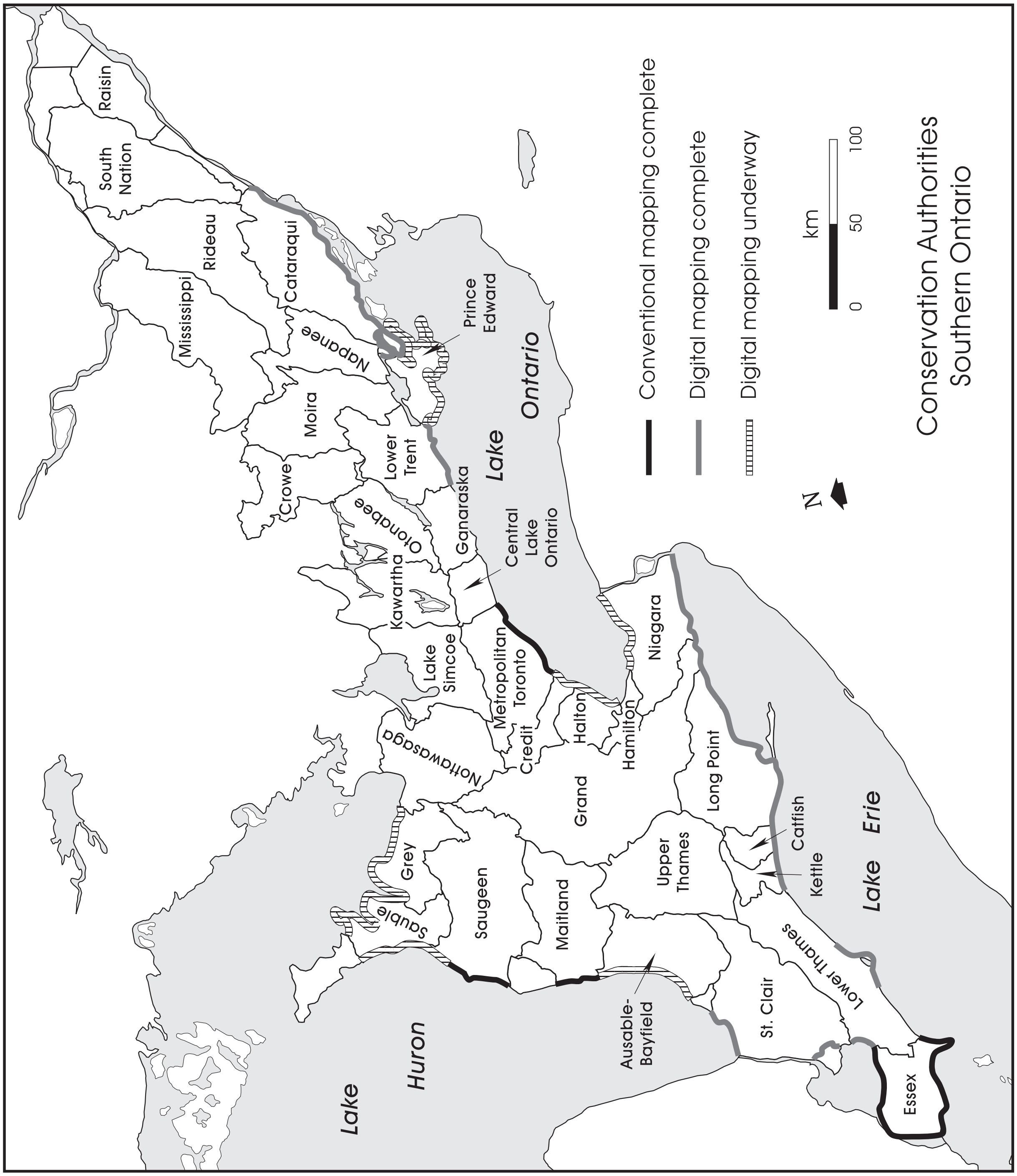
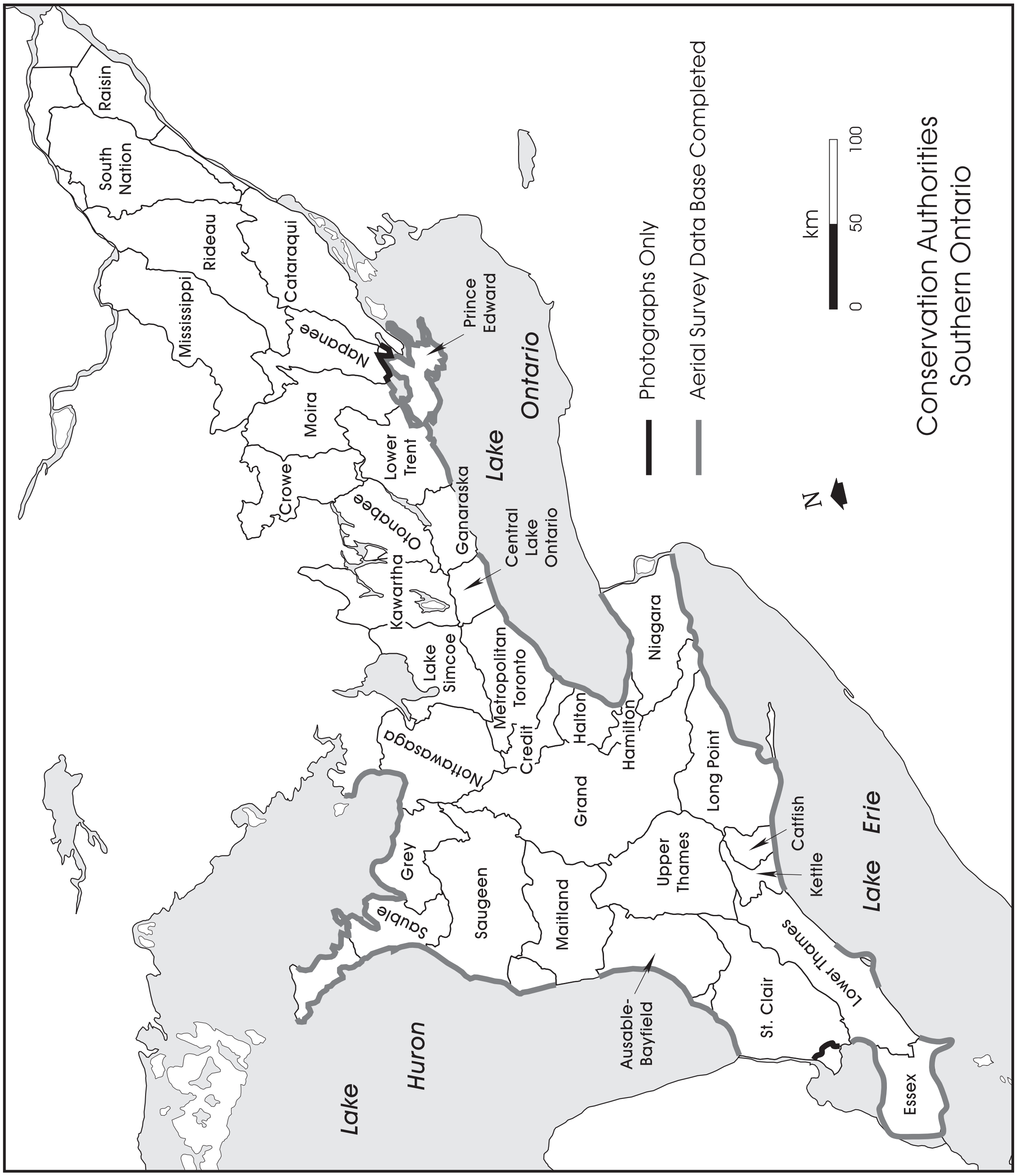


Figure A4.3.4:   FDRP Shoreline Photographs and Aerial Survey



ii) Overview of Map Content

The plan maps produced of the surveyed shoreline for each township were scaled at 10 chains to 1 inch. At this scale which translates to a ratio of 1:7,920, the plan map of the shore is useful for indicating the bearing and distance of the survey traverse line. The waterline and high water mark and/or toe of bluff position are shown roughly to scale although somewhat generalized. The top of bluff position is often included as a dashed line although measurements to the top of bluff were not conducted for many of the surveys and it is assumed the use of the dashed line indicates an approximate top of bluff position.

The overview plan mapping of the shore survey also contains a number of cultural features, mainly roads, railroads and shoreline lots and concessions and owners in some cases, all registered plans and any subdivision plans discovered in their investigations were also included on the overview maps. For each township survey map, the positions of concrete monuments placed by the OLS generally at the end of each township, in the centre of the road, and at the midpoint along the shore of the township were indicated.

A more detailed plan view of the shore survey (Figure A4.3.5) at the scale of 4 chains to the inch (1:3,168) is provided in addition to the overview plan map. This more detailed plan is used to portray intermediate points along the traverse and the side shots which indicate the position of the water's edge, high water mark and/or toe of bluff and in some cases the top of bluff. These side shots are perpendicular to the traverse bearing unless otherwise indicated and the distance from the traverse line is shown on the map. These side shots were taken at a minimum of every 4 chains (80.47 m) along the traverse and for most of each survey, measurements were made more frequently than the 4 chain minimum.

The surveyors were also requested to check and map any existing subdivision plans and to check for any additional plans which may have been registered locally. If any subdivisions were found along the shore which had not been registered, they were to obtain the plans from the owners or others and incorporate these new plans into their final shore survey plan.

The plans always included lot and concession boundaries and more detailed property boundaries were incorporated from the plans collected in residential areas. Many of the surveyors also determined the names of the land owners and these were incorporated onto the plan map. In some cases, especially if the structure was used as a tie-in to bench marks or other permanent features, the external shape of a building was placed on the shore survey plan map.

In some instances, the estimated or assessed value of a building that appeared to be in danger of damage from flooding or erosion was placed on the mapping. Occasionally, the location of shore protection structures were included on the plan survey especially if the feature encountered was perpendicular to the shoreline and was large enough to measure.

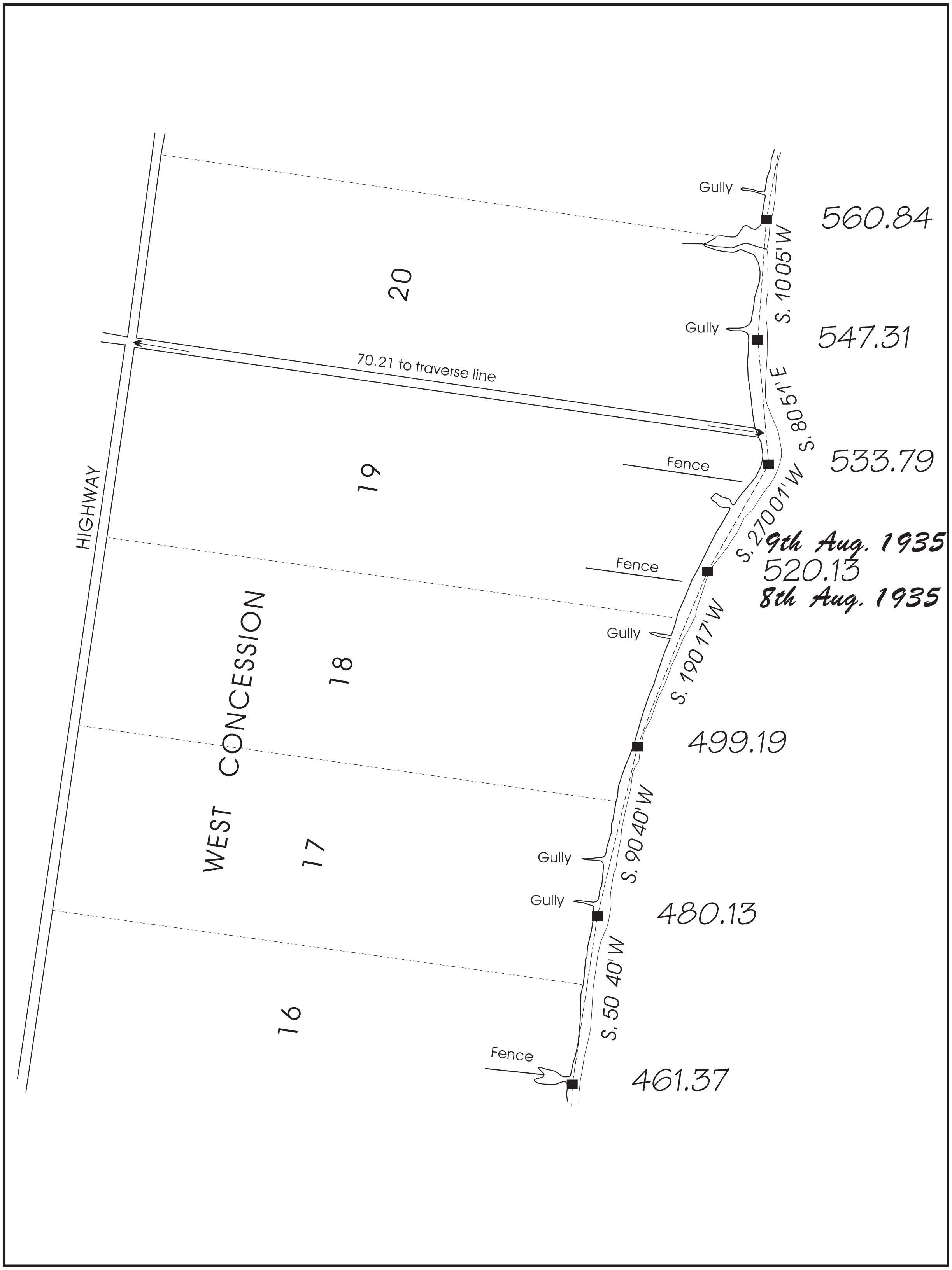
Other features usually placed on the shore survey plans included watercourses (i.e., a single line) and gully locations, locations of streets and roads along with their names in many cases, and the position of rural fence lines which commonly formed the division between lots.

The average height of bluff was often indicated for sections of shoreline accompanied by a description of the vegetation type found or the presence of an unvegetated erosional bluff. The shore survey often provided information on the type of sediment found on the beach in many sections of shore.

Many of the shore surveys provided cross-section profiles perpendicular to the shoreline at intervals of 20 chains (402.34 m) along the traverse. The scales of these profiles were 1 chain equal to 1 inch (1:792) in the horizontal direction and 10 feet equal to 1 inch (1:120) in the vertical direction. These were not complete profiles to the top of bluff, and were primarily concerned with water level and elevation of the high water mark.

All shore surveys appear to provide elevations of water level and high water mark intermittently along the cross-sectional profiles.

Figure A4.3.5: Overview Plan Map of the Shore Survey



The date each stretch of shoreline was surveyed is included on the detailed plan views and some plans actually provide the mean water level for each survey day.

iii) Bench Marks

The surveyors were instructed to indicate the locations of all bench marks. Permanent monuments were to be placed at all original survey posts which could be located in their original positions or which could be ascertained by satisfactory evidence.

From the permanent monuments that were placed, surveyors were to take, where practical, angles and distance between the monument and certain noticeable fixed objects in order to determine the exact position of the monuments at any time in the future in case of disruption to the monument.

The monuments to be used consisted of the following; a Standard Crown Land Iron Post with a standard bronze post; the concrete monuments used at the town lines were to be four feet in length with three feet to be sunk below the ground surface and have a base eight inches square and the top was to be five inches square; a standard rock post was to be placed on top and at the centre of the monument and this was to be the centre of the town line.

All monuments were to be legibly marked using letters and figures to indicate the "point where planted". If it was necessary due to heavy traffic, the monument was to be placed entirely below the surface of the ground.

iv) Coverage and Scales Available

Figure A4.3.6 and Figure A4.3.7 provide a summary by lake or connecting channel, municipality, year surveyed, and surveyor for all of the historic OLS shore surveys available beginning with the most northerly Lake Huron survey and working south through the connecting channels and lakes to the eastern end of Lake Erie. The majority (58 of 77) of the shore surveys, not including Lake Huron/Georgian Bay or St. Joseph channel islands, were undertaken between 1934 and 1938.

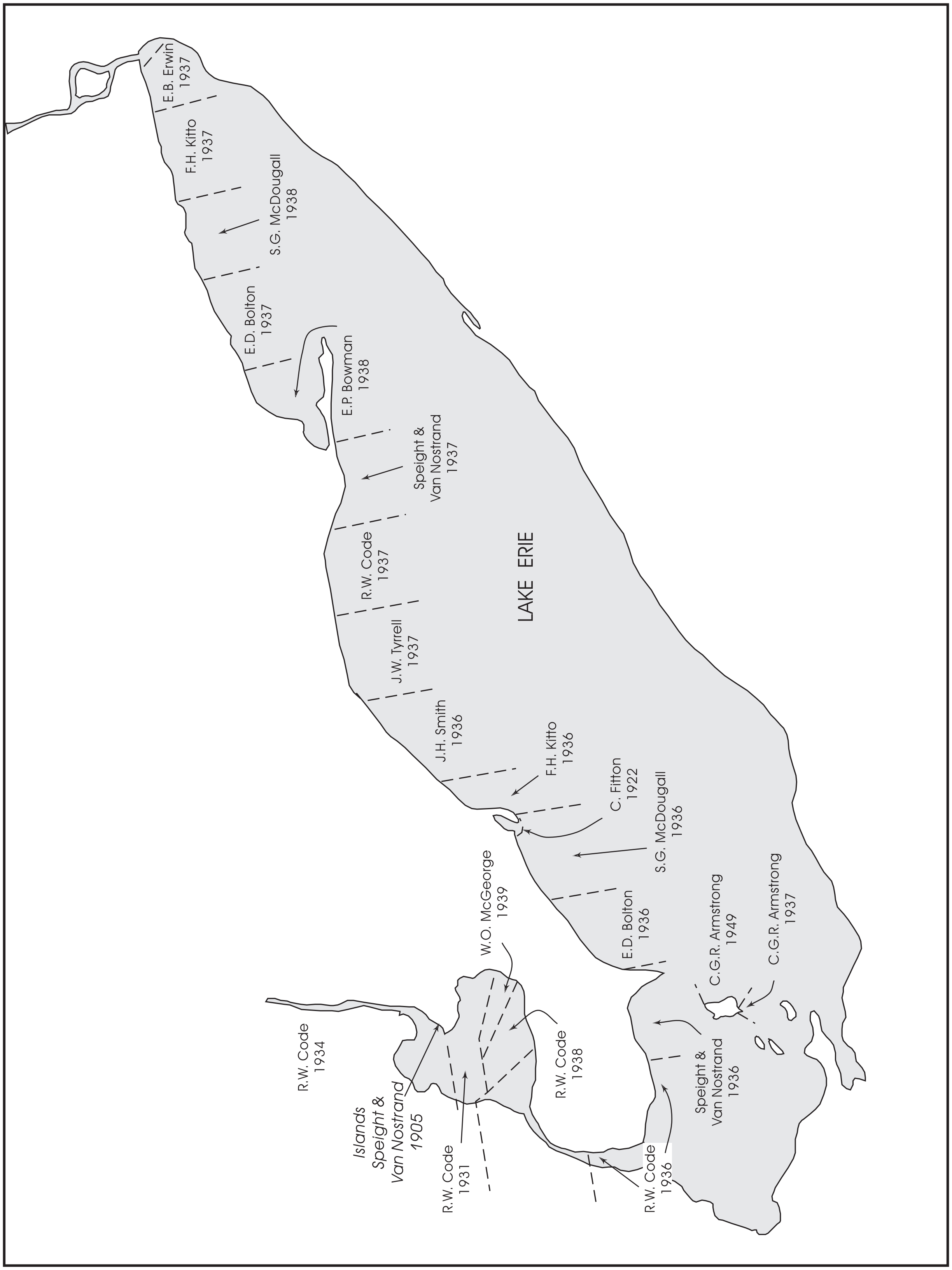
The earliest survey documented on the shore survey index at the office of Survey Records, Ontario Ministry of Natural Resources was of Walpole Island on the St. Clair River dated 1905. No other surveys were taken until 1922 when the section of Lake Erie shoreline between Erieau and Pte. aux Pins was surveyed. The Walpole area of the St. Clair River was resurveyed in 4 segments during 1931. The OLS shore surveys began in earnest on Lake Huron in 1934 with surveys undertaken for 6 southerly townships on Lake Huron and 2 on the St. Clair River. In 1935, 11 township surveys were completed on Lake Huron working north up the shoreline from the township where work was suspended the previous year. In 1936 the OLS surveys concentrated on Lake Erie, doing the 12 western townships and 1 in the lower portion of the Detroit River and 1 on Lake Huron for a total of 14 survey plans. All of the shore surveys (12) conducted in 1937 were for townships along Lake Erie. By 1938, work was started back on Lake Huron with 5 townships, 2 were completed on Lake St. Clair and the 6 most easterly townships on Lake Erie were completed. Only 3 township shorelines were surveyed during 1939, 2 of these on Lake Huron and 1 on Lake St. Clair. By 1940 the program was basically finished as only Collingwood Township on Lake Huron was undertaken.

A few additional surveys were done in the late 1940's and early 1950's. These included surveys of east and south Pelee Island in 1949 and 1951, respectively and resurveys of Yarmouth and Southwold Townships on Lake Erie in 1950. Five OLS surveys are available for which the survey date was not available on the index. All of these are located on the southwestern Lake St. Clair/Detroit River shoreline.

The scale at which the OLS shore survey information is presented on the plans is largely irrelevant because the information must be reconstructed from the original survey information. The survey detail is sufficient to convert the OLS shore survey into a digital format that is directly comparable to the recent large scale mapping such as FDRP or large scale OBM.

Figure A4.3.6: OLS Shore Surveys: Lake Huron

Figure A4.3.7: OLS Shore Surveys: Lake Erie



v) Conversion to Digital

· Reference Points

It is an essential requirement when converting historic OLS shore surveys to digital mapping to have quality georeferenced control points. The geographic position of these control points or survey tie-ins must be determinable on the survey and available as Universal Transverse Mercator (UTM) projection coordinates in order to be used with the recent large scale mapping. Control points are needed at the start and end of each OLS shore survey in order to properly position the traverse line which was referenced to astronomic bearings and to determine the accuracy of the survey. It is useful to have as many intermediate ground control points along the shoreline survey in addition to the controls at the start and finish in order to ensure the consistency of the data along the entire transect.

A list of horizontal ground control references can be obtained for the study area from Geodetic Survey of Canada, Energy Mines and Resources and the Ontario Ministry of Natural Resources. This information may contain some of the ground control points found on the historic OLS shore survey which can then be used as georeferences for the construction of the shoreline map.

Depending on the availability of known georeferenced ground controls from Geodetic Survey and/or the Land and Information Branch that correspond to those found on the OLS plan map, careful examination of the OLS plan map will be required in order to select some potential secondary ground control points. According to sources at these government departments, it is highly unlikely that many of these references will be available as first or even second order geodetic references. Generally the control points found on the OLS shore surveys were established for cadastral surveys and are considered by Geodetic Survey to have no positional accuracy. This implies that many of the references found on the shore survey (e.g., concrete monuments) will not be available through Geodetic Survey sources and their geographic position must be established through other methods. These reference points must be determinable on the recent large scale mapping as this mapping will then be used to derive the coordinates of the ground control point. It may be necessary to confirm the position of a potential control point through field investigations. This is generally possible provided that the cultural features delineated on the OLS shore survey which were used as additional tie-ins to the potential ground control point still exist.

All historic OLS shore surveys have concrete monuments located at both ends of a township and at least one within the borders which can potentially be used as ground control points. Since surveys were generally conducted on a township basis, these concrete monuments should provide a reasonable start and end reference for each survey plan providing they can be located and their geographic position established. These monuments were located in the centre of the road which divides two townships. Depending on road traffic, the concrete monuments may have been buried below the road surface and if no known georeferences are available through the Government files, field confirmation will be required. The availability of reliable start and end control points is essential in establishing the amount of survey error and positioning the reconstructed survey to correspond to the projection of the recent large scale mapping.

Ideally, before the process to reconstruct the OLS shore survey is started, there should be at least 3 reliable ground control points established, near the start, the middle and the end. It would be beneficial to have additional intermediate control points to assist in verifying the accuracy of the survey along the traverse and help to isolate the location of any questionable areas.

Also required is recent large scale mapping from which a comparison can be made to the historic OLS toe and/or top of bluff position. Large scale mapping may also provide georeferenced ground control points especially if houses that were used as tie-ins during the historic OLS survey still existed on the recent large scale mapping.

· Methodology

Because the historic OLS shoreline surveys were conducted using ranges and bearings it has been found most appropriate to use a Coordinate Geometry (COGO) mapping system which enables the user to construct the survey segment by segment. The map to be constructed in COGO uses the ground control points established prior to starting the reconstruction of the survey for horizontal control.

Initially just the traverse line identified on the OLS map should be constructed in COGO so overall accuracy of the OLS map relative to the most recent large scale mapping can be determined. Quadrant bearings in COGO are used in the same manner as the bearings found on the OLS surveys which describe bearings as that amount east or west of north or south (i.e., S35-23-12E represents a bearing of 35 degrees, 23 minutes, 12 seconds east of south). On some shore survey plans, seconds were not included on the bearing measurements, and on others, seconds were represented as a decimal minute and this form can be entered directly into COGO. For the survey traverse line, these bearings and distances were entered at each change in traverse direction. Once the accuracy of the survey traverse line has been established and the position is properly referenced compared to the recent large scale mapping, it is possible to begin construction of the detailed shore surveys.

For the reconstruction of the detailed historical OLS shore survey one must use the more detailed plan information contained in the smaller panels which provide all of the additional survey information as opposed to the survey overview which only describes the distances and orientation changes on the traverse line. Because these shore surveys were conducted on a per township basis, there should be common tie-in points like the concrete monuments between adjacent township surveys. A common point between surveys is a useful place to begin a new reconstruction so the completed maps produced can be easily joined together if so desired.

- **Step 1** Create a COGO arc coverage containing known ground control points as tics to serve as geo-references for the OLS shore survey map.
- **Step 2** Data to be entered starting at a known ground control point like the concrete monument located on the town line between townships.
- **Step 3** Begin to construct shore survey by inputting bearing and each intermittent distance along that bearing of the shore traverse.
- **Step 4** A specific program was developed to allow the user to input perpendicular offset distances at each intermediate point along the traverse. These offsets define the position of the waterline, high water mark, toe of bluff and top of bluff.
- **Step 5** Each arc or line generated was coded to identify it as the traverse line, waterline offset, high water mark offset, toe of bluff offset, top of bluff offset or control point reference line.
- **Step 6** Upon completion of data entry for the township shore survey, produce a check paper plot using a customized program which provides distances and bearings for arc segments.
- **Step 7** Visually compare the data on the check paper plot to that on the original survey and data correction where entered incorrectly.
- **Step 8** Determine survey range and bearing error and correct for change in bearing caused by difference between astronomic north used by OLS and UTM grid north which is projection into which the data is being converted.
- **Step 9** After all appropriate adjustments to OLS survey have been satisfactorily made, generate historic waterline, high waterline, toe of bluff line and top of bluff line from appropriate offset points. These converted OLS data lines can then be compared with the recent FDRP data lines to determine recession rates.

vi) Limitations of the OLS Mapping

Physically, the information is all in place to resurvey the historic OLS shore survey given that the control points can be re-established which also must be done in order to reconstruct it in COGO. Problems with accessibility could occur in areas which experienced high erosion rates, causing the historic shore traverse to be located offshore or during high water level periods when the old survey traverse could be located under water.

On some surveys, bearings were only measured to the closest minutes which would cause some loss of accuracy through determining bearings to the second. However, given the quality of the instruments used and the relatively large distances (i.e., tens of kilometres) being measured for each township plan, any error would be quite small.

If an unacceptable error is encountered during reconstruction of the historic shore survey, it is difficult to ascertain the source of the problem and it can be quite a labour intensive task since one cannot use the recent mapping as an indication of the historic shoreline position and orientation. To try and reconstruct the survey in the field would be both time consuming and expensive and therefore may not be possible if as mentioned previously, much of the original OLS survey line is now located offshore in several metres of water. In cases where an error exists and no practical means of determining the error are available, it may be necessary to either isolate a section in which the error exists if possible and disregard it or apply the error over a section which will somewhat reduce the accuracy but considering the alternative of no information, is probably acceptable.

vii) Ordering of Maps (Availability of Historic OLS Shore Surveys)

The original OLS shore survey plans and field notes are retained at Survey Records, Office of the Surveyor General, Ontario Ministry of Natural Resources. Copies of the shore survey plans and/or field notes can be obtained at Survey Records at the following address:

Survey Records
Ontario Ministry of Natural Resources
P.O. Box 7000
300 Water St., 2nd Floor
Peterborough, Ontario
K9J 8M5

TEL: (705) 755-2100 - contact: Alan Day

c) Ontario Basic Mapping Program: Ontario Ministry of Natural Resources

Maps are produced through the Ontario Basic Mapping Program in two scales:

- Medium Scale Mapping Program (i.e., 1:10,000, 1:20,000)
- Large Scale Municipal Mapping Program (i.e., 1:2,000)

i) Overview of the Program

The Ontario Basic Mapping Program, administered by the Ontario Ministry of Natural Resources (MNR), develops topographical maps that may be used as a base onto which shoreline information may be applied. Most of the province has been mapped once since the program was initiated in the late 1970's.

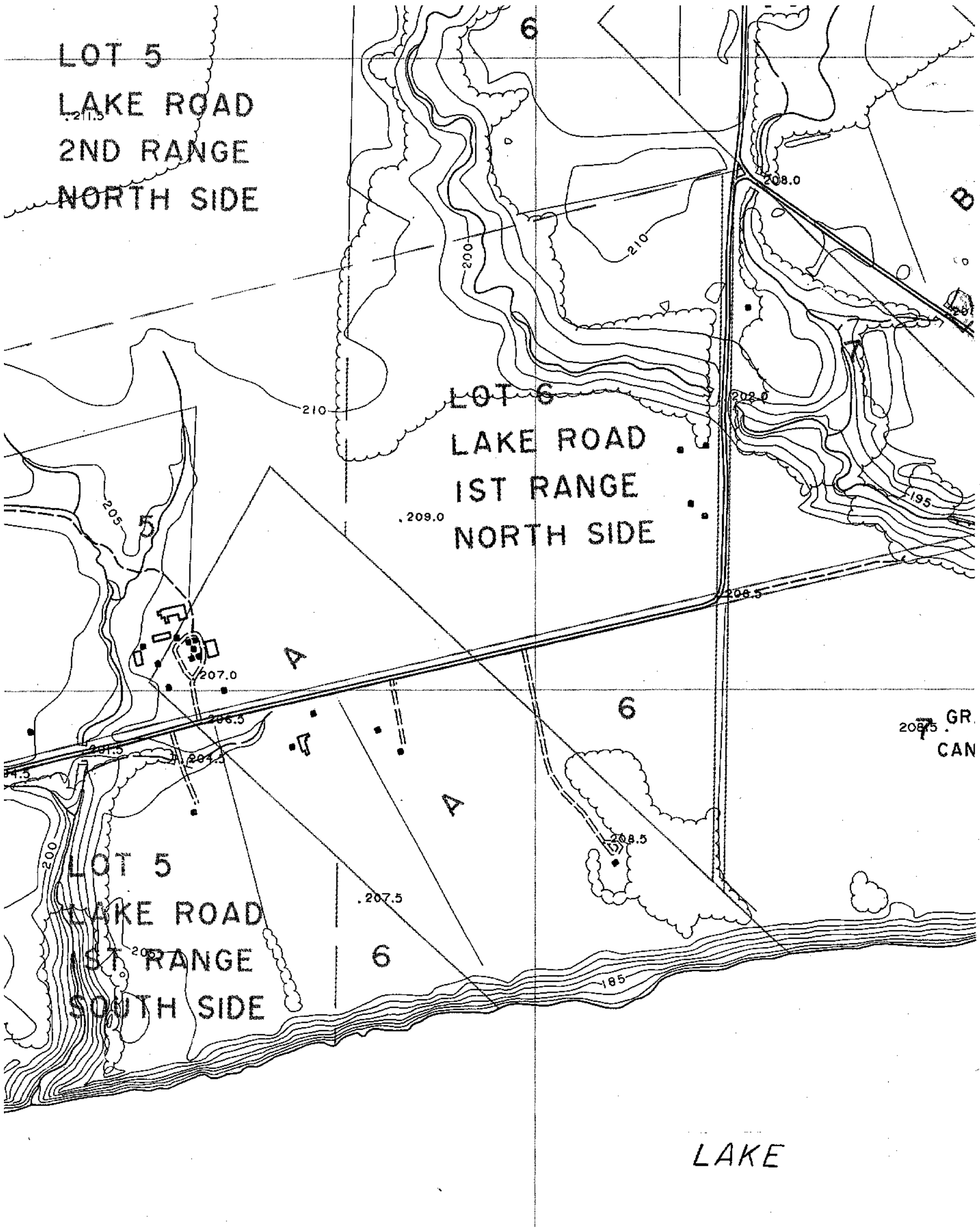
The topographic maps produced under this program are called Ontario Base Maps (OBM). They are available for part of northern Ontario at a scale of 1:20,000, and for part of southern Ontario at a scale of 1:10,000. In addition, the urban areas of the province will eventually be covered with 1:2000 scale mapping, produced in co-operation with local authorities.

ii) Overview of Map Content

Of the three scales of OBM produced, only the 1:2,000 scale maps are detailed enough to be appropriate for use in determining an average annual recession rate (AARR).

Medium scale OBM (i.e., 1:10,000, 1:20,000) (Figure A4.3.8) are not ideal for use in determining an AARR because the contour intervals on these maps are too large (i.e., 5 metres and 10 metres, respectively) to permit accurate

Figure A4.3.8: 1:10,000 OBM Map



identification of the top or toe of a shoreline bluff. Consequently, medium scale OBM maps should only be considered where no other mapping or air photo sources of an appropriate scale are available.

Large scale (i.e., 1:2,000) OBM are prepared according to specifications set out in the Ministry publication entitled Ontario Specifications for Large Scale Topographic Mapping. This document requires that all basic information concerning the datum of the manuscript such as horizontal control points, projection and grid information, shall be located within 0.1 millimetre of its true position.

An overview of the information portrayed on 1:2,000 scale OBM is provided below, along with a sample section of a 1:2,000 scale OBM topographic map:

- topographic contour lines (i.e., 1 metre interval with 0.5 metre interpolations);
- UTM georeferencing and projection (NAD 27, 1976 Adj.);
- horizontal/vertical control points;
- numerous spot elevations (i.e., accuracy to the nearest 0.01 metre);
- the location, shown to shape and scale where appropriate, of buildings, transportation and communications corridors, linear features such as fences and shore protection structures, woodland areas, and water features including drainage ditches; and
- names of all communities, streets, highways, railways, parks, islands and significant water features.

iii) Coverage and Scales Available

· Large Scale Municipal Mapping (1:2,000)

Numerous shoreline communities located throughout the *Great Lakes-St. Lawrence River System* have been mapped conventionally and/or digitally at a scale of 1:2,000 under the Ontario Basic Mapping program. Table A4.3.1 lists the completed northern and southern Ontario shoreline communities.

Each Ontario Basic Mapping municipal mapping project typically covers most of the developed area of the community. However, maps may not be available for all communities or areas within a municipality. Alternatively, mapping projects may extend beyond municipal boundaries to include adjacent communities.

Digital maps are available in ASCII code, ISIF format, which is compatible with most GIS systems including ARC/INFO and SPANS.

NOTE: The Ontario Basic Mapping large scale mapping program is not the only source of municipal mapping. Some larger municipalities such as Metropolitan Toronto, Hamilton, Burlington, St. Catharines and Windsor conduct their own large scale mapping projects. For example, Metropolitan Toronto's GIS Centre (formerly the Metropolitan Central Mapping Agency) has, since 1983, been preparing digital maps at a scale of 1:500 on an Intergraph platform. Independently produced large scale maps such as these are acceptable for use in calculating an AARR, provided that the maps satisfy provincial mapping standards. However, the Ministry does not provide financial or technical assistance for, nor keep records of independent projects. Contact the shoreline municipalities within your area of interest directly.

· Medium Scale Mapping (1:10,000, 1:20,000)

To date, medium scale conventional and/or digital OBM have been produced for most of the Great Lakes - St. Lawrence River shoreline. Figure A4.3.9 identifies the areas of the province to be mapped at a scale of 1:10,000 and the areas to be mapped at 1:20,000.

Areas not yet mapped include a section of Lake Huron shoreline between Kincardine and Grand Bend, and several sections of Lake Superior shoreline. It is anticipated that completed maps of these areas will be available by 1997.

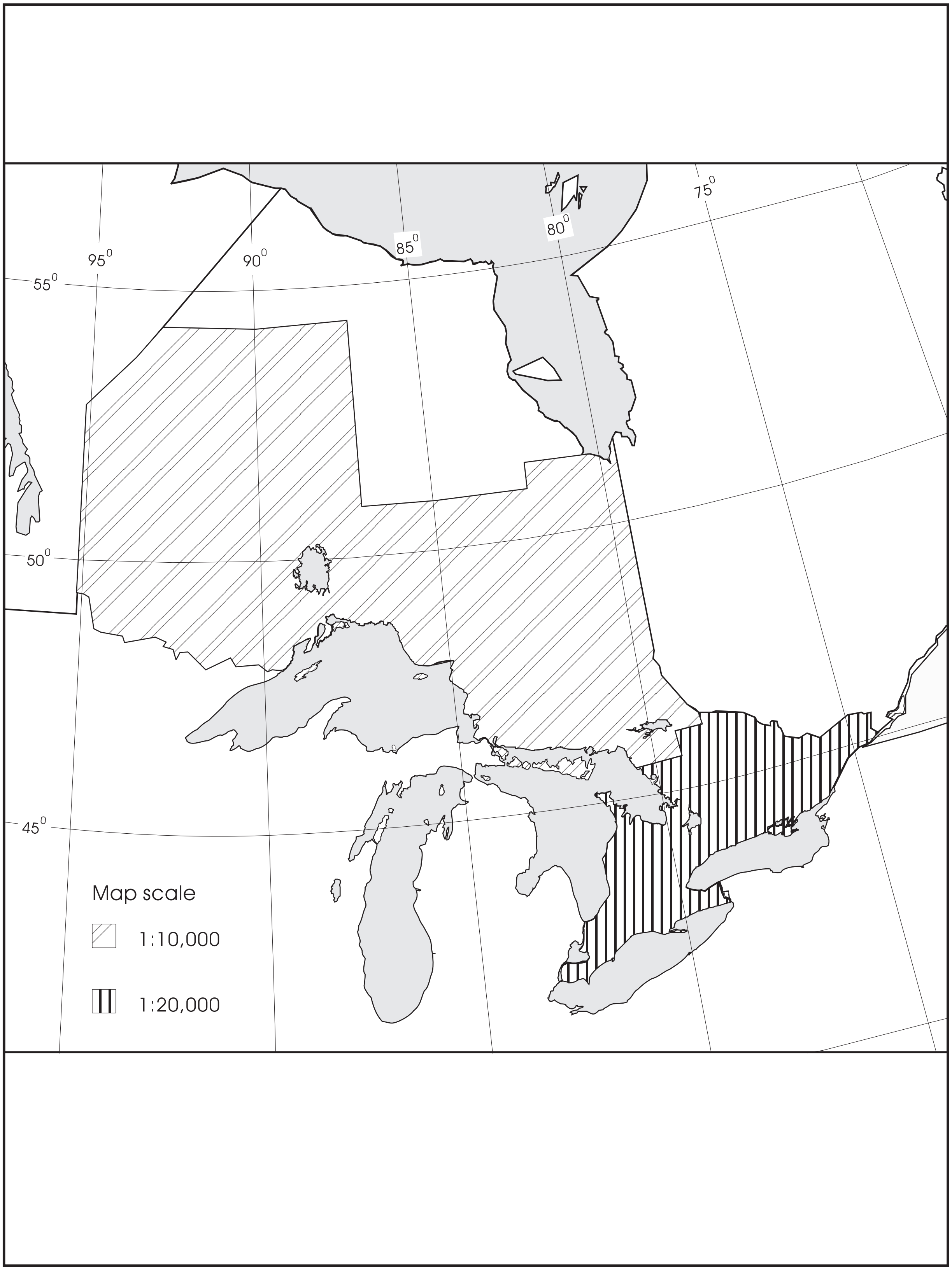
Table A4.3.1
Ontario Basic Mapping Program
Large Scale Municipal Mapping Projects (1:2,000)

MUNICIPAL MAPPING PROJECT	MAPPING AVAILABLE FROM:	YEAR MAPPING COMPLETED
NORTHERN ONTARIO		
Blind River-Matheson	Town of Black River-Matheson Box 601 - Matheson, Ont., P0K 1N0	1980
Bruce Mines	Town of Bruce Mines Box 640 - 11 Hudson Street Blind River, Ont., P0R 1C0	1984
Marathon	Township of Marathon Box 190, Peninsula Building Marathon, Ont., P0T 2E0	1986
Nipigon	Township of Nipigon Box 160 - 25 Second Street, Nipigon, Ont., P0J 1P0	1982
Red Rock	Township of Red Rock Box 447, Salls Street, Red Rock, Ont., P0T 2P0	1986
Schreiber	Township of Schreiber Box 40 - 302 Scotia Street Schreiber, Ont., P0T 1S0	1982
Terrace Bay	Township of Terrace Bay Box 40 - Simcoe Plaza Terrace Bay, Ont., P0T 2W0	1984
The North Shore	Township of the North Shore Box 250 - Algoma Mills, Ont., P0R 1P0	1980
Thessalon	Town of Thessalon Box 220 - Thessalon, Ont., P0R 1L0	1980
SOUTHERN ONTARIO		
Albemarle	Albemarle Township Municipal Building, R.R. #6, Wiarton, Ont., N0H 2T0	1987
Amabel Township	Township of Amabel R.R. #2, Hepworth, Ont., N0H 1P0	1988
Bath	Village of Bath Box 100 - 352 Academy Street Bath Ont., K0H 1G0	1984
Belle River	Town of Belle River General Delivery, 499 Notre Dame St. Belle River, Ont., N0R 1A0	1989
Brockville	City of Brockville Victoria Hall, Brockville, Ont., K6V 3P5	1981
Burlington	City of Burlington Box 5013 - 426 Brant Street Burlington, Ont., L7R 3Z6	1986
Cardinal	Village of Cardinal Box 400 - 152 Walter Street Cardinal, Ont., K0E 1E0	1984

MUNICIPAL MAPPING PROJECT	MAPPING AVAILABLE FROM:	YEAR MAPPING COMPLETED
Carnarvon Township	Township of Carnarvon Box 187, Mindemoya, Ont., P0P 1S0	1990
Collingwood	Town of Collingwood Box 157 - 97 Hurontario Street, Collingwood, Ont., L9Y 3Z5	1986
Cornwall Township	Cornwall Township R.R. #1, Long Sault, Ont., K0C 1P0	1987
Fort Erie	Town of Fort Erie 200 Jarvis Street Fort Erie, Ont., L2A 2S6	1990
Front of Leeds and Landsdowne	Township of Front of Leeds and Landsdowne Box 129, Landsdowne, Ont., K0E 1L0	1984
Grand Bend	Village of Grand Bend P.O. Box 340 - 4 Ontario Street Grand Bend, Ont., N0M 1T0	1989
Iroquois	Village of Iroquois Box 249, Dundas & Elizabeth Streets Iroquois, Ont., K0E 1K0	1984
Kingsville	Town of Kingsville 41 Division Street South, Kingsville, Ont., N9Y 1P4	1988
Leamington	Town of Leamington 38 Erie Street North, Leamington, Ont., N8H 2Z3	1988
Lincoln	Town of Lincoln Box 1030 - 206 King Street West, Beamsville, Ont., L0R 1B0	1987
Lion's Head	Village of Lion's Head Box 208 - Main Street Lion's Head, Ont., N0H 1W0	1987
Maidstone Township	Township of Maidstone R.R. #3 - 1089 Puce Road Maidstone, Ont., N8M 2X7	1989
Moore	Township of Moore Box 40 - 1576 Main Street Brigden, Ont., N0N 1B0	1986
Napanee, Richmond, North Fredericksburg	Town of Napanee Box 97 - 124 John Street Napanee, Ont., K7R 3L4	1985
Newcastle	Town of Newcastle 40 Temperance Street Bowmanville, Ont., L1C 3A6	1986
Niagara Falls	City of Niagara Falls Box 1023 - 4310 Queen Street, Niagara Falls, Ont., L2E 6X5	1986
Picton	Town of Picton Box 1670 - 74 King Street Picton, Ont., K0K 2T0	1984
Pittsburgh	Township of Pittsburgh Box 966, Kingston, Ont., K7L 4X8	1985

MUNICIPAL MAPPING PROJECT	MAPPING AVAILABLE FROM:	YEAR MAPPING COMPLETED
Port Colborne	City of Port Colborne 239 King Street Port Colborne, Ont., L3K 4G8	1986
Port Hope	Town of Port Hope Box 117 - 56 Queen Street Port Hope, Ont., L1A 3V9	1987
Prescott	Town of Prescott Box 160 - 360 Dibble Street West, Prescott, Ont., K0E 1T0	1985
Sandwich West	Township of Sandwich West 5950 Malden Road Windsor, Ont., N9H 1S4	1989
Sarnia	City of Sarnia Box 3018 - 255 North Christina Street, Sarnia, Ont., N7T 7N2	1987
Sombra	Township of Sombra Box 40, Sombra, Ont., N0P 2H0	1985
Southampton	Town of Southampton Box 340 - 201 High Street, Southampton, Ont., N0H 2L0	1985
St. Catharines	City of St. Catharines 50 Church Street St. Catharines, Ont., L2R 7C2	1986
St. Clair Beach	Village of St. Clair Beach 13677 St. Gregory's Road Windsor, Ont., N8N 3E4	1988
St. Edmunds	St. Edmunds Township Box 70 - R.R. #1, Tobermory, Ont., N0H 2R0	1987
Stoney Creek	City of Stoney Creek P.O. Box 9940, Stoney Creek, Ont., L8G 4N9	1988
Tecumseh	Town of Tecumseh 917 Lesperance Road Tecumseh, Ont., N8N 1W9	1988
Trenton	City of Trenton Box 490 - 65 Dundas Street West, Trenton, Ont., K8V 5R6	1984
Wheatley	Village of Wheatley P.O. Box 530 - 171 Erie Street North Wheatley, Ont., N0P 2P0	1989
Wiarton	Town of Wiarton Box 310 - 315 George Street Wiarton, Ont., N0H 2T0	1987

Figure A4.3.9: Proposed Location of 1:10,000 and 1:20,000 OBM Mapping



Most areas have only been mapped once under the medium scale Ontario Basic Mapping program. However, mapping for some areas in and around Metropolitan Toronto and Niagara Region has been revised and republished in digital format. Figures A4.3.10 to A4.3.12 and Figures A4.3.13 to A4.3.15, indicate respectively the current status of conventional and digital medium scale OBM shoreline mapping. Please note that some of the mapping completed in Zone 18 (i.e., south-eastern Ontario, see Figure A4.3.16) does not have topographic contours, but that these maps are currently being revised to include contours.

iv) Ordering of Maps

Conventional large scale OBM are sold by the respective municipality or their appointed agent. For more information please contact the municipality of your concern directly using the list of addresses provided in Table A4.3.1.

Conventional medium scale OBM are ordered by map number from the Ministry of Natural Resource's Information Centre. To order 1:10,000 and 1:20,000 scale paper maps, follow this procedure:

1) Ontario is divided into 22 index map areas. Determine, using the index key provided in Figure A4.3.16, within which index map your area of interest is located. Then, obtain the index map, available free of charge, from the Information Centre.

Natural Resources Information Centre

Room M1-73, Macdonald Block	or	300 Water Street
900 Bay Street		P.O. Box 7000
Toronto, Ontario		Peterborough, Ontario
M7A 2C1		K9J 8M5
TEL: (416) 314-2000		TEL: (705) 755-2000
FAX: (705) 755-1677		FAX: (705) 755-1677

2) Order by map number as per the instructions on the index map. A copy of the order form is provided at the end of this subsection. Allow three weeks for handling and delivery. PRICE: $7.19 each (in 1997).

NOTE: When ordering (order form Table A4.3.2), keep in mind that index maps indicate the year that the maps were published, not the year that the information used to produce the maps was collected, which is typically several years earlier.

All Information Centre orders must be prepaid. Please include a cheque or money order with your order made payable to "Treasurer of Ontario." Remember to add $2.50 for postage and handling ($4.00 if outside Ontario, and $7.00 if outside Canada) and, if applicable, 8 per cent provincial sales tax and 7 per cent federal GST.

Mylar (i.e., chronoflex) and digital maps of all scales are available from private map dealers through a bulletin board site or through a telnet address.

Bulletin Board 1-800-850-8072
Telnet Site: bbs.gov.on.ca

Mylar originals are lent by the Ministry to clients, who in turn select a map reproduction contractor. Mylar reproductions cost on average $35 per map sheet (1997 price), but prices may vary. Mylars, and clear film positives, are available for any area for which conventional mapping exists.

Figure A4.3.10: OBM Conventional Mapping: Lake Superior 1:20,000

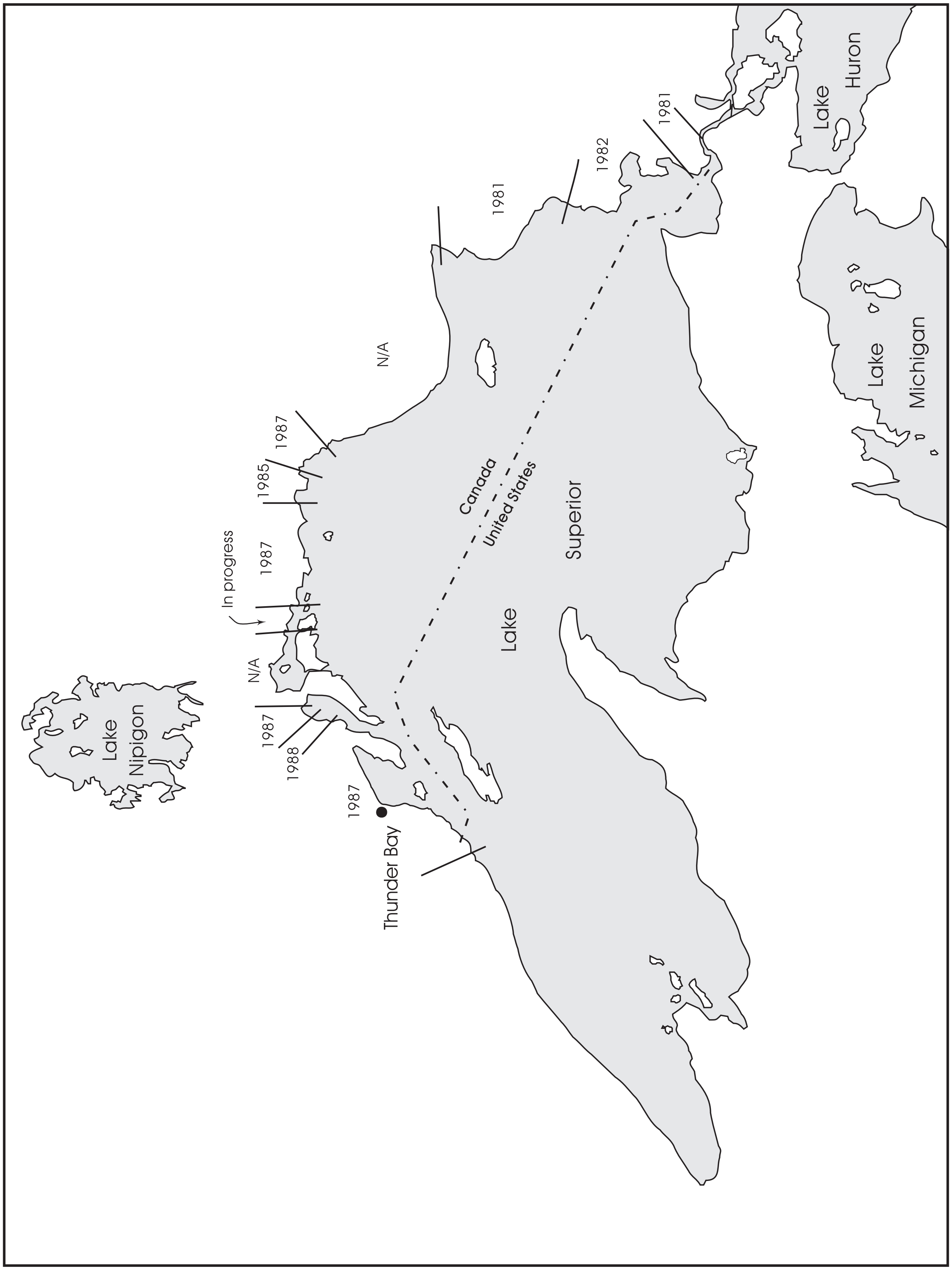


Figure A4.3.11: OBM Conventional Mapping: Lake Huron and Lake Erie; 1:10,000 and 1:20,000

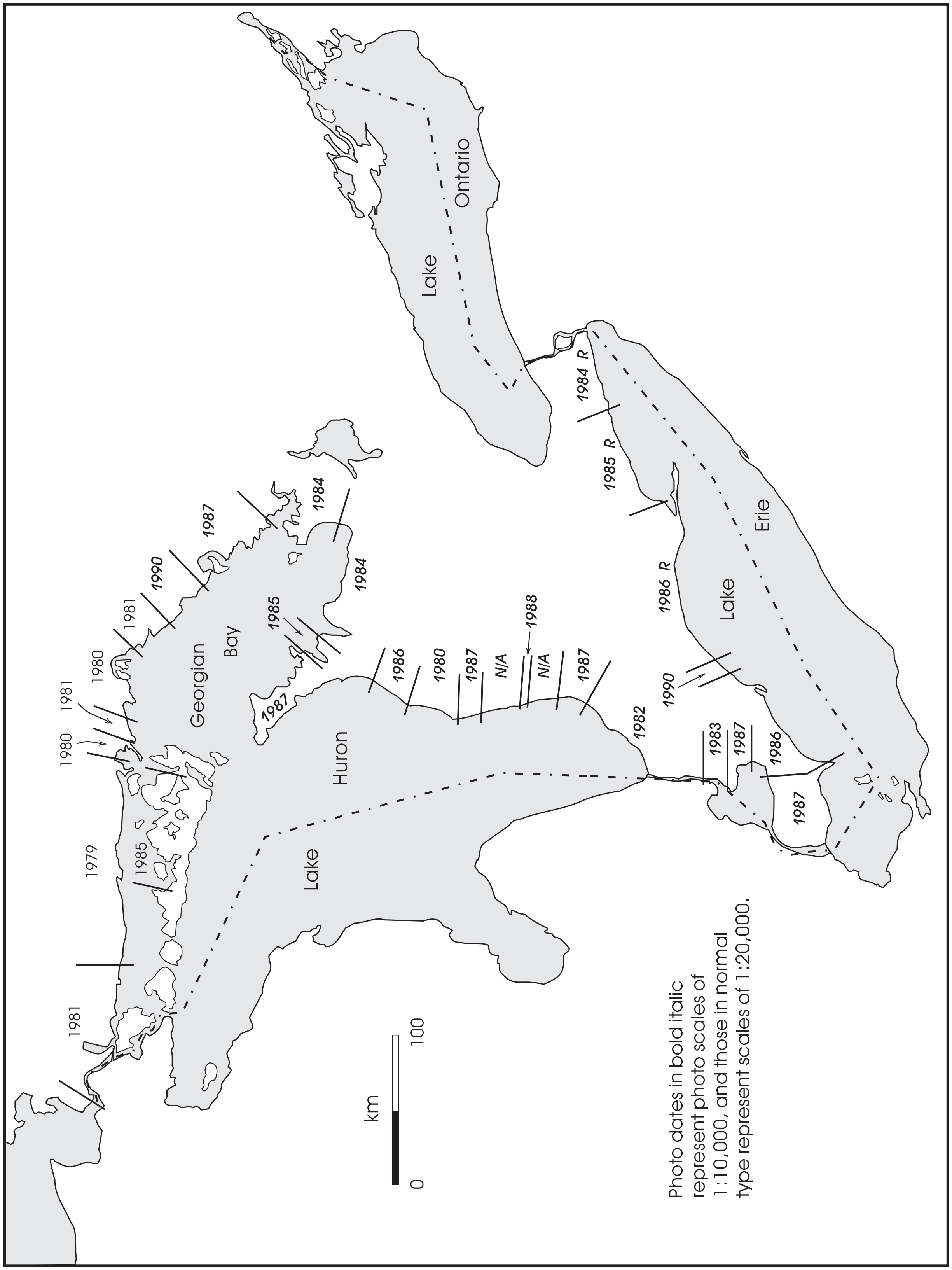


Figure A4.3.12:   OBM Conventional Mapping: Lake Ontario 1:10,000

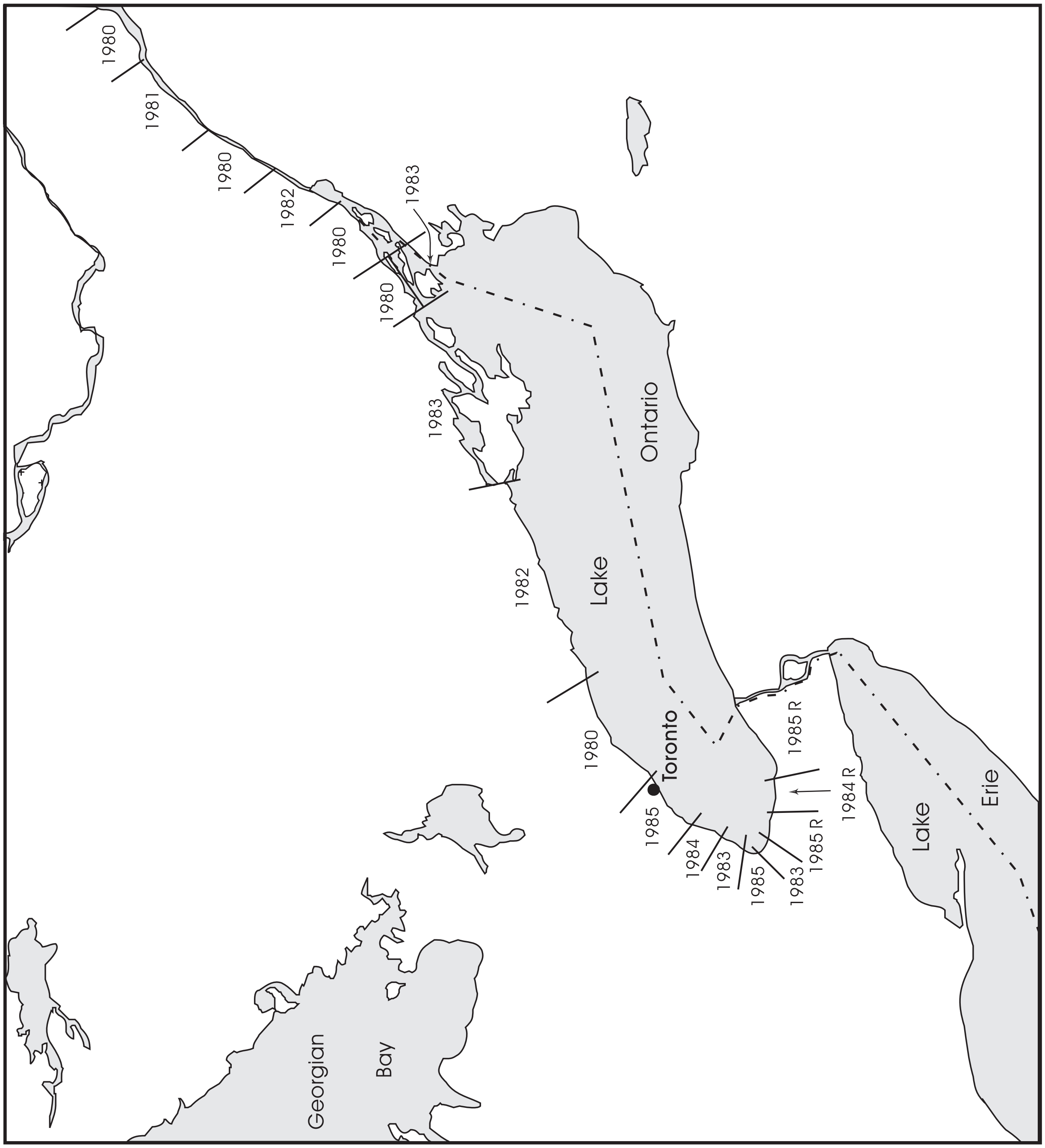


Figure A4.3.13: OBM Digital Mapping: Lake Superior 1:20,000

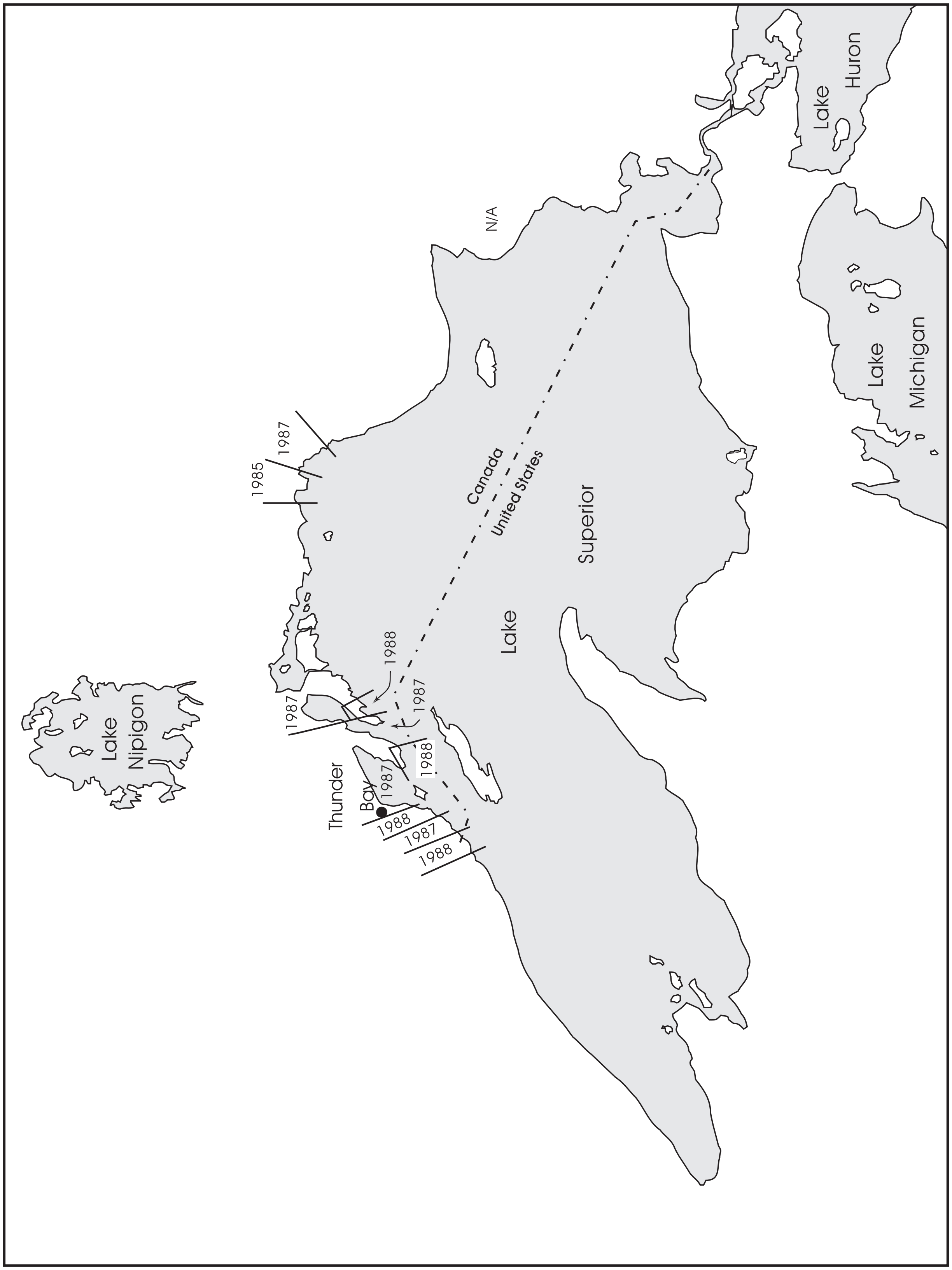


Figure A4.3.14: OBM Digital Mapping: Lake Huron and Lake Erie; 1:10,000 and 1:20,000

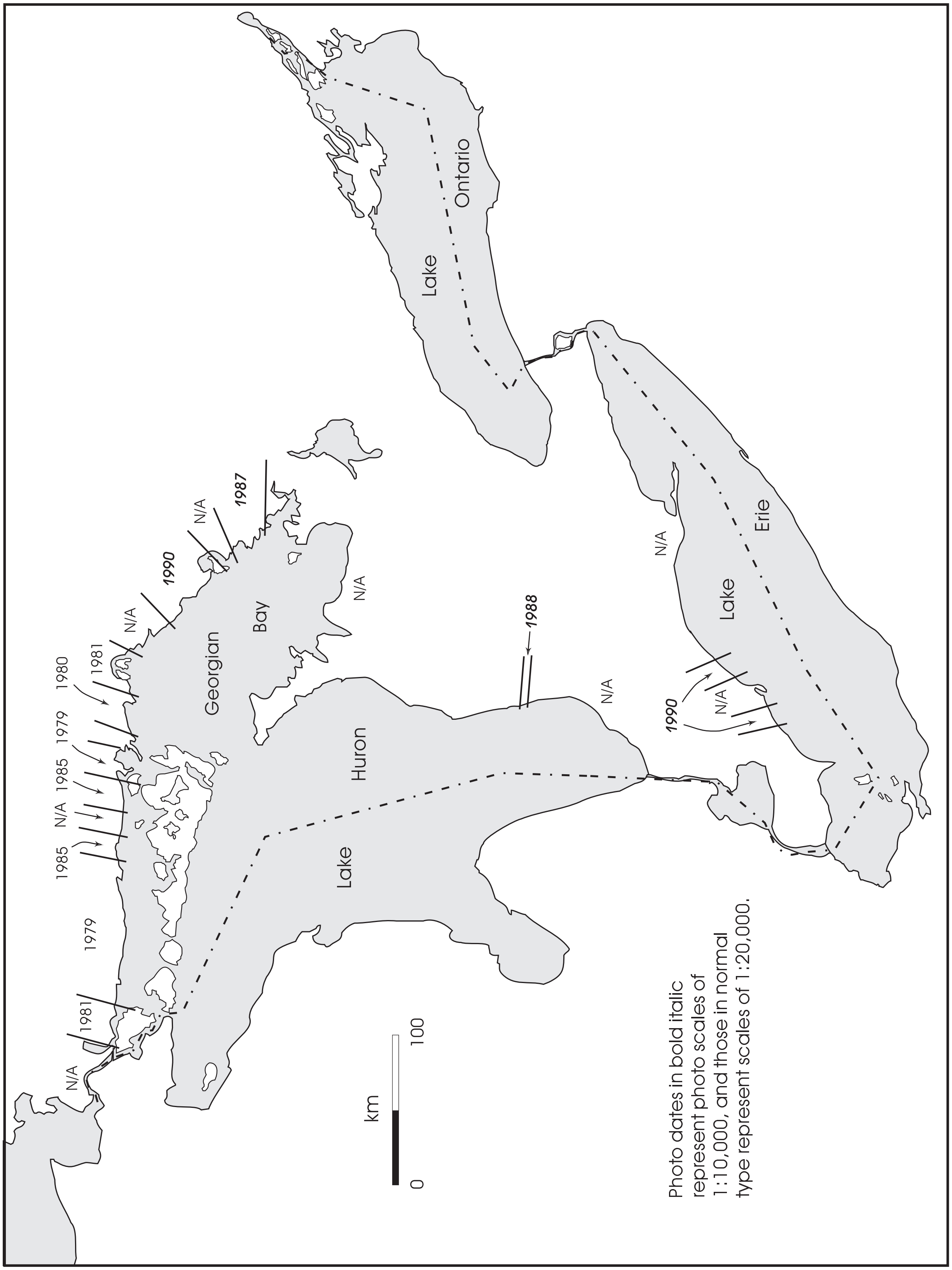


Figure A4.3.15: OBM Digital Mapping: Lake Ontario 1:20,000

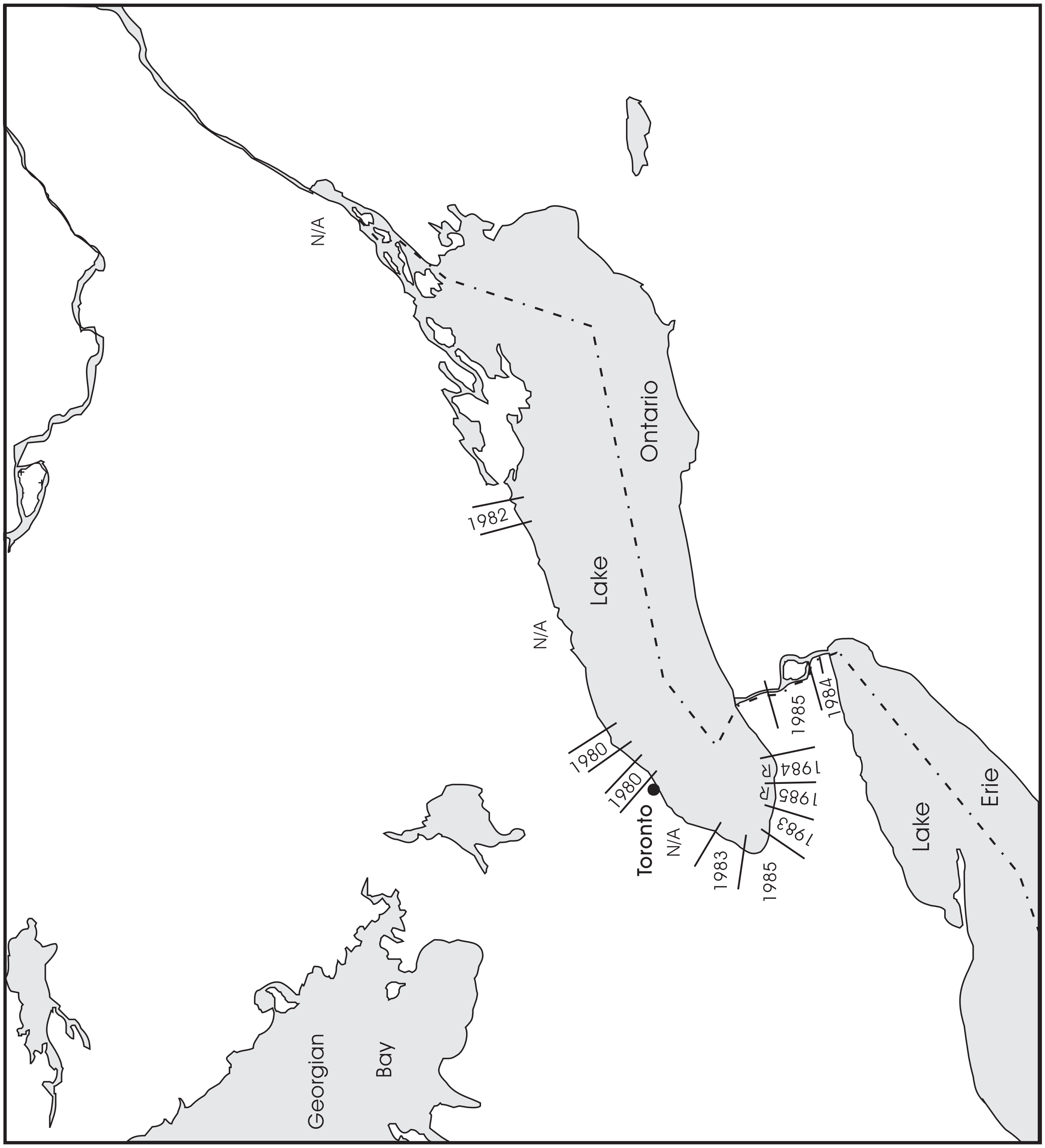


Figure A4.3.16: Index Map for OBM Mapping

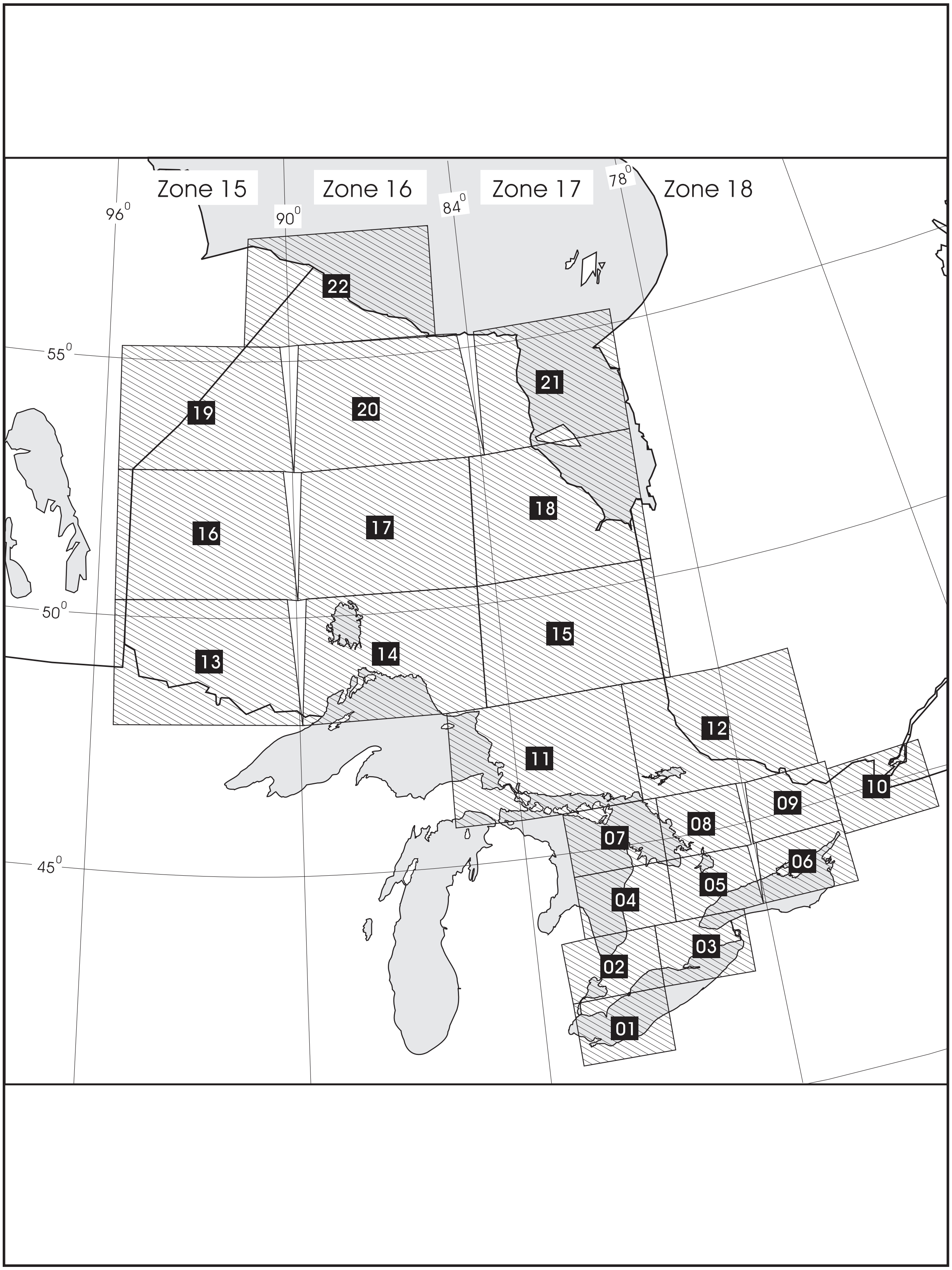


Table A4.3.2: OBM Order Form

Ministry of Natural Resources
Ontario

Natural Resources Information Centre
Room M1-73, Macdonald Block
900 Bay Street,
Toronto, Ontario
M7A 2CI

Ontario Base Mapping Order

Date

Each map costs $6.25
Your payment must accompany your order.
OBM Index Maps are available free of charge.
Maps are available in areas shaded orange or green only on the Index Maps.

Scale	Zone	Base Map Number	Quantity	Total
		Total number of maps required		
		Ontario Residents add 8% provincial sales tax		
		Canadian Residents add 7% federal goods and services tax		

Delivery Rates

Within Ontario $2.50
Other Canadian Provinces/Territories $ 4.28
Outside of Canada $ 7.00
Delivery rates within Canada include 7% federal goods and services tax

=

Receipt No.

Please make your cheque or money order payable to the Ontario Minister of Finance

Total $

Pick-up OR Send to

Name	Telephone

Name		
Address		
City, Town	Province	Postal Code

737(93/10)

Digital files are distributed directly from the Mapping Office. A library fee applies to each order, regardless of the number of tapes (i.e., maps) ordered. Tapes are an additional cost. Digital coverage is indicated on the index maps available from the Information Centre.

d) Ontario Property Assessment Maps

i) Overview of the Program

There are thirty-two Regional Assessment Offices across the province. Twenty-three of these offices border the *Great Lakes - St. Lawrence River System* shoreline. All Regional Assessment Offices prepare large and/or medium scale property assessment base maps for their respective regions, but these maps do not accurately portray shoreline location and are consequently not ideal for use in calculating shoreline recession rates.

Property assessment maps are prepared using information taken from municipal registry office maps that often date back to land surveys originally conducted in the mid-1800's. Subsequent updates to assessment maps have not necessarily included revisions to the location of the shoreline because accurate depiction of the shoreline is not considered a priority.

ii) Overview of Map Content

While property assessment maps are not suitable for use in determining an AARR, they could be useful for other purposes such as locating property lines and ownership. The maps portray property lot dimensions, a legal description of each lot, concessions and assessment roll numbers. They do not contain topographic contours, and are georeferenced only to property and concession lines. Some maps do not indicate their printing date.

A sample section of a property assessment map, scale 1:4800, is provided in Figure A4.3.17.

iii) Coverage and Scales Available

The entire *Great Lakes - St. Lawrence River System* shoreline is not covered by property assessment maps: mapping exists predominantly in settled/developed urban and rural areas. Much of the Lake Superior and Georgian Bay shoreline remains unmapped. The maps are prepared at a wide variety of scales, ranging between 1:100 in densely developed areas to 1:50,000 in less developed areas.

At present, assessment maps are available only in conventional (i.e., paper) format. However, some municipalities intend to digitize their maps in the near future.

For more specific information concerning mapping coverage and scales in areas of your particular interest, contact the relevant Regional Assessment Office.

iv) Ordering of Maps

At present, maps can be purchased for $25.00 (1997 price) each including GST and PST from the appropriate Regional Field Office (Table A4.3.3). Written requests are preferred.

Figure A4.3.17: Property Assessment Map

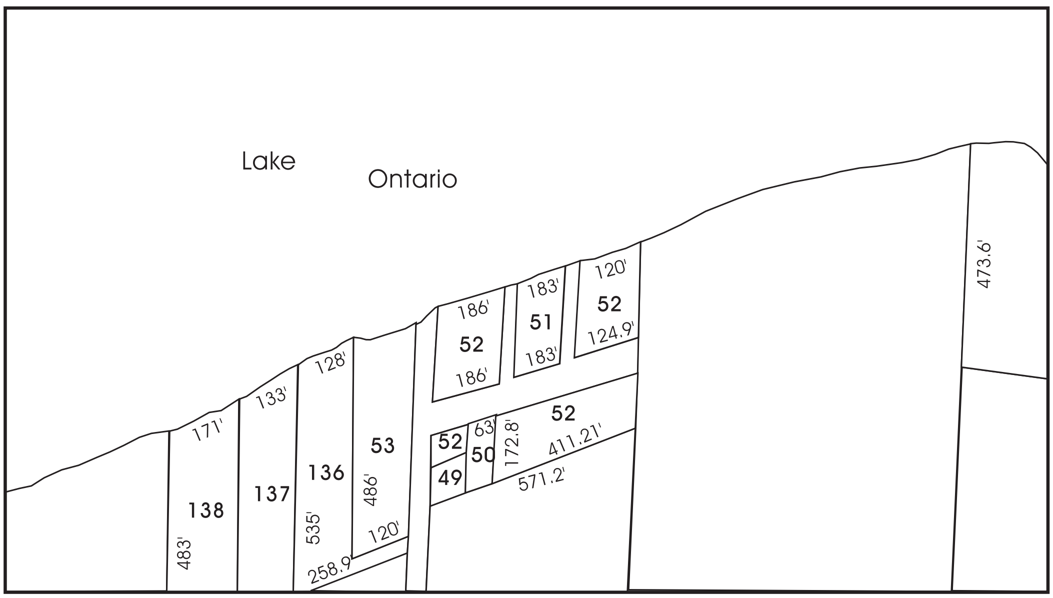


Table A4.3.3
Regional Assessment Offices

Mr. Tony Dufresne Regional Assessment Commissioner P.O. Box 219 132 Second Street East Cornwall, Ontario, K6H 5S7	-TEL: (613) 933-7100 FAX: (613) 933-0597 TOLL FREE: 1-800-267-7194
Mr. David Publow Regional Assessment Commissioner 2479 Parkdale Avenue Brockville, Ontario, K6V 3H2	TEL: (613) 342-8242 FAX: (613) 342-9369 TOLL FREE: 1-800-267-0836
Mr. Ernie Thain Regional Assessment Commissioner P.O. Box 520 80 Division Street Trenton, Ontario, K8V 5R7	TEL: (613) 392-2501 FAX: (613) 392-1937 TOLL FREE: 1-800-267-0542 (for area code 416, 519, 613, and 705) 1-800-267-0538 & 0539 (for area code 613)
Mr. Ken Fagan Regional Assessment Commissioner Suite 300, 90 Eglinton Avenue East Toronto, Ontario, M4P 3A5	TEL: (416) 327-1800 FAX: (416) 314-3319
Mr. Rick Powell Regional Assessment Commissioner 7 Overlea Boulevard Toronto, Ontario	TEL: (416) 292-5244 or (416) 314-8900 FAX: (416) 314-3315
Mr. Dick Humphrey Regional Assessment Commissioner 4 Eva Road Etobicoke, Ontario, M9C 2A8	TEL: (416) 621-9400 FAX: (416) 314-3312
Mr. M.K. Bowen Regional Assessment Commissioner P.O. Box 270 605 Rossland Road East Whitby, Ontario, L1N 5S1	TEL: (905) 432-1071 FAX: (905) 432-8444 TOLL FREE: 1-800-268-2224
Ms. Cathy Farr Regional Assessment Commissioner 4th Floor, 2 Robert Speck Parkway Mississauga, Ontario, L4Z 1T3	TEL: (905) 270-8050 FAX: (905)270-9666
Mr. Bill Bollmar Regional Assessment Commissioner 109 Ferris Lane Barrie, Ontario, L4M 2Y1	TEL: (705) 728-2270 FAX: (705) 728-3077 TOLL FREE: 1-800-461-4230
Ms. Valerie Jones Regional Assessment Commissioner P.O. Box 150 Pine Street East Bracebridge, Ontario, P0B 1C0	TEL: (705) 645-1870 FAX: (705) 645-5204
Mr. Brian Dargel Regional Assessment Commissioner P.O. Box 1270 43 Church Street, Landmark Building St. Catharines, Ontario, L2R 7A7	TEL: (905) 688-0233 FAX: (905) 688-9929

Mr. R.L. Cushing Regional Assessment Commissioner P.O. Box 2112 3rd Floor, 119 King Street West, Provincial Office Tower Hamilton, Ontario, L8N 3Z9	TEL: (905) 521-7469 FAX: (905) 521-7206
Ms. Corinne McCormack Regional Assessment Commissioner 63 Charing Cross Brantford, Ontario, N3R 7K9	TEL: (519) 759-6310 FAX: (519) 759-1011
Mr. Paul Smith Regional Assessment Commissioner 1420 Wellington Road South London P.O. Westminster, Ontario, N6E 3A2	TEL: (519) 681-0050 FAX: (519) 649-3368
Mr. G.E. Morgan Regional Assessment Commissioner P.O. Box 190 57 Napier Street Goderich, Ontario, N7A 3Z2	TEL: (519) 524-7326 FAX: (519) 524-5271
Mr. Ric Clarke Regional Assessment Commissioner Unit 2 - 900, 10th Street West Owen Sound, Ontario, N4K 6V6	TEL: (519) 371-1121 FAX: (519) 371-5885
Mr. Jim Edmunds Regional Assessment Commissioner P.O. Box 1140 435 Grand Avenue West Chatham, Ontario, N7M 5L8	TEL: (519) 354-5460 FAX: (519) 354-1130
Mr. R.J. Speroni Regional Assessment Commissioner 5th Floor, 250 Windsor Avenue Windsor, Ontario, N9A 6V9	TEL: (519) 254-3771 FAX: (519)973-1483
Mr. Don F. Murray Regional Assessment Commissioner P.O. Box 167 1650 Main Street West North Bay, Ontario, P1B 8H2	TEL: (705) 474-6150 FAX: (705) 474-8335
Mr. Richard Moffatt Regional Assessment Commissioner 12th Floor 199 Larch Street, Provincial Tower Sudbury, Ontario, P3E 5P9	TEL: (705) 675-4200 FAX: (705) 675-6610
Mr. John McClenaghan Regional Assessment Commissioner 180 Brock Street Sault Ste. Marie, Ontario, P6A 3B7	TEL: (705) 949-3941 FAX: (705) 949-6472
Mr. Conrad Lalonde Regional Assessment Commissioner P.O. Box 2718 189 Red River Road Thunder Bay, Ontario, P7B 5G2	TEL: (807) 343-7200 FAX: (807) 343-7210

e) Ontario Ministry of Agriculture and Food (OMAFRA)

i) Overview of the Program

The Ontario Ministry of Agriculture and Food (OMAFRA) collects and publishes soil survey, land use, and tile drainage information in the form of maps and reports. This information is available to government agencies as well as the general public.

ii) Overview of Map Content

Four different map series are published by the Ministry of Agriculture and Food. The collective purpose of this information is:

- to show the spatial relationship of the soil resources,
- to identify the suitability of soils for agriculture,
- to demonstrate how the land is being used, and
- to define the extent of tile drainage in the province.

With the exception of the tile drainage maps, all of the maps are georeferenced using the Universal Transverse Mercator (UTM) system and use National Topographic Series (NTS) maps as the base map for their information.

- **Soil Survey Information**

  Since the beginning of this century, the Ministry, in cooperation with Agriculture Canada and the University of Guelph, has been collecting soil information for the agricultural portions of the province. The results of these studies have been published in the form of soil maps and reports on a county basis (Figures A4.3.18 to A4.3.20). More detailed information is now being collected for those areas that were surveyed prior to 1940.

- **Canada Land Inventory Information**

  The Canada Land Inventory Information is essentially an interpretation of the soil resource information. Four classification rating systems were developed: agriculture, forestry, recreation, and wildlife. The Ministry of Agriculture and Food is only involved with the C.L.I. ratings for agriculture. In the agricultural capability rating system, all mineral soils are classified into seven classes based on their potentials and limitations for agriculture. Agricultural capability maps are compiled at a scale of 1:50,000.

Figure A4.3.18: Soil Survey Maps at 1:63,000 Scale

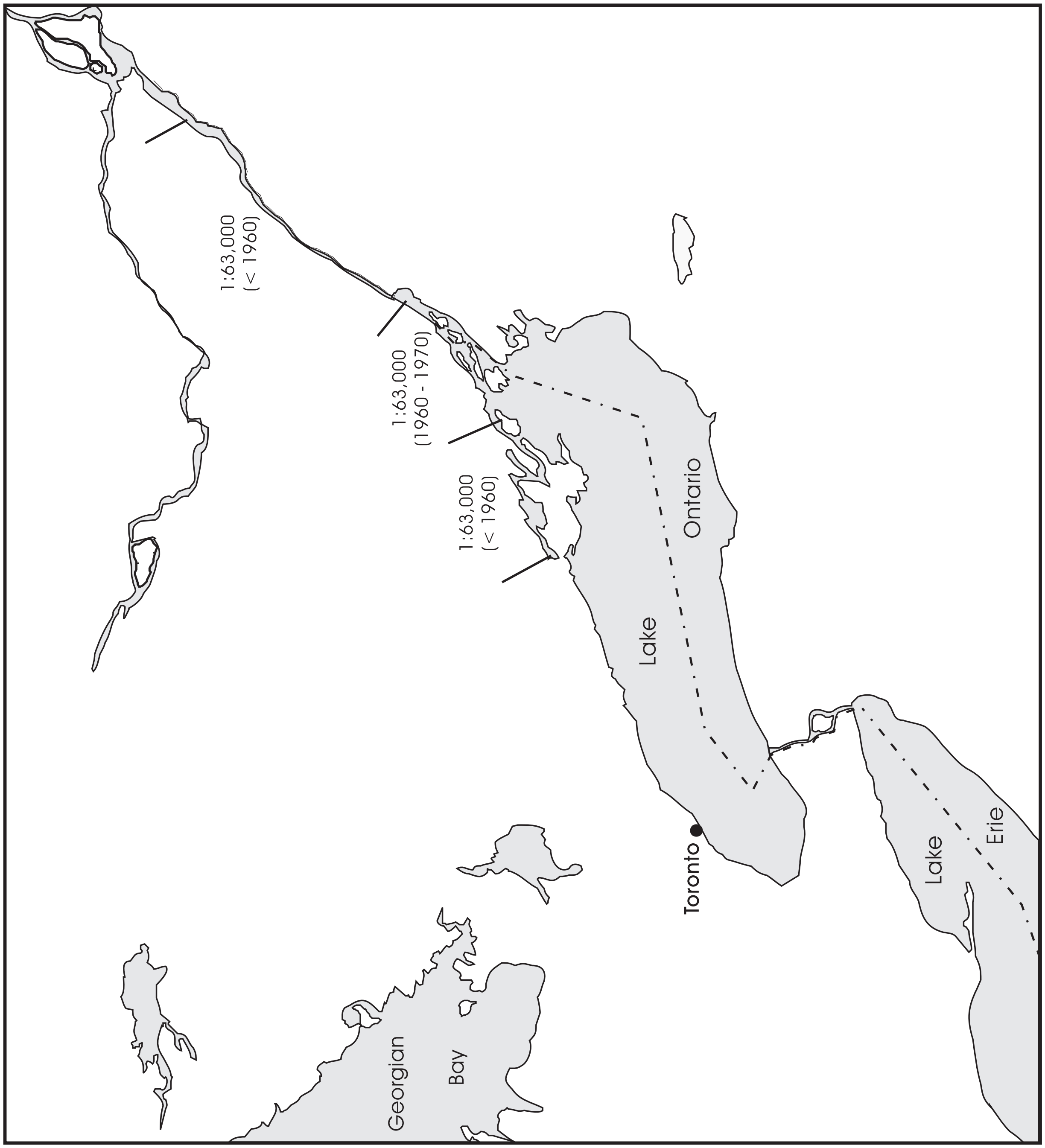


Figure A4.3.19: Soil Survey Maps at 1:50,000 Scale

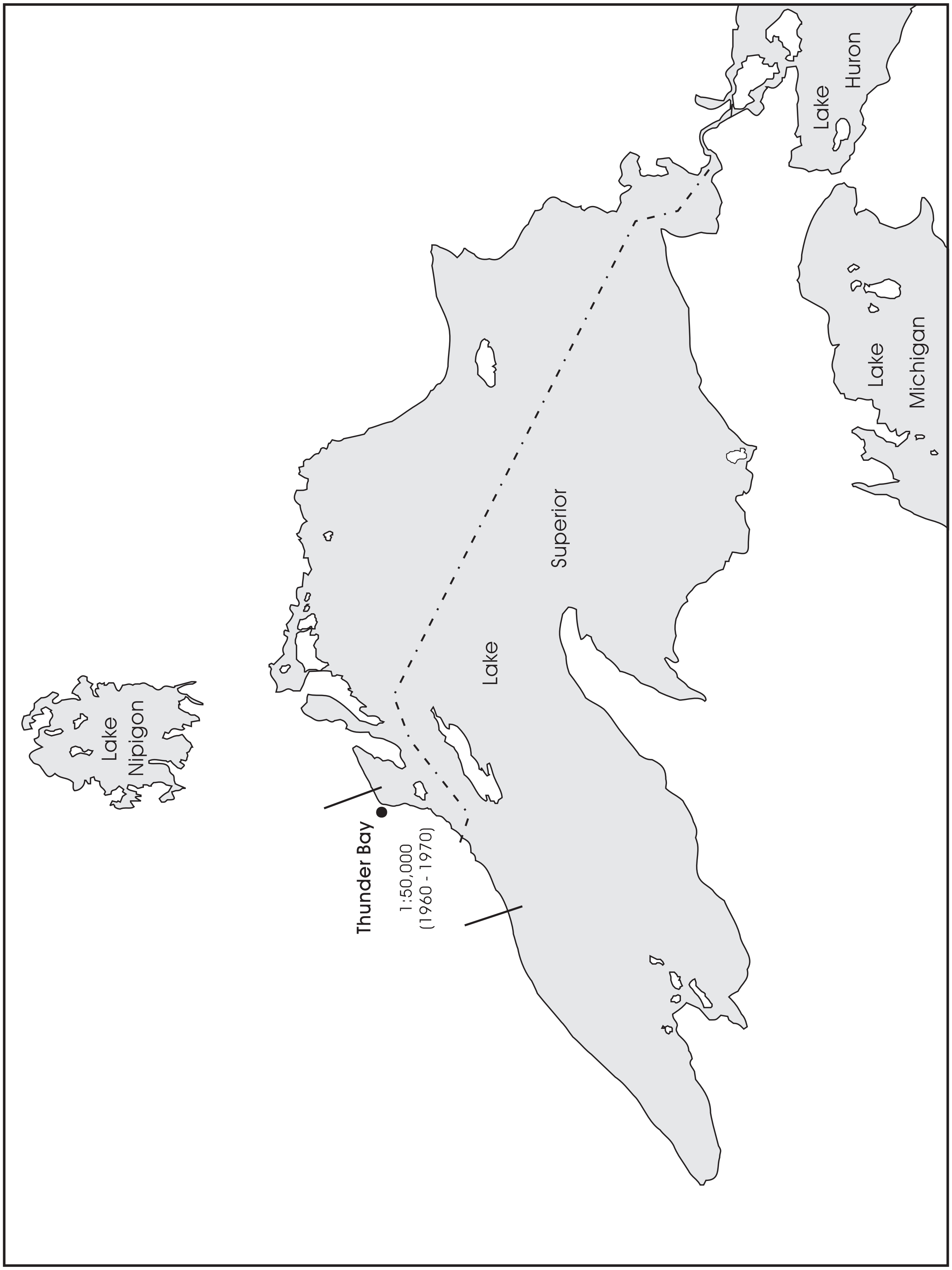
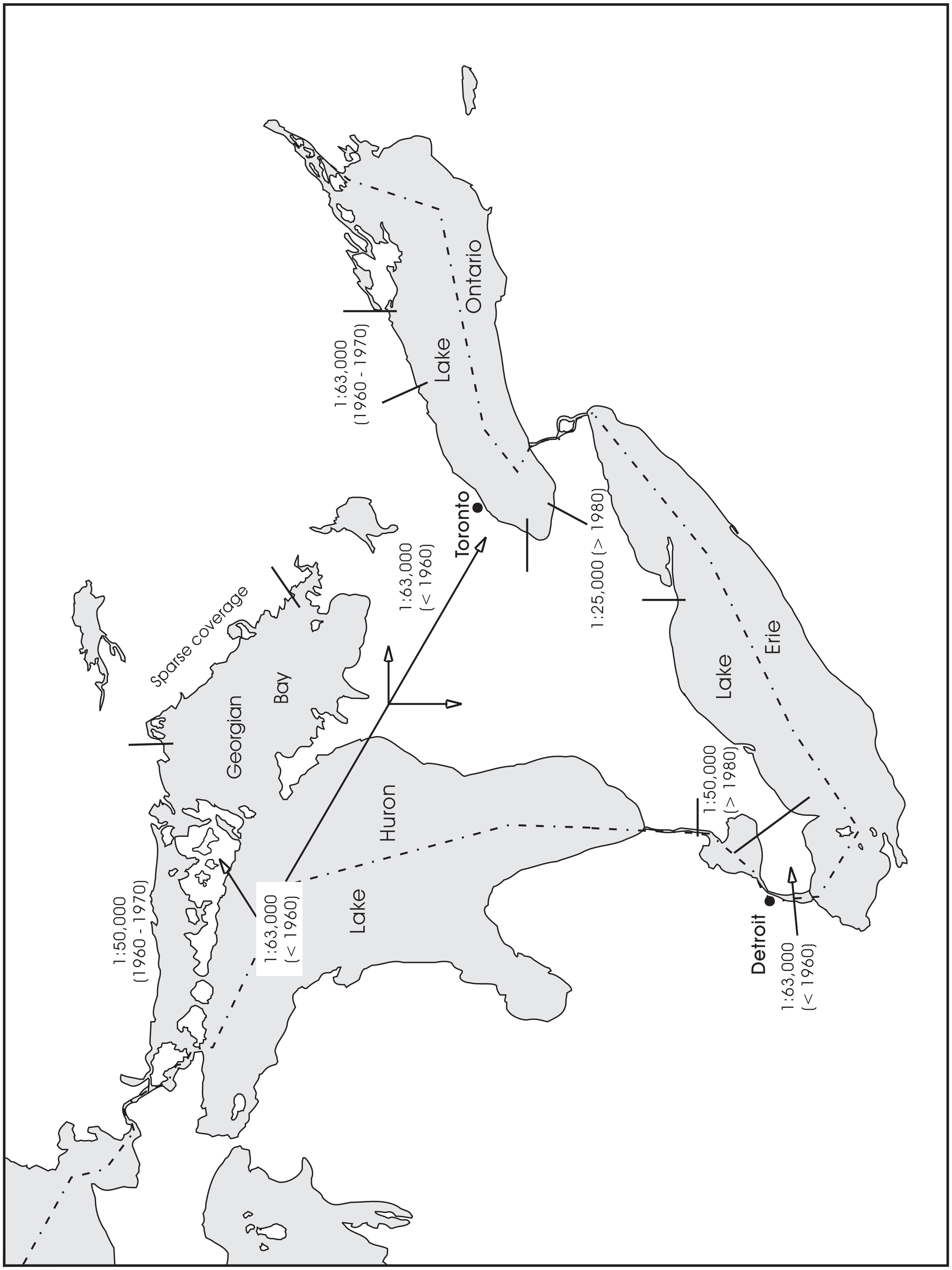


Figure A4.3.20: Coverage of Soil Survey Maps of Varying Scales and Years



- **Agricultural Land Use Information**

  In the period from 1982 to 1984, OMAFRA conducted a land use inventory for all of the agricultural regions in the province. Based on the shape and size of the fields as well as the crops that were grown, the information was grouped into a series of land use systems (i.e., rotations) which gave the maps a more contemporary dimension. The result of this survey was the Land Use Systems maps that are available on a township basis at a scale of 1:50,000. No attempt has yet been made to update this information.

- **Tile Drainage Information**

  Simultaneously with the Land Use Survey, the Ministry collected information on the extent of tile drainage (i.e., random as well as systematic drainage systems) in the province. The initial information was gathered from farmers and field observations. Municipal tile drainage information was obtained from information collected by the townships and from engineering reports. The information was compiled and published on township maps at a scale of 1:25,000. Annual updates are being made to these maps from engineering and installation reports submitted to the Ministry.

The above mentioned maps are not ideal for use in determining average annual recession rates (AARR) due to their small scales. However, the soil resource information contained on OMAFRA maps may provide insight into the soil types along the Great Lakes - St. Lawrence River shoreline.

iii) Coverage and Scales Available

Most of the shorelines of the Great Lakes - St. Lawrence River lowlands are covered by the four types of resource maps. The vintage of the available coverage for each resource map type is shown on the Index Maps at the end of this section.

- **Map Scales**:

  Soil Survey Maps

  The map scales for the soil maps vary from 1:25,000 to 1:63,360 depending on when the map was made. More recently, maps have been produced at a scale of 1:50,000.

  C.L.I. Capability For Agriculture Maps

  All C.L.I. maps are produced at a scale of 1:50,000. However, since 1970 more accurate tabular form C.L.I. ratings have also been produced.

  Land Use Maps

  All land use maps are at a scale of 1:50,000.

  Tile Drainage Maps

  All tile drainage information is provided at scales of 1:25,000 or 1:30,000.

iv) Digital Information

The Ontario Ministry of Agriculture, Food, and Rural Affairs through its G.I.S. Unit is in the process of digitizing all available soils information for the province. The digitized maps include information on potential soil erosion, capability for agriculture, soil tillage, soil compaction, other soil limitations, and infiltration/ permeability rates. To date, all the land use information has been digitized. Tile drainage maps have yet to be digitized.

All information is being digitized using PC ARC-INFO software. This information can be imported into several other systems including the SPANS GIS system. There is a charge per file. A file typically contains coverage of one township).

For more information regarding the availability of digital information call 1-888-466-2372.

General Inquiries at OMAFRA : 1-888-466-2372
Contact Lou Donafreo

v) Ordering of Maps

For information or orders for hard copy maps (NOTE: mylars are not available), contact the Ministry of Agriculture, Food, and Rural Affairs in Guelph at the following address:

Ontario Ministry of Agriculture, Food, and Rural Affairs
Resources Management Branch
Agriculture Centre
52 Royal Road
P.O. Box 1030
Guelph, Ontario
N1H 6N1

TEL: (519) 826-3587
FAX: (519) 826-3259

Small orders can be placed by phone, while larger orders should be placed either by mail, fax, or in person. A nominal fee will be charged depending on the size of the order. All orders should be placed at least one week in advance.

f) Ontario Hydro

i) Overview of the Program

Ontario Hydro produces conventional (i.e., paper) and digital maps at a variety of scales and levels of detail to satisfy the requirements of specific projects. Collectively, the maps provide complete coverage of the Great Lakes -St. Lawrence River shoreline. However, general coverage of any given section of the province at a consistent scale and with consistent content is not available.

Ontario Hydro does not maintain a central inventory of the maps produced by its numerous divisions and is not equipped to publicly distribute maps. As a result, locating and acquiring potentially useful maps may be difficult. It is recommended that other map and air photo sources are pursued prior to approaching Ontario Hydro.

g) National Topographic Series (NTS) Mapping

i) Overview of the Program

National Topographic System (NTS) Mapping is prepared by the federal Department of Energy, Mines and Resources (EMR) and compiled in Ottawa at the Canada Map Office. NTS maps provide topographic coverage of the entire landbase of Canada at scales of 1:50,000, 1:250,000 and 1:1,000,000. NTS maps are not appropriate for use in determining average annual recession rates (AARR).

ii) Overview of Map Content

An overview of the information portrayed on 1:50,000 scale NTS maps is provided below.

- topographic contour lines, 50 ft. interval
- UTM georeferencing and projection
- horizontal / vertical control points
- spot elevations
- the location, typically represented by symbols, of buildings; transportation, communications and utility corridors; linear features such as fences and shore protection structures; physical landforms; and water features including drainage ditches
- names of all communities, highways, islands and significant water features

iii) Ordering of Maps

NTS maps are available in paper and digital formats (CCOGIS). Contact the Customer Information extension of the Canada Map Office at (613) 952-7000 for more information.

h) Canadian Hydrographic Service Charts (CHS Charts)

i) Overview of the Program

The Canadian Hydrographic Service produces and distributes nautical charts, sailing directions and tide tables of the navigable waters of Canada. These products are intended for use by commercial and recreational mariners, and as such do not contain the landside information necessary to make them an appropriate source for the purposes of monitoring shoreline recession.

ii) Overview of Map Content

Nautical charts and their supporting documents include information concerning, for example, tides, water levels, aids to navigation and berthing facilities. Much of this information is invaluable to mariners, but is not required when calculating an average annual recession rate (AARR).

Conversely, some of the information required to calculate an AARR is not present on nautical charts. Specifically, nautical charts do not include topographic contours. This prevents accurate identification of the top or toe of a shoreline bluff. Nautical charts and reports could, however, be useful for related projects such as bathymetric studies.

NOTE: If information is required on water levels, monthly mean water levels information is available, free of charge, through the federal Department of Fisheries and Oceans' monthly publication entitled Great Lakes Water Level Bulletin.

iii) Coverage and Scales Available

The entire *Great Lakes - St. Lawrence River System* shoreline is currently covered by a mosaic of CHS nautical charts of various scales. However, many of these maps have been prepared at too small a scale to be appropriate for the purpose of studying shoreline change.

Only maps scaled at 1:5,000 or better are recommended. However, most of the Great Lakes charts are scaled between 1:20,000 and 1:75,000. Along the St. Lawrence River, Ontario shoreline, most charts are scaled between 1:12,000 and 1:25,000. Throughout the system, some harbours have also been mapped, typically at a scale ranging from 1:5,000 to 1:10,000.

iv) Ordering of Maps

To indicate the coverage area and scale of each of its charts, the Department of Fisheries and Oceans annually produces a series of chart catalogues. For information concerning current coverage within the Great Lakes Basin, order the "Catalogue of Nautical Charts and Related Publications: Catalogue 3, Central Canada" using the address noted below or from a local CHS chart dealer. There is no charge for this publication. Charts are available only in paper format (i.e., no digital, mylar, etc. versions).

Most charts are $20 each (1997 price), although some larger scale, small-craft, charts are priced at up to $33 each (1997 price). Payment for mail orders must be made in advance, by VISA or MASTERCARD credit cards, by money order or by bankable remittance payable, in Canadian funds, to the Receiver General of Canada and sent to:

Hydrographic Chart Distribution Office
Department of Fisheries and Oceans
1675 Russel Road, P.O. Box 8080
Ottawa, Ontario
K1G 3H6

TEL: (613) 998-49 31/32/33
FAX: (613) 998-1217

Material that is delivered in conformity with order is not returnable for exchange or refund.

A4.3.4 Programs and Sources of Aerial Photographs

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

a) National Air Photo Library - Department of Energy, Mines and Resources (EMR), Ottawa

More than four million aerial photographs, taken of Canada since the 1920's, are indexed and stored at the National Air Photo Library in Ottawa.

i) Coverage, Scales and Formats Available

Large scale (i.e., less than or equal to 1:20,000) photos of varying scale and year of exposure are available for most of the *Great Lakes - St. Lawrence River System* shoreline. In some areas, particularly within southern Ontario, black and white photography is available at a variety of different scales and years. Large scale colour and infra-red photography is also available, but only for a very limited number of areas. All photographs vary in visual quality dependant upon scale and age.

ii) Enlargements

Greater detail can be obtained from an aerial photograph if it is enlarged. Enlargements of any factor up to five times the original image size, and not necessarily an integer, can be performed by the Library. If you require a portion enlarged from an aerial photograph, mark the portion on a copy of the photograph. The portion should be a square, between 15 and 20 cm across, with the sides of the square parallel to the sides of the photo.

iii) Mosaics

Reprints of mosaics (i.e., a composite of many air photos cut and joined together to create a single picture covering a larger area) are available for many areas in Canada. However, the mosaics are typically too small in scale for use in calculating AARRs.

iv) Microfiche

Complete aerial coverage of Canada is available on 16 mm black and white microfilm. Index maps showing relative ground positions of the photography have been placed on 35 mm colour microfiche.

v) Flight Line Index Maps

Black and white reproductions of topographical maps, on which the flight lines of the aircraft have been drawn, are available from the Library. Generally, the centres of every fifth photograph are indicated. Aerial photo coverage of small or large areas may be selected using these indices.

vi) Payment

Prepayment in Canadian funds by cheque or money order, payable to the Receiver General for Canada, is required for all products or services if your agency does not have an active credit account with the Library.

Table A4.3.4
Aerial Photograph Price List (October 1997)

Contact Prints	Monochrome	$ 6.95
	Colour (Negative Original)	$ 10.95
	Colour (Positive Original)	$ 15.00
Digital Scanned Images	Monochrome 300 DPI 1 to 4	$ 18.00
	Monochrome 300 DPI 5 to 9	$ 14.00
	Monochrome 300 DPI 20 plus	$ 10.00
	Monochrome 600 DPI 1 to 4	$ 24.00
	Monochrome 600 DPI 5 to 9	$ 20.00
	Monochrome 600 DPI 20 plus	$ 16.00
	CD-ROM	$ 20.00
	Diskette	$ 2.00
Enlargements	Dimensions	
	25cm x 25cm (10")	$ 22.00 *
	38cm x 38cm (15")	$ 26.00 *
	50cm x 50cm (20")	$ 30.00 *
	76cm x 76cm (30")	$ 45.00 *
	101cm x 101cm (40")	$ 60.00 *
	101cm x 152cm (40" x 60")	$ 85.00 *
Flight Line Index Map		$ 3.00

***** Prices quoted are for monochrome enlargements. Colour enlargements are also available but are expensive and not necessary for the given project.

A $5.00 handling charge applies to all Canadian orders. Stated prices are subject to change without notice and do not include applicable sales taxes.

vii) Ordering of Photos

All photographs should be ordered from the National Air Photo Library in the manner outlined below.

1. Mark your precise area of interest on a suitably scaled topographical map (photocopies are acceptable) obtainable through local map dealers listed in the "Yellow Pages", or from the Canada Map Office, 615 Booth Street, Ottawa, Ontario, K1A 0E9.

2. Send the map (it will be returned to you) to the National Air Photo Library and request all of the flight line index maps that satisfy your scale and year of exposure requirements for the marked area. You can then use the flight line maps to select the photographs specifically required.

3. Forward the reference codes of the desired photographs to the address below. Orders can be made by mail, fax or in person and must be pre-paid. Allow 2 to 4 weeks for delivery.

National Air Photo Library
615 Booth Street
Ottawa, Ontario, Canada
K1A 0E9

TEL: (613) 995-4560
FAX: (613) 995-4568

b) Canada Centre for Inland Waters (CCIW) - Environment Canada (IWD), Burlington

The Canada Centre for Inland Waters (CCIW) maintains a small library of large scale aerial photographs. The collection represents half of the photographs taken (i.e., specifically, every second photograph from each flight line) for use with the Canada/Ontario Flood Damage Reduction Program (FDRP) (see A4.3.3(a)). The other half of the photographs are held by shoreline conservation authorities.

i) Coverage and Scales Available

The photography covers most of the *Great Lakes - St. Lawrence River System* shoreline within Ontario. The length of mainland shoreline between Sault St. Marie and approximately Penetanguishene, on Georgian Bay, was not flown. In many places, coverage exists for two different years. Scales and years of photography are depicted in Figures A4.3.21 and A4.3.22, and can be summarized as follows:

L. Superior	1986	1:8,000	FDRP
L. Huron (partial)	1985 & 1988	1:8,000	FDRP
L. Erie	1985 & 1988	1:8,000	FDRP
L. Ontario	1986 & 1989	1:8,000	FDRP
St. Lawrence River	1978	1:10,000	FRI

The 1978 coverage of the St. Lawrence River is Forest Resource Inventory (FRI) photography, acquired from the Ministry of Natural Resources.

The Canada Centre for Inland Waters did not produce any of the photography in its collection and does not possess any of the negatives. CCIW only maintains a collection of prints. Negatives for all of the photos are available from the National Air Photo Library in Ottawa.

Figure A4.3.21: FDRP Photo Coverage 1978-1986

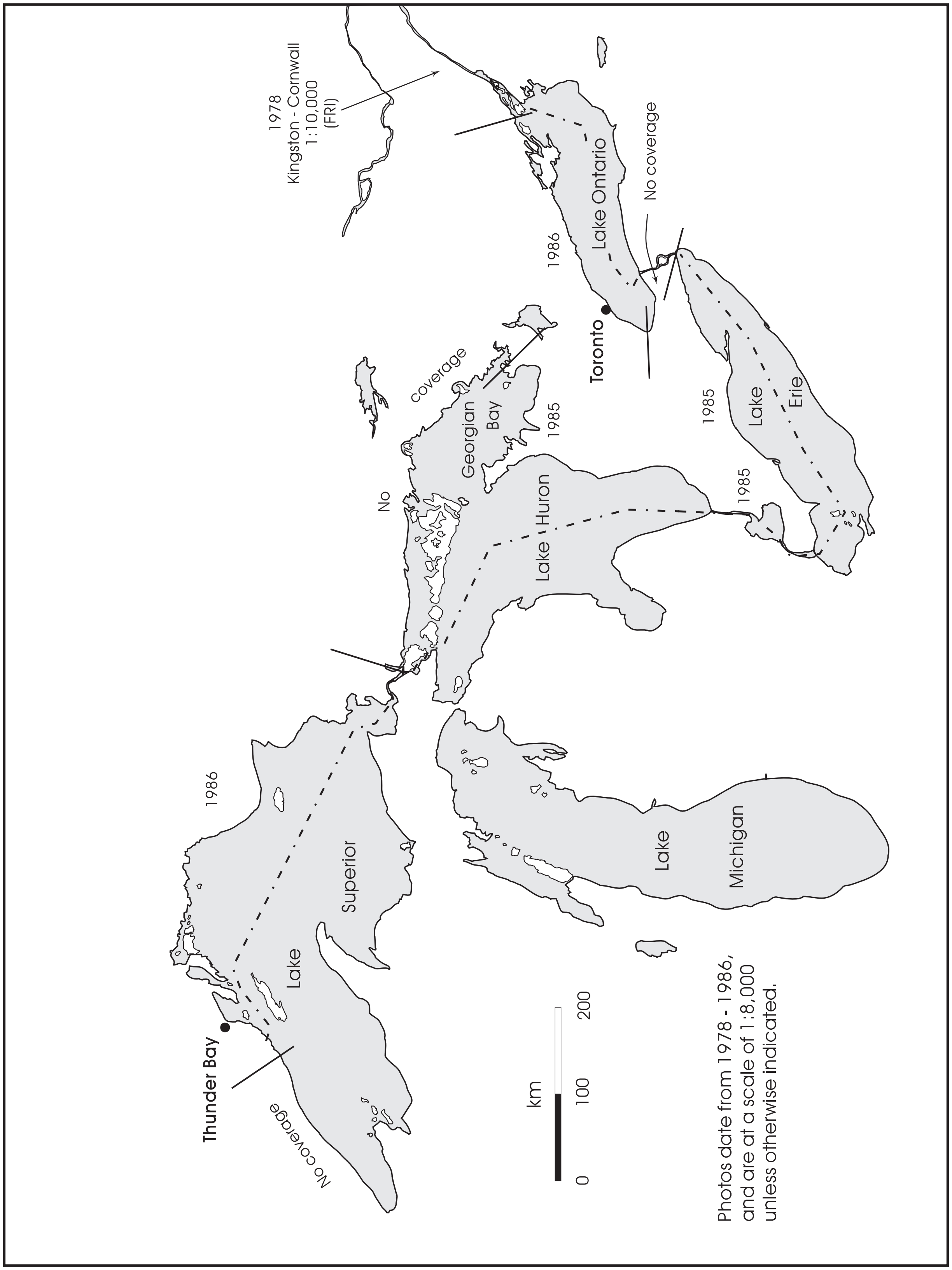
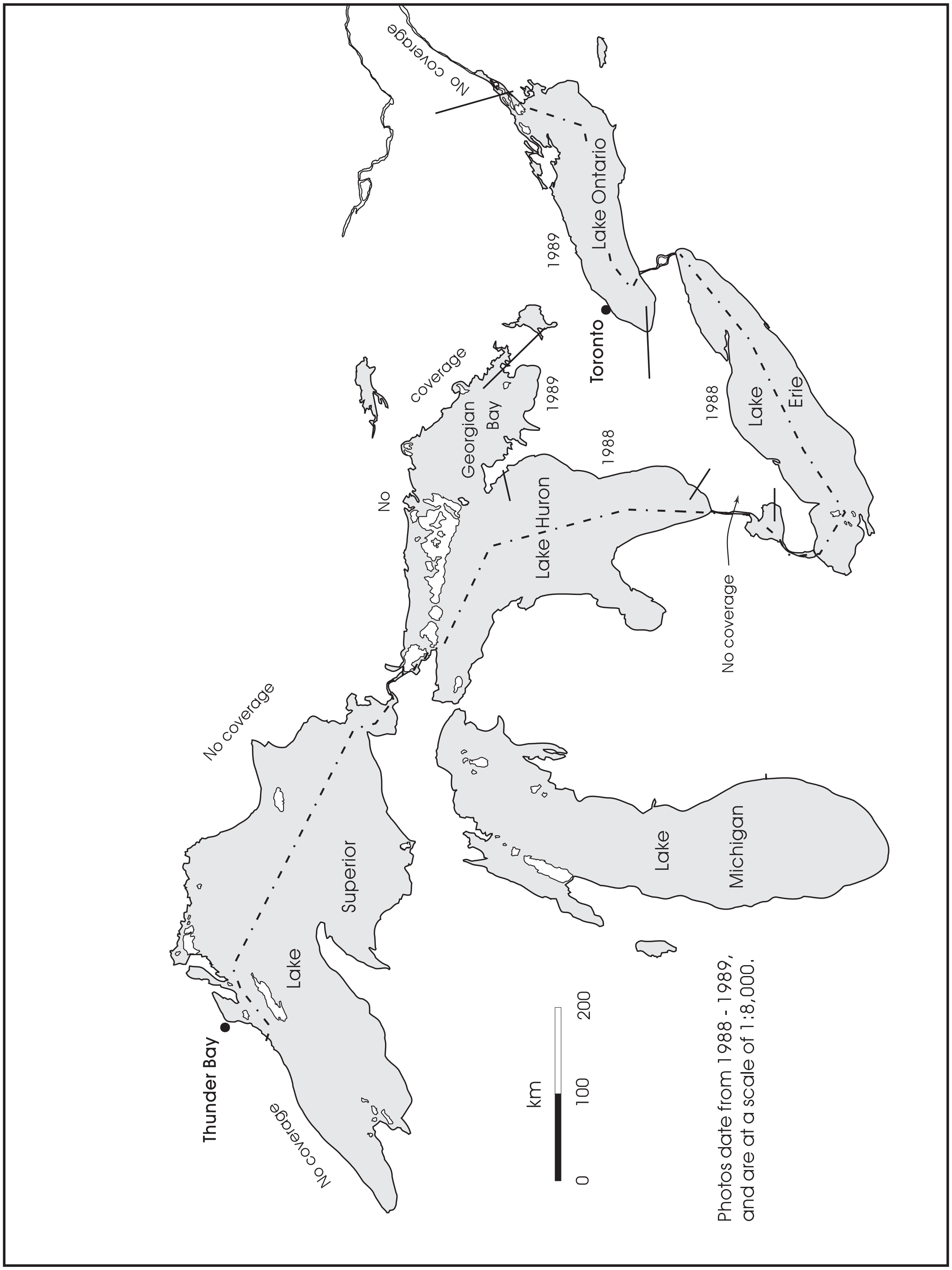


Figure A4.3.22: FDRP Photo Coverage 1988-1989



c) Ontario Ministry of Natural Resources (MNR)

The Ontario Government undertakes aerial photography for various projects, most notably to provide data for the Forest Resources Inventory program, the Ontario Base Map program and for various shoreline and inland studies. The Ministry of Natural Resources (MNR) produces and maintains these aerial photo collections.

Presented here is a breakdown of the photography currently available through the Ministry's Natural Resources Information Centre. Much of the information presented in this section has been adopted directly from the MNR publication "Map and Aerial Photograph Catalogue: 1991/92", available from the Ministry of Natural Resources Information Centre.

i) Coverage and Scales Available

The Ministry has photographs ranging in scale from 1:8,000 to 1:100,000 and in year from 1946 to 1991. Many of these photographs have been compiled for one of three major projects: the Forest Resources Inventory (FRI); the Ontario Basic Mapping (OBM) program; and the 1985 Shoreline Photography project.

A detailed inventory of the scales, years and area of coverage of these three projects is offered in several series of maps at the end of this section. This information is summarized in Figures A4.3.23 to A4.3.29.

FRI Photo Coverage:	1946-1957	Figure A4.3.23. FRI.1
	1958-1966	Figure A4.3.24
	1966-1976	Figure A4.3.25
	1977-1989	Figure A4.3.26
	1987-1991	Figure A4.3.27
OBM Photo Coverage	1973-1988	Figure A4.3.28
Shoreline Coverage:	1985	Figure A4.3.29

Note that OBM photography is taken at scales of 1:30,000 and 1:50,000, and is therefore inappropriate for use in calculating AARRs unless enlarged. You may wish to consult with aerial photography representatives at the Ministry's Natural Resources Information Centre before placing an order, to find out what additional possibilities exist for your specific area of interest.

Figure A4.3.23: FRI Photo Coverage 1946-1957

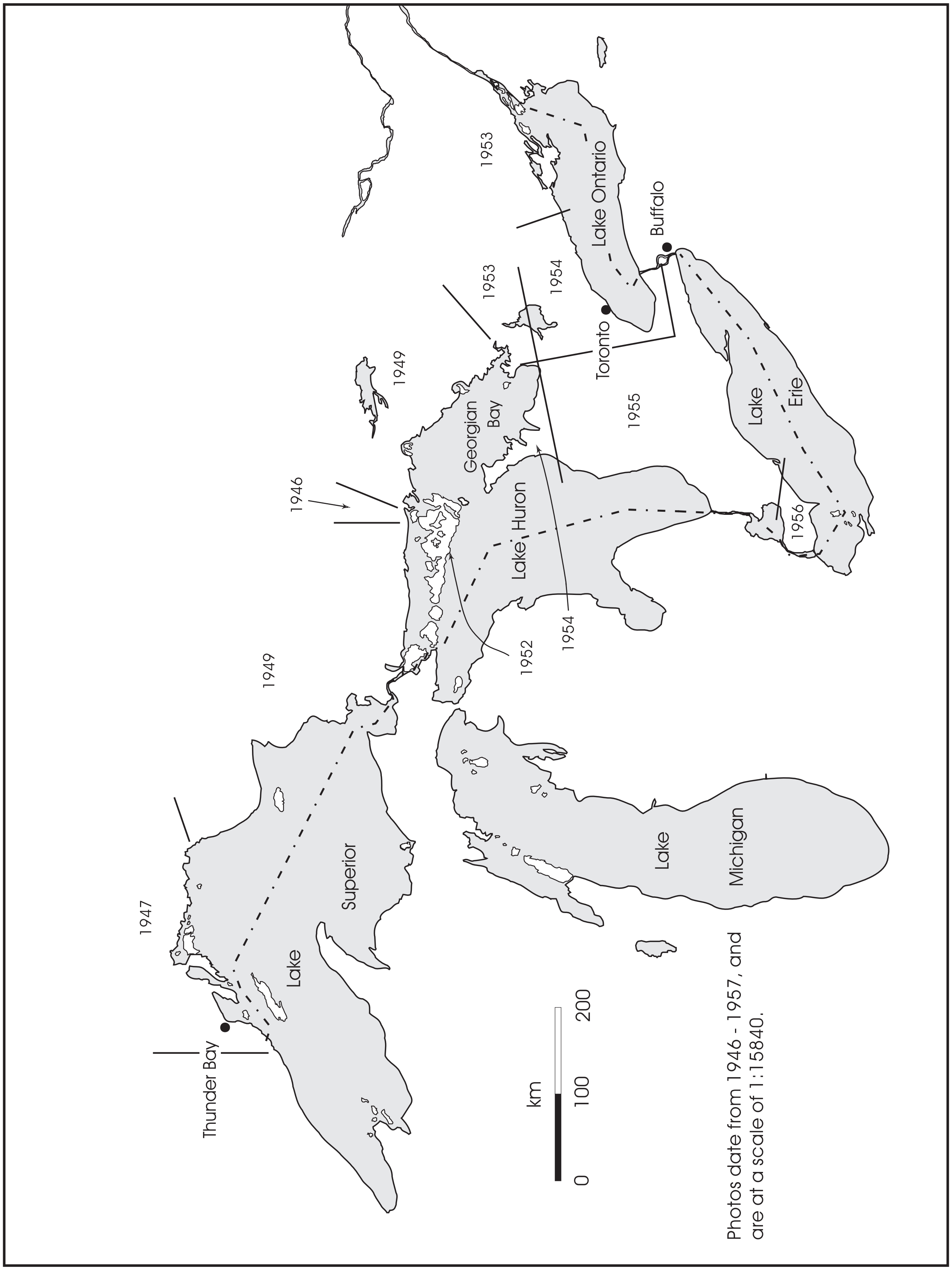


Figure A4.3.24: FRI Photo Coverage 1958-1966

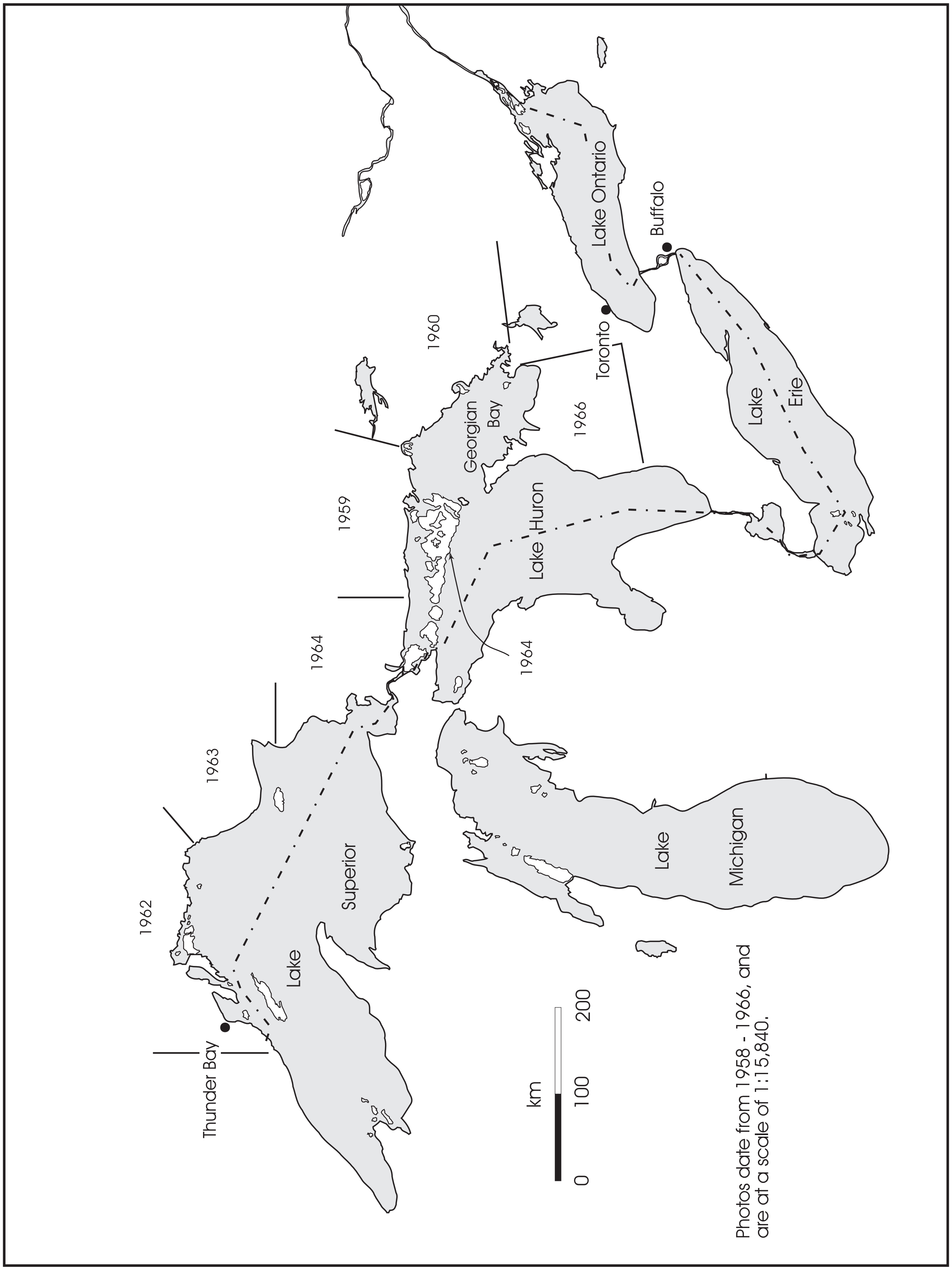


Figure A4.3.25: FRI Photo Coverage 1966-1977

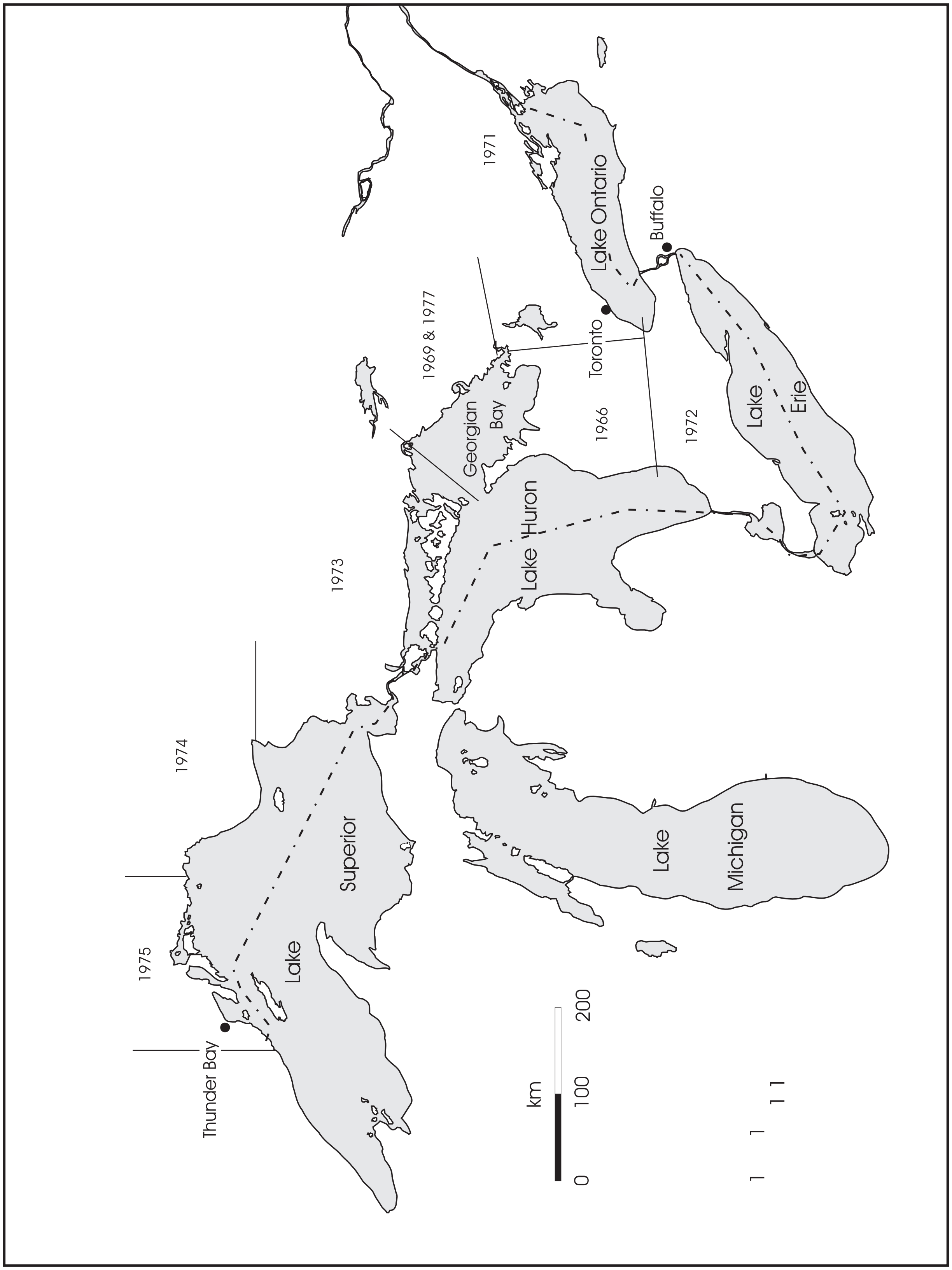


Figure A4.3.26: FRI Photo Coverage 1978-1989

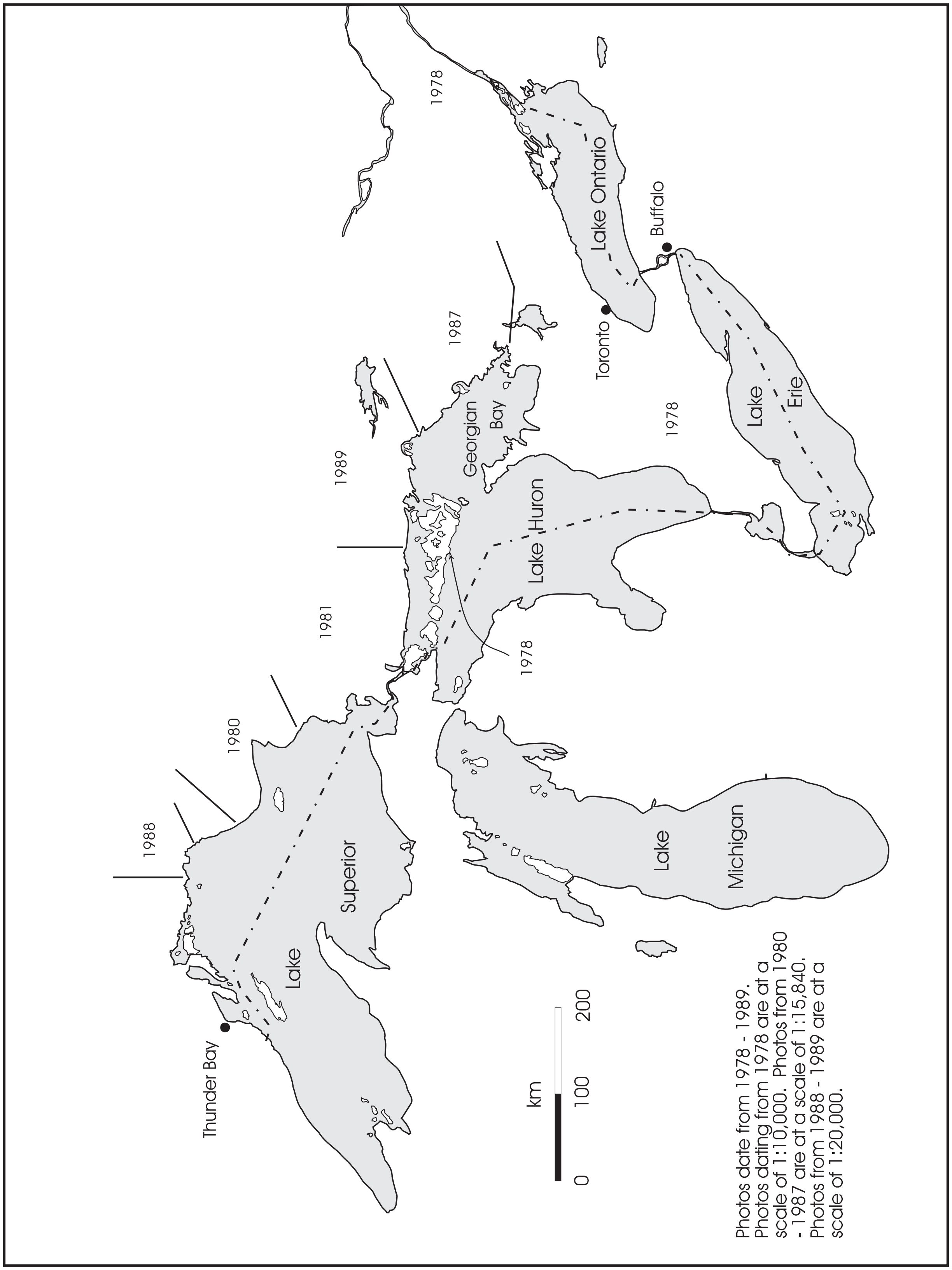


Figure A4.3.27: FRI Photo Coverage 1990-1991

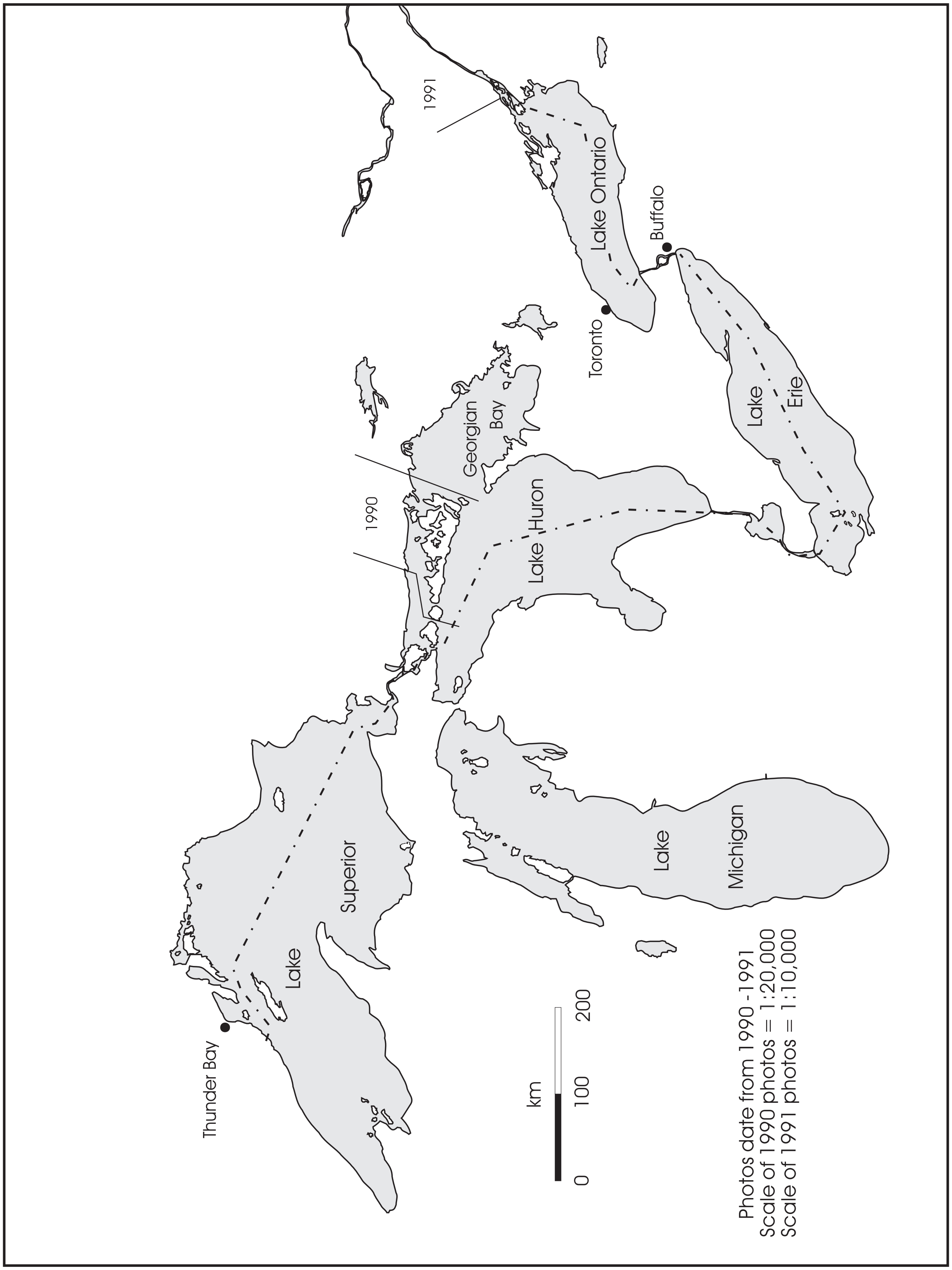


Figure A4.3.28: OBM Photo Coverage 1973-1988

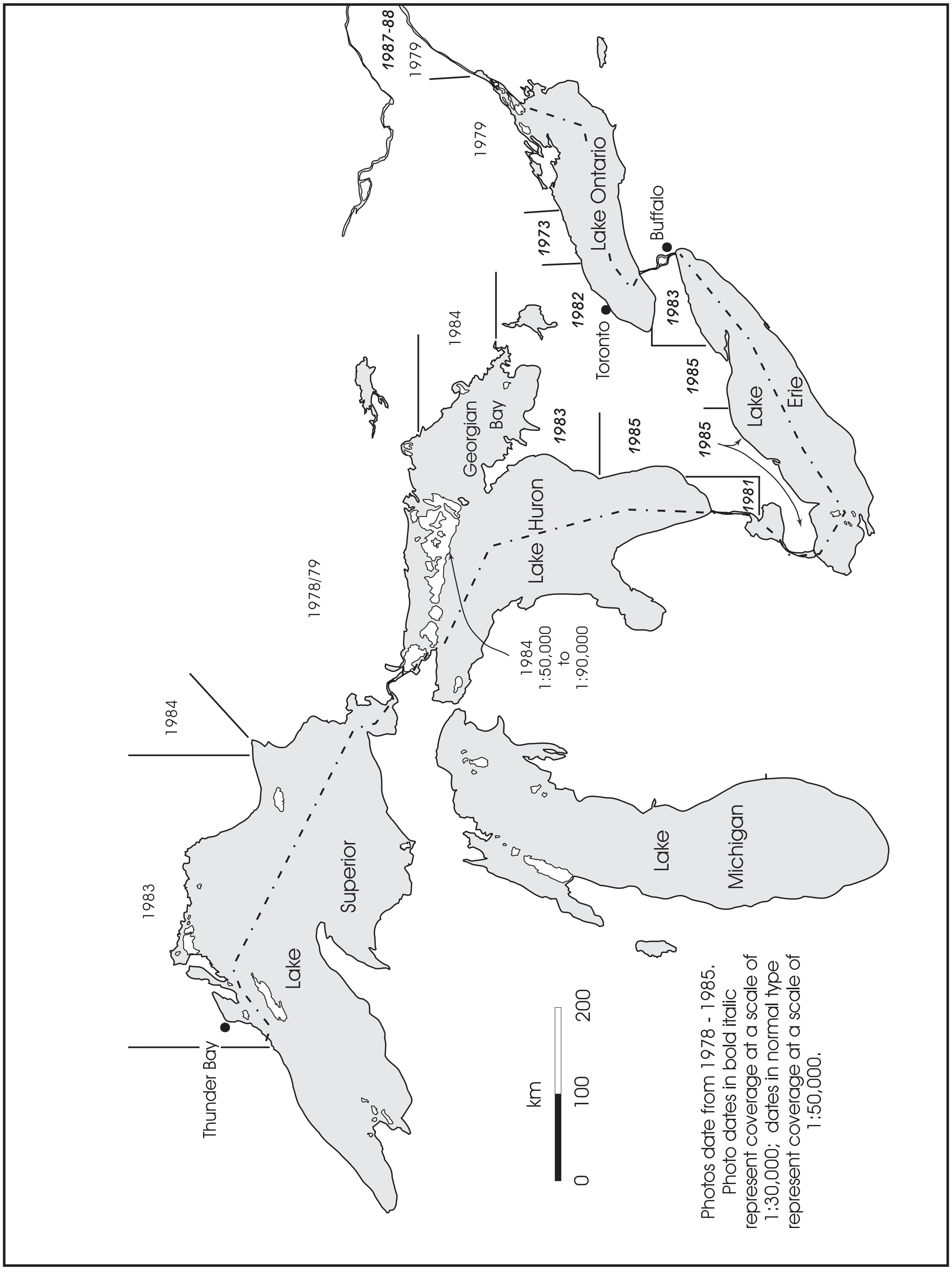
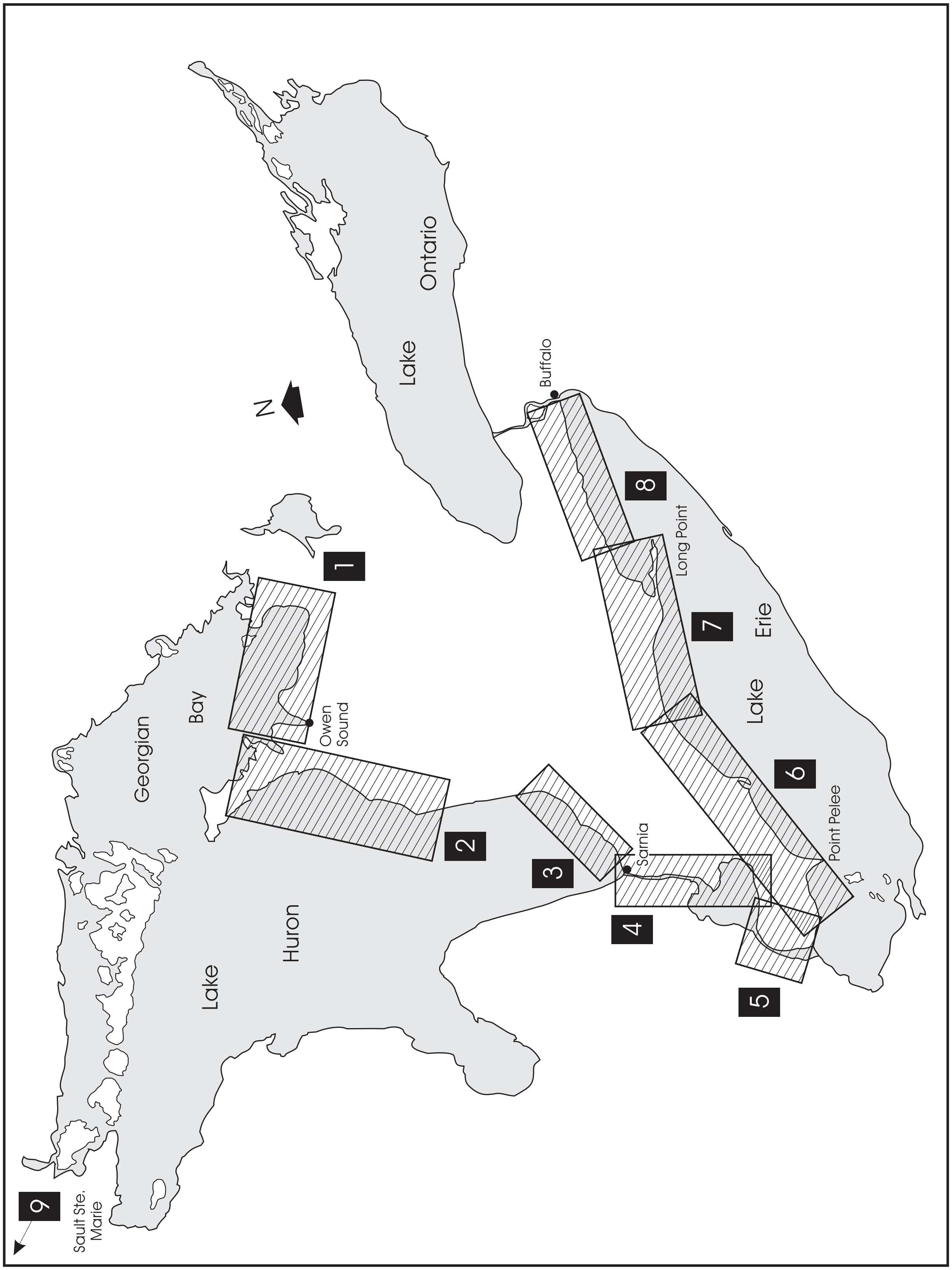


Figure A4.3.29: Shoreline Coverage 1985



ii) Aerial Photograph Products

Numerous aerial photograph products are available through the Information Centre. Table A4.3.5 lists these products. The prices quoted are accurate as of October, 1992 and do not include tax and handling charges.

The Information Centre also distributes, free of charge, flight index maps, which can be used to reference flight lines and approximate photo centres for any area of the province that has been photographed.

Table A4.3.5
Aerial Photo Series Available from the Ministry of Natural Resources

Project	Scale	Area/ Photo	General Location	Year
Forest Resources Inventory (FRI) (flown in the summer)	1:10,000	2.3 km x 2.3 km	Southern Ontario	1978
	1:15,840	3.6 km x 3.6 km	various parts of the province	1961 to 1987*
	1:20,000	4.6 km x 4.6 km	various parts of Northern Ontario (below the tree line)	1988 to 1990*
Ontario Base Mapping (OBM) (flown in spring)	1:30,000	6.9 km x 6.9 km	most of Southern Ontario	1979 to 1988*
	1:50,000	11.5 km x 11.5 km	Northern Ontario Brighton-Brockville	1979
	varies 1:50,000 to 1:90,000	11.5 km x 11.5 km to 20.7 km x 20.7 km	Manitoulin	1984
	1:100,000	23 km x 23 km	Sault Ste-Marie area (parts of: St. Joseph Island, Lake Nipissing, Manitoulin, Georgian Bay, North Channel, Lake Superior)	1978 - 1979
Shoreline Photography (flown in July)	1:8,000	1.8 km x 1.8 km	parts of: Lake Erie, Lake Huron, Georgian Bay, Detroit River, Lake St. Clair, Lake George, and Little Lake George	1985

** Only the most recent photography for any given area is available for viewing at the Public Information Centre. However, negatives for earlier photography mentioned here are accessible for print production.

iii) Enlargements

The Information Centre will make enlargements at pre-determined increments that range from 2.0 to 13.2 times the original scale of the photograph. The specific enlargement increments offered, as well as the resultant scales and charges are listed in Table A4.3.6. Enlargements of increments other than those listed cannot be performed by the Information Centre.

Table A4.3.6
Aerial Photo Products Available from the Ministry of Natural Resources

PRODUCT	SIZE	DESCRIPTION	PRICE
Contact Print	9"x 9"	A print processed from the original negative onto high quality resin matte paper.	$9.78
Quick Print	9"x 9"	A print produced on high quality resin-coated paper from a contact print (a "photo of a photo"). The quality is not as that of a contact print, but they are processed "while you wait" (maximum of ten per day).	$9.78
Diapositive	9"x 9"	A positive transparency of the original negative. The ink may be ordered on the front or the back of the transparency.	$9.78
Air Photo Mosaic	40"x 28"	A composite of many air photos cut and joined together. The mosaics are from 1954 and 1978 photography (scale, 1:10,000) and cover some parts of Southern Ontario. Note that the composites exist already; you cannot choose how the photos are grouped.	starting from $57.50

Note that 2x to 4x are "complete enlargements", in that the entire original negative is enlarged to the chosen size. However, 5x to 13.2x are "partial enlargements", in that only a certain portion of the photo can be enlarged to fit onto 40"x 40" photo paper which is the maximum size of photo paper carried by the Information Centre. The size of the portion varies according to the size of the enlargement.

iv) Ordering of Photos

Ontario government ministries or agencies requiring aerial photographs should contact the Air Photos Section of the Natural Resources Information Centre.

Orders should be made in the same manner as required by the National Air Photo Library in Ottawa (see Part 2, Section "AA"). Orders can be made by mail, fax or in person and must be pre-paid. Allow three weeks for delivery of contact prints and diapositives ($2.50 handling charge; 1997 price) and six weeks for enlargements ($2.50 handling charge; 1997 price).

Ontario Ministry Natural Resources Information Centre
300 Water Street, 1st Floor
P.O. Box 7000,
Peterborough, Ontario
K9J 8M5

TEL: (416) 314-2000 or (705) 755-2000
FAX: (705) 755-1677

d) Other Provincial Ministries

Most of the aerial photography used by the Ontario Government is produced and maintained by the Ministry of Natural Resources (MNR). Consequently, aerial photography requirements that cannot be met by the MNR are not likely to be met by another provincial ministry.

It is recommended that an investigation of Ontario Government aerial photography sources begin with the Ontario Ministry of Natural Resources' Information Centre, Air Photos Section (416) 314-2000 or (705) 755-2000 .

e) Ontario Hydro

As with provincial ministries, much of the aerial photography used by Ontario Hydro is acquired from the Ministry of Natural Resources. Ontario Hydro also produces its own aerial photography, but is not equipped to publicly distribute this information. As a result, it is recommended that other sources of aerial photography are investigated prior to approaching Ontario Hydro.

A4.3.5 References

Anders, F.J. and Byrnes, M.R. 1991. Accuracy of Shoreline Change Rates as Determined from Maps and Aerial Photographs. Shore and Beach Vol. 59, No. 1 pp.17-26.

Clow, B. and Leatherman, S.P., 1984. Metric Mapping: An Automated Technique of Shoreline Mapping. Proceedings of American Society of Photogrammetry, pp 309-318.

Crowell, M., Leatherman, S.P. and Buckley, M.K., 1991. Historical Shoreline Change: Error Analysis and Mapping Accuracy. Journal of Coastal Research Vol. 7, No. 3, pp.839-852.

Ellis, M.Y., editor, 1978. Coastal Mapping Handbook. U.S. Department of the Interior, Geological Survey; U.S. Department of Commerce, National Ocean Survey; U.S. Government Printing Office, Washington, D.C. 199p.

Lattman and Ray, 1965. Aerial Photographs in Field Geology. New York: Holt, Rinehart and Winston, 221p.

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Lillesand, T.M. and Keifer, R.W., 1979. Remote Sensing and Image Interpretation. New York: Wiley, 612p.

Stafford, D.B., 1971. An aerial photographic technique for beach erosion surveys in North Carolina. CERC Technical Memorial No. 36, 115p.

TECHNICAL GUIDE FOR
GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

APPENDIX A4.4

METHODS TO CREATE HISTORIC-RECENT

SHORELINE POSITION MAPS

METHODS TO CREATE HISTORIC-RECENT SHORELINE POSITION MAPS

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A4.4 METHODS TO CREATE HISTORIC-RECENT SHORELINE POSITION MAPS

The purpose of Appendix A4.4 is to outline the methods to create historic-recent shoreline position maps for the purpose of determining the average annual recession rate(s) for a particular stretch of shoreline. Discussion of these methods will be provided through the following four tasks:

- identification of the relevant shoreline data required to create a historic-recent shoreline position map;
- evaluation of the availability of pertinent historic-recent information sources and the issues associated with using map and aerial photography in creating historic-recent shoreline position maps;
- recommended procedures to create a historic-recent shoreline position map; and
- development of a step-by-step procedure to determine the average annual recession rate from a historic-recent shoreline position map for natural shoreline and/or altered shoreline**.**

A4.4.1 Identification of Relevant Shoreline Data Required to Create a Historic-Recent Shoreline Position Map

A number of shoreline data or geomorphic features can be used to compile a composite historic-recent shoreline position map. In compiling a composite shoreline position map for the purpose of obtaining average annual shoreline recession rates, it is advantageous to extract and map the historic and recent positions of the physical and cultural shoreline characteristics presented in Table A4.4.1

Table A4.4.1
Physical and Cultural Shoreline Reference Points

Physical Shoreline Characteristics

- toe of bluff
- top of bluff
- shoreline/waterline
- significant contours
- outline of gullies and watercourse

Cultural Shoreline Characteristics

- planimetric outline of houses (scale dependent)
- roads/railways
- bridges
- protection works
- property boundaries
- land use

a) Physical Shoreline Characteristics

The simple definition of a shoreline is the physical interface between land and water. The position of the shoreline on a beach face, however, depends on the extent of wave uprush and on the elevation of the water at the time of mapping or aerial photography.

As such, the shoreline is not considered to be the most ideal reference point to measure shoreline position changes. In some situations (i.e., beaches), however, the shoreline is the only practical shoreline reference point available.

To improve the accuracy and reliability of the created map information, adjustments must be for the different water elevations that may occur between the historic and recent maps and/or photographs. Should these adjustments not be made an unacceptable amount of error would be introduced into the recession rate measurements. To minimize this error a common datum should be selected to which all measurements are converted. Following this procedure assures an equal basis of comparison for all data sources. Adherence to this requirement can only be accomplished if detailed shoreline contours are known.

Determining the location of beaches, which normally undergo seasonal changes with erosion, particularly during the summer, can also prove challenging. To improve the accuracy and reliability of the created map/aerial photography information it is important that the aerial photography be obtained at the same time of the year to insure that seasonal changes, which can be quite substantial, are not interpreted as permanent changes.

i) Toe of Cliff/Bluff/Bank

The process of determining the toe of the cliff/bluff/bank differs depending on the erosional shore type involved. To assist in this process **Part 4: Erosion Hazard** (Sections 4.4 and 4.5) of this Technical Guide should be consulted.

ii) Top of Cliff/Bluff/Bank

The process of determining the top of the cliff/bluff/bank differs depending on the erosional shore type involved. To assist in this process **Part 4: Erosion Hazard** (Sections 4.4 and 4.5) of this Technical Guide should be consulted.

iii) Outline of Gullies and Watercourses

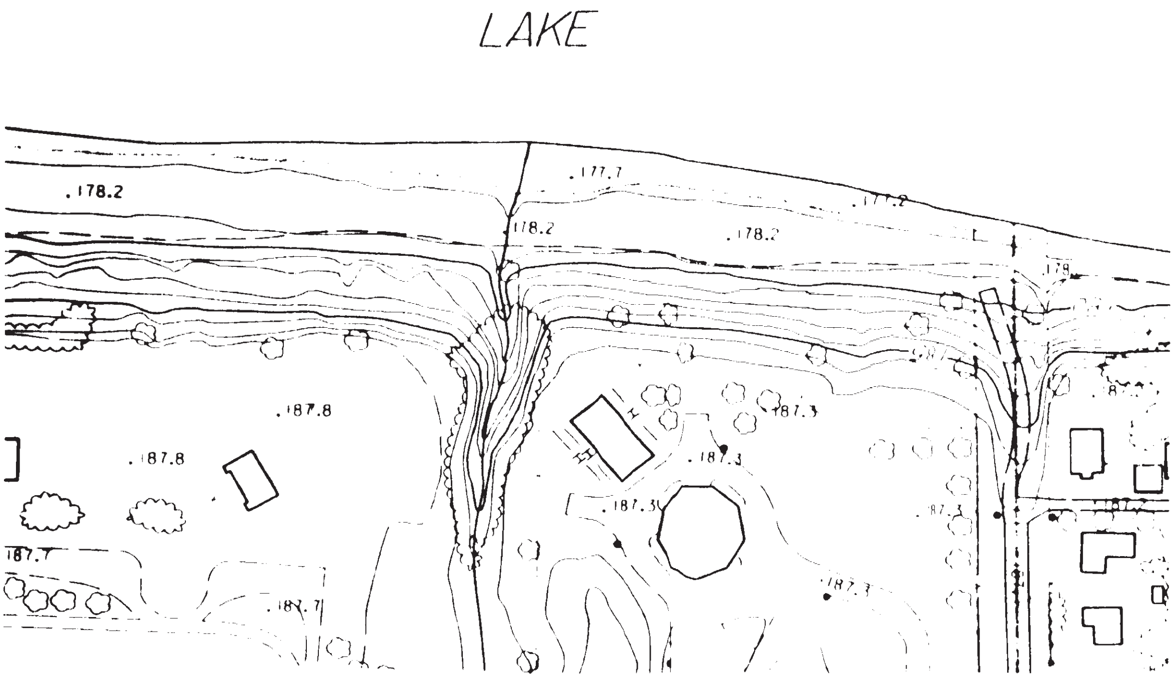
The presence of gullies and watercourses along the shoreline are clearly distinguishable by their marked change in the top of bluff orientation when compared with the toe of the shore bluff (Figure A4.4.1). Gullies and watercourses can have a major influence on local recession rates.

b) Cultural Shoreline Characteristics

i) Significant Contours

Significant contours simply refers to a selected series of map contours which will assist the interpreter in understanding the nature of the topography without creating confusion. For instance, when creating a contour map for a bluff face, a 5 metre contour interval should be plotted rather than a 1 metre contour interval.

Figure A4.4.1: Identification of Gully Forms on FDRP Maps



ii) Houses

Houses are very useful as reference points for scale verification and georeferencing. The planimetric outline of the house roof will be clearly distinguishable on aerial photographs and on topographic mapping with a 1:5,000 or larger base scale. Where 1:10,000 and smaller scale mapping is used the houses will be represented by a point.

iii) Roads/Railways

Roads and railway lines are a second useful reference points for scale verification and georeferencing. On 1:5,000 and larger scale mapping the road will be represented by two lines. Care should be taken to determine if these lines represent the side of the hard or soft shoulder of the road. To improve accuracy in calculations, it is recommended that the centre of these road features be used. On 1:10,000, or smaller scale mapping, roads are presented as single lines.

iv) Bridges

Bridges can often be used as reference points for scale verification and georeferencing.

v) Protection Works

Knowing the location, type, and condition of protection works as well as the length of time it has existed can be very important in determining and interpreting the average annual recession rate at a particular shoreline point location. Protection works can also be very useful in scale verification and georeferencing.

vi) Property Boundaries

Positionally correct property boundaries superimposed on historic-recent composite shoreline position maps can be very important in the accurate delineation and implementation of the *erosion hazard*. As with other cultural features, property boundaries can assist in scale verification and georeferencing.

A4.4.2 Historic-Recent Shoreline Position Data Sources

The first task in creating a historic-recent shoreline position map is to research and evaluate the availability, quality and accuracy of pertinent historic map and aerial photograph coverage information sources.

a) Historic Maps

Historic maps of the *Great Lakes - St. Lawrence River System* shoreline have existed from the time of Ontario's first settlers. The earliest comprehensive set of maps that are useful for determining recession rates date back to the 1930's. Similarly, the earliest aerial photographs of the *Great Lakes - St. Lawrence River System* date back to the late 1920's.

A general summary of available historical maps and aerial photographs covering Ontario's *Great Lakes - St. Lawrence River System* shoreline and a critique of some of the issues that should be addressed when using these information sources are provided in "Appendix A4.3: Historical Maps and Aerial Photographs" of this Technical Guide.

As can be expected, some sources of map information are superior to others depending on their extent of coverage, content and scale. The critical factors to be used in the selection of map sources for the purposes of calculating the average annual recession rate for a particular shoreline location are outlined in Table A4.4.2.

Table A4.4.2
Criteria to be Considered when Selecting Map Sources

CRITERIA TO BE CONSIDERED WHEN SELECTING MAP SOURCES
1. Map scale must be ≤ 1:5,000 2. Topographic contour interval of 0.5 metre - 1.0 metre 3. Toe and top of bluff should be distinguishable 4. Georeferenced (i.e., UTM, latitude and longitude, etc.) 5. Depiction of cultural/social features (i.e., roads, houses, etc.)

Based on these criteria, Tables A4.4.3 and A4.4.4 list the map sources that are recommended and not recommended for the purposes of measuring shoreline change. Those map sources identified in Table A4.4.4 as "not recommended" have been identified as inappropriate for the purposes of measuring shoreline change for two general reasons:

- they do not satisfy some or all of the criteria specified in Table A4.4.2; and
- they are difficult to locate or acquire.

Table A4.4.3
Recommended Sources for Maps and Aerial Photographs

SOURCE	SCALE
FDRP	1:2,000
OLS	1:4,800
Large Scale OBMs	1:2,000
Aerial Photos	≤ 1:20,000

Table A4.4.4
Sources Not Recommended for Maps and Aerial Photographs

SOURCE	SCALE	REASONING
Medium Scale OBMs	1:10,000; 1:20,000	inappropriate scale
Property Assessment Maps	1:100 - 1:50,000	inaccurate shoreline
OMAF Mapping	1:50,000	inappropriate scale
Ontario Hydro Maps/Photos	---	inaccessible
NTS Maps	1:25,000; 1:50,000	inappropriate scale
CHS Mapping	1:1,200 - 1:100,000	no topographic contours
Aerial Photos	> 1:20,000	inappropriate scale

b) Aerial Photographs

Aerial photographs are recommended database sources for the compilation of historic-recent shoreline position maps. Aerial photographs, however, are not geographically positioned, and as such, distortion corrections must be made prior to and/or concurrent with the compilation process. Completing the distortion corrections will ensure that shoreline positions compiled from corrected aerial photographs can be compared to those compiled from planimetric maps or other corrected aerial photographs.

Compiling shoreline position information from aerial photographs is more complicated than obtaining information from maps. The primary reasoning for this difference in process complexity is that aerial photographs do not contain defined control points such as latitude-longitude tick marks or triangulation stations. This can be overcome, however, through the use of a type of control point referred to as a secondary control point. The secondary control point can usually be obtained by matching features on aerial photographs (e.g., corners of buildings, ends of jetties, and road intersections) with their mapped counterparts.

Most physical and cultural features on an aerial photograph occupy positions other than their true relative map positions. A variety of distortions intrinsic to aerial photographs must be eliminated or minimized to reduce measurement errors to an acceptable level. These include:

- radial distortion due to topographic relief as represented on a two-dimensional photograph;
- tilt and pitch of the aircraft at the time of exposure; and
- scale variations caused by changes in altitude along a flight line.

Photographic distortions are a particular problem when older air photos are used. With improved camera optics, concerns related to photographic distortions have not been considered as major considerations or problems after the mid-1940's.

A second concern involves the use of contact prints instead of negatives to annotate shoreline position. In specific, the use of contact prints, rather that negatives, have been shown to affect mapping accuracy due to shrinkage and stretching of old paper prints and ultimately, the distortion of the original base information during printing.

Current practices of using stable materials for making standard prints, as well as improved photographic processing, have significantly reduced the impact of this problem.

For additional information and a more detailed discussion on issues associated with using aerial photographs, Appendix A4.3: Historic Maps and Aerial Photographs of this Technical Guide should be consulted.

When using aerial photographs, for the purposes of identifying and measuring shoreline change, aerial photograph sources at a 1:20,000 or larger scale are recommended. To improve the accuracy of measurement obtained from aerial photographs, enlargements of the photographs to a scale equivalent to 1:5,000 is recommended.

A4.4.3 Procedures to Create Historic-Recent Shoreline Position Maps

Calculations of recession rates should be based on long-term histories of shore change for one primary reason, the toe and top of cliff/bluff/bank recession rates tend to be highly variable in the short term due to the complex processes involved with bluff erosion (described in Section A4.4.1).

Recognizing that this measurement is highly dependent on the time of the measurement, one should not:

- compile historic-recent shoreline position maps spanning short periods of time;
- take sequential measurements during undisturbed periods; or
- take measurements during catastrophic periods of bluff erosion.

If repetitive measurements are to be used to determine the average annual recession rate, the measurements should be taken at the same period in the erosion cycle when the bluff has generally the same topographic form. These concerns are minimized if measurements are made using historic and recent information that is separated by long periods (i.e., decades) of time.

Proper selection of the time period separating the historic and recent information to be used in the creation of a historic-recent shoreline position map has a direct influence on the quality and reliability of the resultant recession rate calculations. Selecting the maximum span of years between the different shoreline position data will maximize the measurable amount of shoreline change. This in turn will minimize the effect of measurement error and increase the reliability of the measured recession rate. Conversely, the error will be greater and reliability lower where either the data sources cover small spans in time and/or the shoreline change between the historic and recent data is small and difficult to measure. For these reasons, the recommended span of time between historic and recent data sources, for the purposes of measuring and determining average annual recession rates, is a minimum of 35 years.

There are three methods that can be used to create a historic-recent shoreline position map including:

- Overlay of historic mapping on recent topographic mapping;
- Overlay of historic photographs on recent aerial photographs; and
- Overlay of historic mapping on recent aerial photographs or vice versa.

In all cases it is recommended that a historic-recent shoreline position map be generated that uses the most recent information as the base with the historic information superimposed over the base information. The final composite map should be produced on a stable base mylar to ensure longevity and to remedy concerns normally associated with the use of conventional paper maps (i.e., shrinkage). For ease of interpretation and future updating, it is further recommended that all plotted lines be dated and that symbols be used to distinguish between the plotted lines.

a) Method 1: Overlaying Historic Mapping on Recent Topographic Mapping

Creating a historic-recent shoreline position map using only maps and charts is a fairly straightforward process of overlaying similar scaled historic information onto the recent topographic base information, however, datum changes must be taken into account.

In general, the creation of the composite map involves enlarging or reducing all of the maps and charts to a common scale, projection, and co-ordinate system using common control points as references. Once completed, a composite historic-recent shoreline position map will delineate and differentiate between the historic and recent shoreline, and toe and top of cliff/bluff/bank positions, as well as outline any landside drainage features and any important cultural features. From this composite of overlain historic and recent shoreline information, changes in shoreline position can be measured and the average annual recession rate determined.

The enlargement or reduction and subsequent overlaying of historic and recent shoreline information can be accomplished in a variety of ways. Numerous mapping instruments (i.e., Map-O-Graph, Zoom Transfer Scope) and several types of projection light-tables can make this an easy task. For a more precise transfer and measurement of shore change, one alternative is to digitize the map data using electronic digitizers and, without plotting a composite map, a variety of software packages can be used to adjust the data to a common map scale. These data sources can then be used for calculating temporal and spatial rates of shoreline change and generating a composite map, if desired.

For the purposes of further clarification on the use of maps Appendix A4.3: Historical Maps and Aerial Photographs should be consulted.

b) Method 2: Historic Aerial Photographs on Recent Aerial Photographs

Using aerial photographs to generate a historic-recent shoreline position spatial database for the purposes of determining shoreline recession rates is significantly more involved than using only maps (i.e., as outlined in Method 1 above). First, only the centre portion of the aerial photographs must be used to reduce the impact of tilt distortion and secondly, variations in photography scale must be carefully taken into consideration.

Should the technique used to evaluate the magnitude of shoreline change involve the use of aerial photographs, one must ensure that the selected technique includes rectifying the aerial photograph or data derived from the aerial photograph prior to any measurement being taken.

In recent years, a variety of manual techniques have been developed. Most photogrammetric companies and government agencies can produce rectified aerial photographs, referred to as orthophotos, which in essence have removed the tilt distortions and scale variations through the use of large stereoscopic plotters. This is achieved by having the equipment place the aerial photograph back into its tilted position and then projecting the image downward at the proper scale. The projected image, having had all tilt and scale variations removed, is then reproduced as a rectified vertical aerial photograph that can be treated as a regular map.

Smaller instruments, such as the Vertical Sketchmaster, which work on the same basic principle as the large stereoscopic plotters do remove tilt and scale variations, however, they are not as accurate. Projecting instruments, such as light tables and Map-O-Graph, can remove scale variations between aerial photographs, however, they cannot correct for tilt distortion. Similarly, the Zoom Transfer Scope can correct for scale variations and partially compensates for tilt by shrinking or stretching an image in one direction, however, since tilt causes differential scale distortion across the photograph, shrinking or stretching in one direction is not sufficient to remove all tilt effects. As a general rule, when using any smaller instruments, aligning carefully selected control points and working in small areas of the aerial photograph tends to produce the most satisfactory results.

Over the past decade, a variety of automated techniques have been developed to produce composite shoreline maps from aerial photographs. Several computer software packages are now available that allow a small mapping laboratory to generate composite shoreline maps from original map and aerial photograph data sources. For aerial photographs, most of these techniques use various algorithms, including a "least squares adjustment" to rectify the data to a scaled, non-tilted condition. This procedure involves digitizing control point information on an aerial photograph and comparing the location of each point to its known location in a geographic coordinate system. The least squares procedure then uses a calculated correction factor to adjust a group of control points to their "proper" position. As a result, the correction is not specific to tilt or scale variations, but simply corrects the data for all inherent errors simultaneously. The resulting correction is a "best fit" position for all control points on an aerial photograph. A general rule in the use of this technique is that the greater the number of control points used the greater and more reliable the resultant "best fit" position. After a correction factor has been calculated, it is then applied to all shoreline data points digitized from the aerial photograph.

When using aerial photographs, in the absence of qualified in-house personnel or the absence of the required technology, it is recommended that a qualified mapping firm possessing the required skills and technology be retained to perform the creation of the historic-recent shoreline position map.

For the purposes of further clarification on the use of aerial photographs, Appendix A4.3: Historical Maps and Aerial Photographs of this Technical Guide should be consulted.

c) Method 3: Historic Mapping on Recent Aerial Photographs

This method is simply an integration of the two previous methods. All concerns associated with the use of maps and aerial photographs have to be considered. Again it is recommended that when using aerial photographs in the absence of qualified in-house personnel or the required technology, a mapping firm possessing the required skills and technology be retained to perform the creation of the historic-recent shoreline position database.

d) Historic-Recent Shoreline Position Map Accuracy and Precision Considerations

Regardless of the method used to compile the historic-recent shoreline position map, a statement evaluating the accuracy, precision and reliability of the information, including an assessment of the effect of cumulative errors, should be required to accompany the final composite mapped information.

The ultimate test of map accuracy is to compare the location of points on the map with their actual field location. For the purposes of testing map accuracy, the most straightforward method is to select several stable, well defined points, such as road intersections, in the field and to determine their actual location by precise surveying or special photogrammetric techniques. The mapped positions are then checked against the surveyed positions determined in the field.

Electronic digitizers and computers, using a variety of software, have greatly facilitated the creation of historic-recent shoreline position maps from combinations of historical maps and aerial photographs.

Regardless of which technique is selected to produce the composite shoreline change map and to then calculate shoreline change rates, the various sources and implications of data or map error must be evaluated to determine the overall credibility and reliability of the final product.

For instance, the smallest unit that can be measured using an electronic digitizer, is 0.025 millimetres. This produces a potential ground measurement error of 0.125 metres on a 1:5,000 scale map. Recognizing that to determine rates of change requires that two position measurements be taken, the combined potential ground measurement error could be as much as 0.25 metres.

In addition, the process of matching projected aerial photographs to the base maps may produce a source of data or map error which is difficult to assess quantitatively. Although much depends on the skill of the photo-interpreter, this type of error is no greater than that involved in determining the scale of a photograph by comparing measurements between points on the aerial photograph and the same points on a map. In either case, the error can be substantial if there are few stable man-made or natural features available for making scale measurements. To further complicate measurement accuracy, it is difficult to match ground features on aerial photographs and maps to any closer than a 10 metres ground distance.

As such, the combined potential measurement error, when using two aerial photographs having a scale of 1:5000, can be as much as 12.5 metres. The 12.5 metre potential error represents the sum of three separate errors (i.e., each with 0.5 probabilities), so the combined probability of such an error is 0.125. If the error is normally distributed about zero error then the standard deviation should be about 6.3 metres. With quality imagery and use of an electronic digitizer, the error of measurement is within ±6.3 m.

In summary, although the total measurement error is potentially as much as 12.5 metres, the potential error is usually within 6.3 metres. When annual rates of change are calculated the potential error must be normalized for time, (i.e., a 5 metre error with 10 years between photos converts to an error of 0.5 m/yr in terms of defining average annual recession rates). Measurements of erosion rates to a resolution as low as ±0.05 m/yr are readily feasible if the time interval between photos is large enough and the shoreline position changes from aerial photograph to aerial photograph are as large as they are in most open coast exposures.

A4.4.4 Procedure for Determining the Average Annual Recession Rate from the Historic-Recent Shoreline Position Map

Once a historic-recent shoreline position map has been created where shoreline positions have been recorded accurately, measurements of changes in toe and top positions can be made directly from the map or calculated directly from digitized data. The manual approach outlined in a step-by-step process below involves establishing transects perpendicular to the shoreline at the desired along-the-shoreline interval and measuring top and toe of bluff distances between shorelines along each transect. The measured distance is then divided by the time interval between shorelines to determine rate of change at that shoreline point location.

For projects covering large areas that require a high density of calculated shoreline position changes, automated techniques can save significant amounts of time. The automated procedure is similar to the manual technique. Transects are established perpendicular to an arbitrary baseline that is parallel to the current shoreline, and the intersection of these transects with each shoreline represents a data point. Baseline length depends on general shoreline orientation and natural breaks in shoreline continuity.

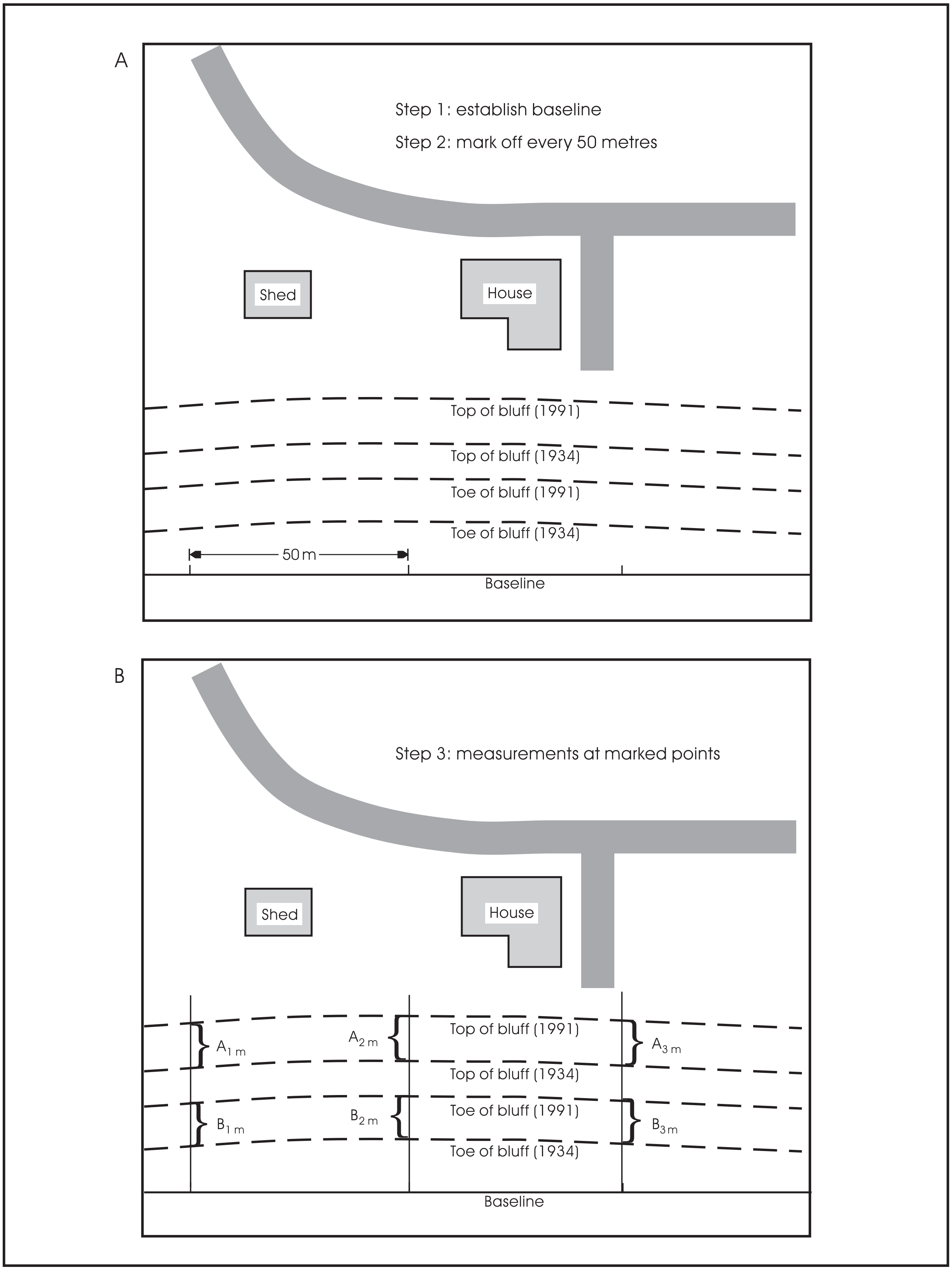
a) Step-by-Step Procedure to Determine Average Annual Recession Rates

- **Step 1** Establish a baseline parallel to the shoreline (Figure A4.4.2a). The baseline direction will change with changes in shoreline orientation.
- **Step 2** Mark off every 50 metres along the baseline and mark off the locations where shoreline orientation changes (Figure A4.4.2a).
- **Step 3** Take measurements at every "marked" point along the baseline perpendicular to baseline/shoreline. Document any changes between corresponding historical shoreline positions for toe of cliff/bluff/bank, top of cliff/bluff/bank and shoreline (Figure A4.4.2b).
- **Step 4** Divide the measured map distances by the number of years between the different historic shoreline positions (e.g., A_1 m divided by 37 years and B_1 m divided by 37 years). Using the composite map scale, convert the average annual historical position change rate to an average annual recession rate.
- **Step 5** Examine the average annual recession rates and look for similar recession rates for stretches of shoreline. You may wish to smooth the data using a moving average.
- **Step 6** Compare the average annual recession rates with the historical recession rates documented in previous historical recession rate studies.
- **Step 7** Decide on an average annual recession rate for each of the measurement points.

When measuring and calculating average annual recession rates from various sources of information there are a number of factors which require evaluation including:

- accuracy consideration when determining average annual recession rates;
- the need to take measurements at the toe and top of the cliff/bluff/bank;
- what actions should be taken when toe and top of the cliff/bluff/bank recession rates vary;
- what actions should be taken when only the toe or top of the cliff/bluff/bank can be measured; and
- identifying any other potential factors complicating the determination of the average annual recession rate (i.e., landside drainage (gullies), shoreline protection works, and fill).

Figure A4.4.2: Procedure to Determine Average Annual Recession Rate



TECHNICAL GUIDE FOR GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

APPENDIX A4.5

METHODS TO CREATE HISTORIC-RECENT

DIGITAL SHORELINE POSITION MAPS

METHODS TO CREATE HISTORIC-RECENT DIGITAL SHORELINE POSITION MAPS

TABLE OF CONTENTS

A4.5 METHODS TO CREATE HISTORIC-RECENT DIGITAL SHORELINE POSITION MAPS

The intent of Appendix A4.5 is to provide an overview of the methods to create historic-recent digital shoreline position maps using:

- historic mapping on recent topographic mapping; and
- historic aerial photographs on recent aerial photographs approaches.

Discussion of each of these approaches will include step-by-step procedures to be followed in the creation of the historic-recent shoreline position maps.

A4.5.1 Historic Mapping on Recent Topographic Mapping

Generally, the recent mapping should pose little difficulty for the user in the way of extracting the desired physical and cultural features. Ideally, where the recent mapping exists as digital files, the information can be easily obtained and then compared to historic mapping which has been converted to a similar scale, projection and coordinate system.

The following are the steps required to obtain the required information in the format necessary to determine the average annual recession rate at points along the shoreline:

- **Step 1** Determine the scale, projection, and coordinate system, if any, of the historic and recent mapping intended to be compared. The recent mapping should contain all of the pertinent information and it is probably most desirable to construct the historic mapping so that it can be compared using the parameters found on the recent mapping. Most of the recent mapping will be in Universal Transverse Mercator coordinates and projected into the appropriate UTM zone based on their geographic position and will be mapped at a large scale.
- **Step 2** Begin the compilation of required information using the recent mapping. If available in digital format, data will already exist in a known geocoordinate system and projection and the original scale of the mapping will be evident. Using pre-assigned nomenclature assigned by the mapping contractor, different physical and cultural features can be extracted using appropriate software (e.g., GIS, AutoCad). If recent mapping exists only in conventional hard copy format (i.e., paper, mylar), it will require the conversion of needed information into digital format.
- **Step 3** Draw on the position of the toe and top of the cliff/bluff/bank based on contours or if applicable, choose the appropriate contour line to represent this data. If gullies are present on the map in question, determine outline of gully based on contours.
- **Step 4** Determine the georeferenced control points on the mapping. Most recent mapping will contain a grid pattern of geocoordinates with appropriate values indicated. A minimum of six (6) control points should be selected with one located in each corner of the map and the remaining two near the map centre in order to create a good distribution of controls to minimize data conversion errors when data is transformed to the desired projection.
- **Step 5** Devise a classification or coding convention for different features (i.e., shoreline=class 1, toe of bluff=class 2, etc.) or utilize the feature codes used for the digital FDRP maps so that different features are distinguishable when doing comparisons using mapping software or on hardcopy plots of the final historic-recent shoreline position map.

- **Step 6** Affix the hardcopy map, preferably mylar to minimize shrinkage problems, securely to the digitizing table and name the file appropriately in a manner which suggests what it contains (e.g., year of data and area name). Write this name on hardcopy map for later identification.

- **Step 7** Perform the appropriate set-up routines for the digitizing software package being used. This may include, but is not limited to, providing map descriptions, setting up working field/area, and entering control point coordinates.

- **Step 8** Begin conversion of the required physical and cultural features found on map to digital format. Digitize all appropriate features and assign pre-determined code to each feature. Each feature is to be positioned according to the geocoordinates entered for control points. Most of the required features should already be present on the recent mapping where large scale FDRP or OBM mapping is used. Cultural features such as property boundaries and land use, although useful for later interpretation, will be difficult to extract from recent topographic mapping unless they were specifically mapped.

- **Step 9** Upon completion of the digital capture process of required features on the recent mapping, ensure that the digital file is saved in an appropriate format.

- **Step 10** Historic mapping will probably present a more difficult conversion process than for the recent mapping given that there may be different projections, if any, used on the historic mapping. Many of the historic maps may not have a clearly discernible projection and there may not be any geocoordinates in the form of a grid or spot coordinates found on the map. If georeferences are indicated and the projection is known, then this information can be used to convert the required physical and cultural data into digital format and then it can be compared to the recent mapping.

  If no geocoordinates or projections appear on the map, the mapper will have to locate common control points which exist on both the historic and recent mapping. Features such as road intersections, corners of houses, utility poles and other physical or cultural features which can be precisely located on both maps should be selected. The actual geocoordinate of the control point will have to be determined from the georeferenced recent map and the actual coordinate applied to the same control point on the historic map. This process will cause the historic map data to be transformed to a "best fit" of the recent mapping when converted to the same projection and scale based on the distribution and accuracy of the placement of the control points. Obviously, the more reliable the placement of the control point and the greater the density of points, the more "accurately" that the data on the historic map will be placed in reference to the recent map.

- **Step 11** Upon the determination and digital entry of the georeferenced control points on the historic mapping, the required data can be collected following steps 6-9. The file should be named appropriately in order to distinguish it from other files and a consistent nomenclature for the coding of features should be employed.

- **Step 12** Bring the required historic and recent map data together in a composite map of the same scale, projection, etc. and produce a hardcopy plot of the information for determination of the average annual recession rate using the step-by-step methodology described in Appendix A4.4: Methods to Create Historic-Recent Shoreline Position Maps of this Technical Guide.

A4.5.2 Historic Aerial Photographs on Recent Aerial Photographs

The comparison of historic to recent aerial photographs is the least recommended approach to determine the average annual recession rate along the shoreline. Using aerial photographs to find the average annual recession rate can be accomplished by simply transforming the digital features collected on one photograph to the same scale and coordinates as those used on the other photograph through the selection of common ground control points. The preferred approach when using aerial photographs would be where the geographic coordinates for each control point are known enabling the historic and recent aerial photographs to be compared without the use of actual geographic references. To use this approach, however, requires that the common ground control points are identified and a suitable generic reference system is devised.

The use of aerial photographs should pose little difficulty for the user in extracting the desired physical and cultural features except for the determination of any topographic data. Fortunately, the identification of the toe and top of the cliff/bluff/bank is easily made using aerial photographs and is often more precisely located than when using topographic mapping.

The following are the steps to obtain the required information in the format necessary to determine the average annual recession rate as points along the shoreline.

- **Step 1** Determine the scale of the historic and recent aerial photographs and the position of the desired features to be captured relative to the centre of the photographs. The recent photograph should contain all of the pertinent physical and cultural information except for topography as opposed to the historic photograph which may contain fewer cultural features or different features than those found on recent photographs. To alleviate problems with detail and differences in scale, it is strongly recommended that the area of interest on the photographs be enlarged to approximately the same scale for each photograph.

- **Step 2** Choose ground control points that can be referenced on both the historic and recent aerial photographs and are identified on recent mapping. The availability of identifiable ground control points is critical for the historic aerial photographs since fewer features existed or may have been altered or removed by the time of the recent photograph. A minimum of six (6) control points should be selected and they should be distributed across the photograph in order to give a best fit transformation. Unfortunately, the availability of potential ground control points can be lessened depending on the amount of space taken up by the lake in the photograph. Ideally, references will be located in a similar distribution as those suggested for maps, with one located in each corner of the area of interest on the photograph and the remaining two near the photo centre in order to create a good distribution of control points.

  It is preferable if geographic coordinates can be determined for all ground control points so the acquired digital information can be transformed to a common scale and projection for comparison. If no mapping is available at an adequate scale to determine geocoordinates for each control point, references can be constructed given the known scale of the photograph and careful measurement to determine distances between control points. If the same reference values are applied to the control points on the other photograph a digital product can be produced from which comparisons can be made in order to determine changes in shoreline position and quantify these changes.

  Features such as road intersections, corners of houses, utility poles and other physical or cultural features which can be precisely located on both photographs should be selected as ground control points. The actual geocoordinate of the control point will have to be determined from a georeferenced map of an appropriate scale and the actual coordinate applied to the control points on both photographs. This process will cause the digitally extracted physical and cultural data to be transformed to a "best fit" based on the coordinates of the control points. The accuracy of this transformation of the digital data to the same projection and scale is determined by the distribution and accuracy of the placement of the control points. Obviously, the more reliable the placement of the control point and the greater the density of control points the more "accurately" the data will be positioned in relation to the given coordinates of the ground control points.

- **Step 3** Determine the position of the toe and top of the cliff/bluff/bank on the recent aerial photograph. Selection of this information is dependent on the height of the cliff/bluff/bank, if any, and the position of the information on the photograph compared to the other photograph. This may indicate that the toe of the cliff/bluff/bank position cannot be used due to different orientations of photos which can distort the actual horizontal distance between toe and top of bluff as seen from the photograph depending on the camera angle. It is recommended that for greater accuracy and confidence in the final results when using aerial photographs, that only the top of cliff/bluff/bank position should be used as a reference for determining recession rates. Using the top of cliff/bluff/bank will rectify any altitude or perspective distortions since most of the land landward of the bluff is relatively flat around the Great Lakes. Top of cliff/bluff/bank positions are quite evident on aerial photographs as a break in topography unless obscured by vegetation. If gullies are present on the photograph in question, determine the outline of gully based on same criteria as for the top of the cliff/bluff/bank.

· **Step 4** Begin the compilation of required information using the aerial photographs. Devise a classification or coding convention for different features (i.e., shoreline=class 1, toe of bluff=class 2, etc.) so that features are distinguishable when doing comparisons using mapping software or on hardcopy plots of the final historic-recent shoreline position map that will be created from the information acquired from the aerial photographs.

· **Step 5** Affix the enlarged recent aerial photograph securely to digitizing table and name the file appropriately in a manner which suggests what it contains (e.g., year of data and area name). Write this name on the aerial photograph for later identification.

· **Step 6** Perform the appropriate set-up routines for the digitizing software package being used. This may include, but is not limited to, providing map descriptions, setting up the working field/area, and entering control point coordinates.

· **Step 7** Begin the conversion of required physical and cultural features found on the aerial photograph to digital format. Digitize all appropriate features and assign pre-determined codes to each feature. Each feature is to be positioned according to the coordinates entered for the control points. Most of the required features should be present on the recent aerial photograph. Cultural features such as property boundaries and land use, although useful for later interpretation, will be easier to extract from aerial photographs than topographic mapping although exact property boundaries cannot be determined strictly from the aerial photographs.

· **Step 8** Upon completion of the digital capture of required features on the aerial photograph, ensure that the digital file is saved in an appropriate format.

· **Step 9** Begin the extraction of required data from the historic aerial photograph following steps 3-8 provided quality ground control points have been determined. The file should be named appropriately in order to distinguish it from other files and the same nomenclature for the coding of features should be employed.

· **Step 10** Bring the required historic and recent digital aerial photograph data together in a composite map of the same scale, projection, etc. and produce a hardcopy plot of the information for determination of the average annual recession rate using the step-by-step methodology described in Appendix A4.4: Methods to Create Historic-Recent Shoreline Position Maps of this Technical Guide.

TECHNICAL GUIDE FOR
GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

APPENDIX A4.6

METHODOLOGIES TO MONITOR SHORELINE RECESSION

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A4.6 METHODOLOGIES TO MONITOR SHORELINE RECESSION

The purpose of Appendix A4.6 is to provide a description of suggested procedures for measuring shore profiles or cross-sections from ground measurements, which, when done annually, can provide valuable information on the erosion/recession rates and contributing processes at the monitoring sites. The two primary methodologies involve the use of a: 1) field monitoring program; or 2) photogrammetric monitoring program.

A4.6.1 Field Monitoring Program

Of fundamental importance in the use of this technique is the need to re-establish a representative shore profile baseline. This could, for example, extend along a property boundary, across the tableland, down the bluff face, across the beach, and along the lake bottom to some desired distance offshore. This representative shore profile baseline is then measured and surveyed, and a schematic cross-section or profile of the existing land surface is developed. When the exact same location is measured, surveyed and a representative cross-profile is prepared on an annual basis the amount and rate of erosion can be measured linearly and in volumetric terms.

Ideally, the measurements should be done about the same time each year. The month of July or August, is the recommended period for monitoring since the summer months tend to represent a quiescent erosion period and generally provides similar environmental conditions.

In addition to the summer survey some may wish to replicate the measurements after major storm events to assess the catastrophic nature of erosion and/or to obtain an understanding of the magnitude of damage done by various intensities of storms in their region. Monitoring of this type of information will aid in the development and selection of appropriate shoreline management options to address existing shoreline erosion concerns.

As a general rule, it is recommended that measurements be made at locations where erosion is visibly occurring (refer to Part 4: Erosion Hazard, Section 4.2).

Given the variability in the physical characteristics of the *Great Lakes - St. Lawrence River System* shoreline, one should note that there are essentially two types of measurement sites that can exist. The first involves the shore profile, consisting of a bluff feature, where measurements are taken across a portion of tableland (e.g., on top and landward of the edge of the bluff), down the bluff face and continuing along the beach/offshore fronting the bluff. The second general shore form involves beach environments where the beach may be backed by a dune complex. In this latter situation, measurements should begin in the backshore area where little change in shore profile has been observed over time and then extend the measurements lakeward across the beach and into the lake.

Although annual measurements are recommended, economics may limit the frequency and the extent that measurements are taken. Where measurements are taken, the subsequent preparation of topographic surveys from the landside feature should extend lakeward to a depth where an individual is able to wade out into the lake or connecting channel. It is important and recommended that shoreline managers obtain profile measurements of the nearshore zone at least every 5 years to provide sufficient information to understand the processes and potential impacts that nearshore lowering may have on any particular shoreline reach.

There are various survey methods and equipment available for monitoring shoreline erosion. They vary from simple to complex, from hand levels to electronic distance measurement, and can yield similar data results using the same technique. A discussion of various surveying methods is outlined in Appendix A6.1: Methods to Determine Elevations and Horizontal Distances.

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

a) Onshore Measurements and Tasks

- **Step 1** Determine the water level information for the time period in which the surveying will be undertaken.

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

- **Step 3** Set up theodolite or similar equipment (see Appendix A6.1: Methods to Determine Elevations and Horizontal Distances for more information on surveying techniques) on the base profile line near the bluff crest to view backsights and downslope. Starting well enough back from the crest of the bluff/bank to be in an area of little change, place markers on the base profile line at points where major slope changes occur on the tableland, at the top of the bluff/bank, down the bluff/bank slope, at the toe of the bluff/bank and across the beach.

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

- **Step 4** Set up the level or similar equipment and establish the elevation of the level by reading the elevation from the bench mark. Determine the elevations of the marked survey points. A detailed description of determining elevations by levelling is described in Appendix A6.1. For offshore points to waist or shoulder deep water, the rod person must ensure than they position themselves on the base profile line by aligning with the markers. In doing so, care should be taken to pin the measuring chain to a known point on the beach to simultaneously measure this distance with the measurement of the beach/offshore elevation, or by using stadia.

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

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

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

b) Offshore Measurements and Tasks

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

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

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

c) Compilation of the Surveyed Information

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

A4.6.2 Photogrammetric Monitoring Program

A field monitoring program for monitoring erosion is considered to be superior to the implementation of a photogrammetric monitoring program since photogrammetric work does not yield underwater information. Photogrammetric processes can, however, process large amounts of space and time. An additional benefit of photogrammetric monitoring programs is that they provide the linear information in addition to providing volumetric and morphologic data, whereas, field survey measurements yield only linear information.

Limiting the photogrammetric monitoring process to measuring only very major slope changes is adequate provided these detailed measurements are maintained over an entire erosional cycle. Similarly, only measuring the top to toe of the cliff/bluff/bank and the angle or repose may be a reasonable short-cut once cyclical bluff slopes recur. Given that measurements using photogrammetric processes are not time dependent (i.e., the process can be undertaken on an as needed basis with the length of historical record being dependent on the available time frame of the photograph coverage), use of the photogrammetric monitoring process provides some flexibility in the frequency, number, location and span of historical records of shore profiles which can be evaluated in determining shore recession/erosion rates.

To improve measurement accuracy and the overall reliability of resultant erosion rate information, photogrammetric cross-sections should be measured at the same location on two successive sets of aerial photographs. While this method does not yield nearshore erosion rates, it does provide a far more economical method of determining shoreline erosion/recession rates when compared to the field monitoring method.

Similar to the field monitoring method, the first step in establishing a photogrammetric monitoring program is to identify a control or reference point from which the measurement(s) will be made. The second step involves the identification of a base shore profile line or transect from which all photogrammetric measurements will be taken. This line, usually extending from a fixed property line, across the bluff/bank tablelands, down the bluff/bank face, across the beach and to the waterline, should provide a representative profile of the shoreline in the selected area.

Ideally, photogrammetric measurements should be done annually and at about the same time of year. The spring or fall period, when leaf cover is minimal and does not obscure the shoreline and bluff/bank features, is recommended for best results. When photogrammetric measurements are taken at the exact same location, year after year, the amount and rate of erosion can be measured linearly and in volumetric terms.

Care should be taken to ensure that where photogrammetric monitoring programs are established that the work (i.e., measurements and evaluations) is done only by those who are experienced in aerial photo interpretation and who have access to the correct equipment.

When taking measurements from photogrammetric cross-sections, vertical elevations are to be determined along the cross-sections at approximately five metre horizontal intervals for a distance of 60 metres inland from the water's edge and at approximately 20 metre intervals over the next 140 metres inland, or to the 0000 point on the original section, whichever is the lesser of the two measurements. In the event that an eroding bluff face is identifiable for more than 60 metres inland from the water's edge, then a 5 metre horizontal interval is recommended for use inland to the top of the bluff/bank. In addition, vertical elevations are to be determined and recorded at points of significant change in slope (e.g., toe and bluff) and at the 0000 point. All horizontal distances are to be referenced to the 0000 point previously established for the cross-sections and identified on the site plans. On average, the number of vertical elevation points per cross-section over the project should not exceed 24.

The horizontal and vertical data are to be reported in tabular form for each cross-section, and for ease of tabulation and future referencing, a separate page should be used for each cross-section. A hand-drawn site plan map, not to scale, should be included on the page for each new section, with the reference point, shoreline, cross-section line, and other identifiable cultural features shown.

The vertical and horizontal accuracy requirements specified for FDRP mapping in Schedule "C" of the Canada/Ontario Flood Damage Reduction Program Agreement shall apply to the determination of the cross-sections.