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The Postglacial Tilting of Lake Ontario: Erosion and Lake-Level Control

By: Dr. Richard A. Young
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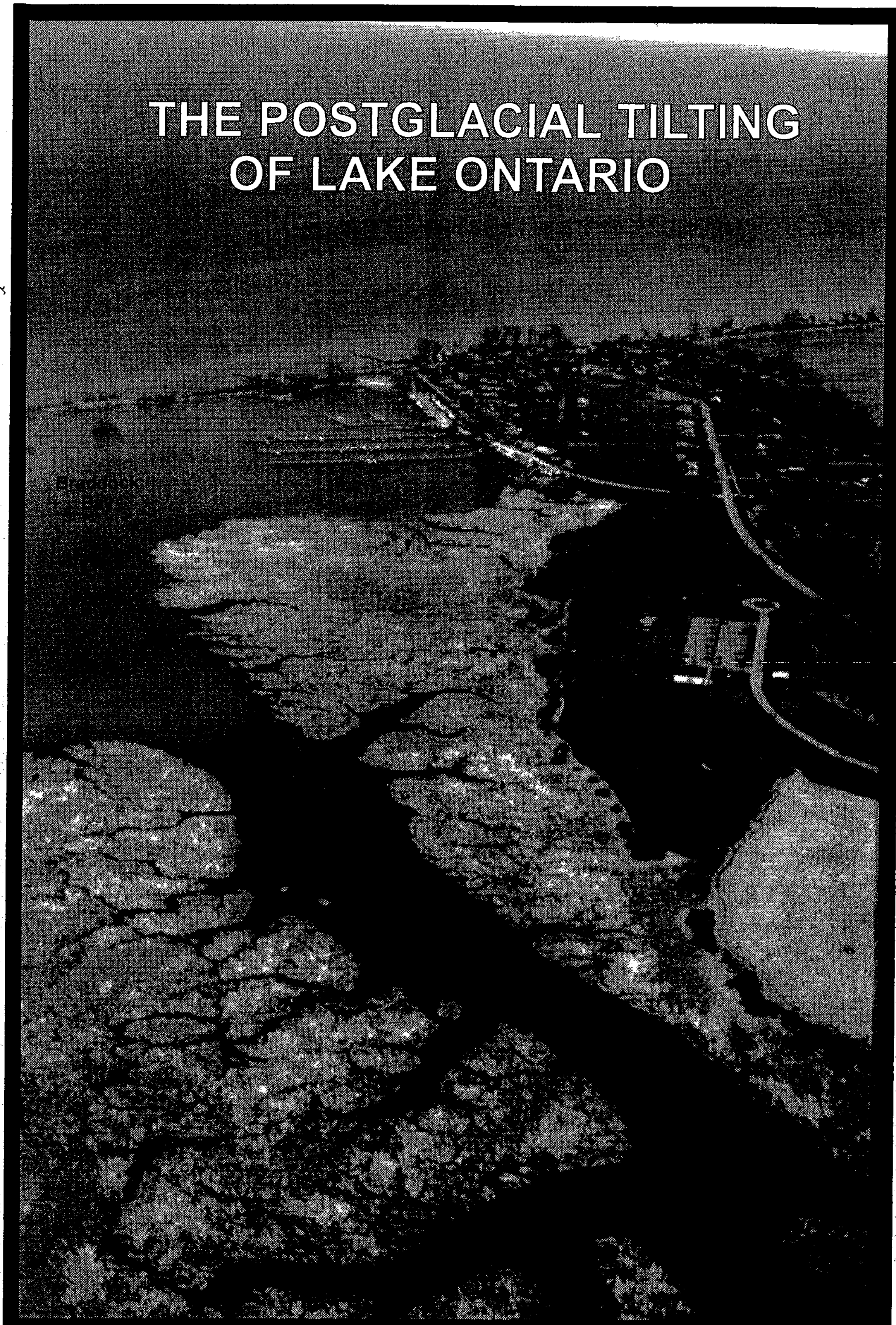
THE POSTGLACIAL TILTING OF LAKE ONTARIO



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THE POSTGLACIAL TILTING OF LAKE ONTARIO: A COMPLICATION FOR HISTORIC LAKESHORE EROSION STUDIES AND MODERN LAKE-LEVEL CONTROL

by
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Impact of the Last Ice Age

When glaciers most recently covered much of North America, the weight of the continental ice sheet depressed the earth's crust over a large region centered near Hudson's Bay. When the ice melted, the earth's crust slowly began to rebound toward its former level. For this reason the modern shoreline of Lake Ontario has been changing gradually ever since the disappearance of the last ice sheet, which retreated northward from Rochester about 12,600 years ago. When glacial ice melted back from the northern Adirondacks, the St. Lawrence River outlet for Lake Ontario was finally opened to the Atlantic ocean. Previously, while the St. Lawrence Valley was ice-bound, glacial meltwater from the Finger Lakes region was temporarily diverted through the Mohawk Valley and down the Hudson River.

The earth's crust in the St. Lawrence Valley was depressed more than in the western Lake Ontario Basin, due to the northward thickening of the ice. Thus the elevation of the St. Lawrence outlet threshold for water flowing to the Atlantic Ocean was originally lower than today, as was sea level before the ice sheets completely melted. For a short period the level of early Lake Ontario was over 200 feet lower than at present. This occurred between 11,000 and 12,000 years ago. For a short time marine waters invaded the eastern St. Lawrence Valley to a position west of Ogdensburg. This short-lived body of saline water is known as the Champlain Sea.

A record of gradual southwest tilting of the land (postglacial rebound) over the past 12,000 years is preserved in the shoreline traces of extinct glacial lakes, which formed along the melting ice front (Figure 1). Such shorelines were originally horizontal. The best known of these extinct lake shorelines is glacial Lake Iroquois, now followed by Ridge Road, or "the Ridge" (Rt. 104). The upward warping of the oldest shorelines in a northeast direction shows that the Thousand Islands area has risen at least 800 feet more than the west end of Lake Ontario during the last 12,000 years. The present-day rate of uplift (glacial rebound) has slowed, but it is still measurable, as shown by the recent uplift contours on Figure 1. The contours show that the current rate of differential tilting across the entire Ontario basin is still nearly one foot per century between the Thousand Islands region and Buffalo, NY.

Significance for Lake Shoreline Geography and Changes

Although the depth and shoreline elevation of Lake Ontario are greater now than when the glaciers first melted, the opposite sides of the Lake are being affected very differently. The faster uplift of the St. Lawrence region causes submergence of the southwestern shoreline, including Monroe County, while slowly elevating the northeastern shore of the Lake, as denoted by the location of the fine dashed line on Figure 1 passing near Oswego. The slowly rising water level in Monroe County has several effects, the most obvious being the "drowned" geography of the lake shore. The Monroe County shoreline has the classic, textbook appearance of a submerged coastline, where the lower reaches of rivers have been flooded, creating ponds and marshes bounded by sand bars (Figure 2). The rate of this gradual water level increase is slow and the magnitude is much smaller than the obvious seasonal oscillations in lake level (Figure 3). However, low shoreline features are being steadily submerged, while wave erosion is enhanced along banks and bluffs made of unconsolidated glacial sediments, especially sections containing non-cohesive sands (Figure 4).

The precise measurement of lake level and of lake shore submergence is complicated by the fact that elevations on the North American continent, as well as global sea level, are constantly changing. Following our improved understanding of "plate motions" on the earth beginning in the 1960's, it has become clear that elevations of the land surface in eastern North America change as the North American plate moves away from the mid-Atlantic Ridge. Postglacial sea level changes result from the worldwide melting of glaciers, as well as from slow changes in the shape of the sea floor caused by the growth of mid-ocean ridges. All of these gradual changes are unpredictable and difficult to measure because of the lack of stable (fixed) reference points on the earth's changing surface. Elevation measurements (such as lake levels) must be tied to established, historic reference points (bench marks) on the solid earth and to mean sea level, both of which were assumed to be relatively stable when surveying methods were first developed and refined. Lake Ontario water levels are currently referenced to a water level gage near Oswego, NY, which can be compared to the 1985 revised "reference zero point" established at Rimouski, Quebec. The control points used to monitor Lake Ontario levels are subject to gradual change and have a degree of uncertainty. Elevation control datum points established as long ago as 1903 are periodically corrected for gradual changes that continue to affect all land areas, as well as for the gradual rise or fall in "mean" sea level.

Implications for Lake Shore Erosion and Lake Levels

It should be apparent that the significance of terms such as "mean lake level" or "control elevation" for Lake Ontario are somewhat arbitrary, in view of our current understanding of the instability of the earth's oceans and continents. However, regardless of the current "base level" control used to define the elevation of the water surface of Lake Ontario, the shoreline of the lake will continue to tilt by the amount shown approximately on Figure 1. This will continue to cause an apparent rise in lake level in Monroe County that is independent of any arbitrarily established lake-level control elevation. The amount of submergence of the Monroe County shoreline, relative to the northeastern side of the lake has been on the order of 1.5 to 2 feet since the area was settled, and submergence will continue to be about 0.75 feet per century for the foreseeable future. There are obvious conclusions to be drawn from this relationship for individuals concerned with lake shore erosion problems and ongoing lake level control issues. Owners of structures or properties established along the lake shore around the turn of the current century should expect that average water levels, regardless of natural or man-made variations, are now causing impacts that are 0.75 to 1.00 feet higher than if postglacial tilting had not occurred.

As shown diagrammatically on Figure 3, the amount of relative submergence due to tilting during any one year is insignificant by comparison to seasonal climatic variations, but the long-term trend makes up an increasingly significant proportion of the short-term lake-level changes as time progresses.

The precise monitoring of subtle earth movements and related geologic phenomena, as well as the maintenance of accurate water level gages, are critical to an accurate understanding of issues related to Great Lakes water-level changes. The long-term geologic perspective should be an integral part of current discussions relating to lake-shore flooding, erosion, and land-use planning.

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Southwesterly tilting of the Lake Ontario basin is a slow response to the removal of the weight of the last continental glaciers. The resulting postglacial rebound has caused the southern shore of the Lake to spill over onto the northern edge of Monroe County, gradually submerging the land and creating embayments and drowned river mouths such as Irondequoit Bay, Braddock Bay, Cranberry Pond, Long Pond, Buck Pond and Round Pond (Figure 2). This is currently occurring at nearly 9 inches per century in Monroe County because the St. Lawrence River near Massena is rising 1.25 feet, while Rochester is only rising 0.5 feet per century at the present time. Note the lake shoreline at 11,440 and 6,000 years ago. The fine dashed line passing near Oswego indicates the approximate boundary between the emerging and submerging portions of the Lake Ontario shoreline.

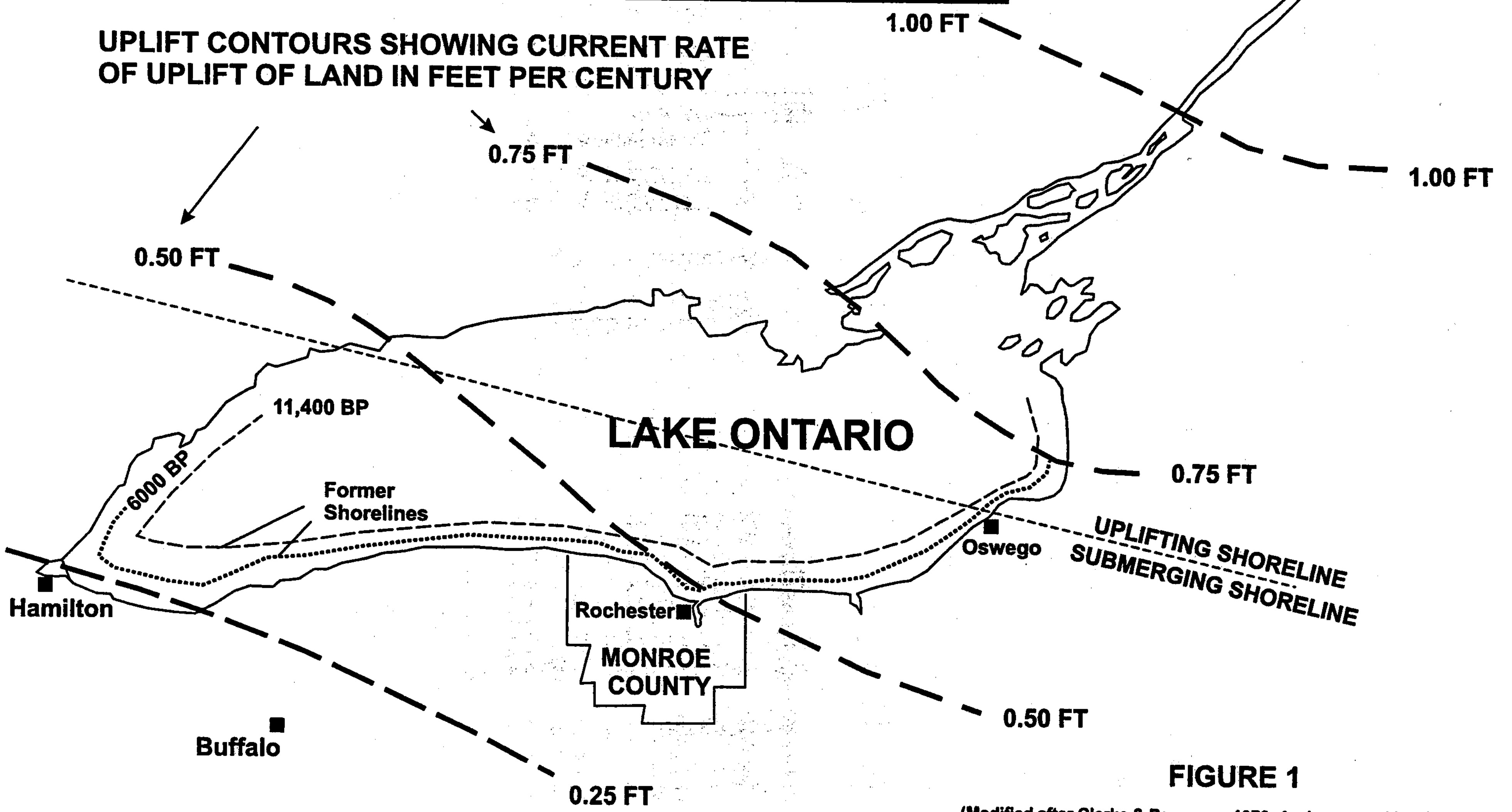

FIGURE 1

(Modified after Clarke & Persoage, 1970; Anderson and Lewis, 1985)

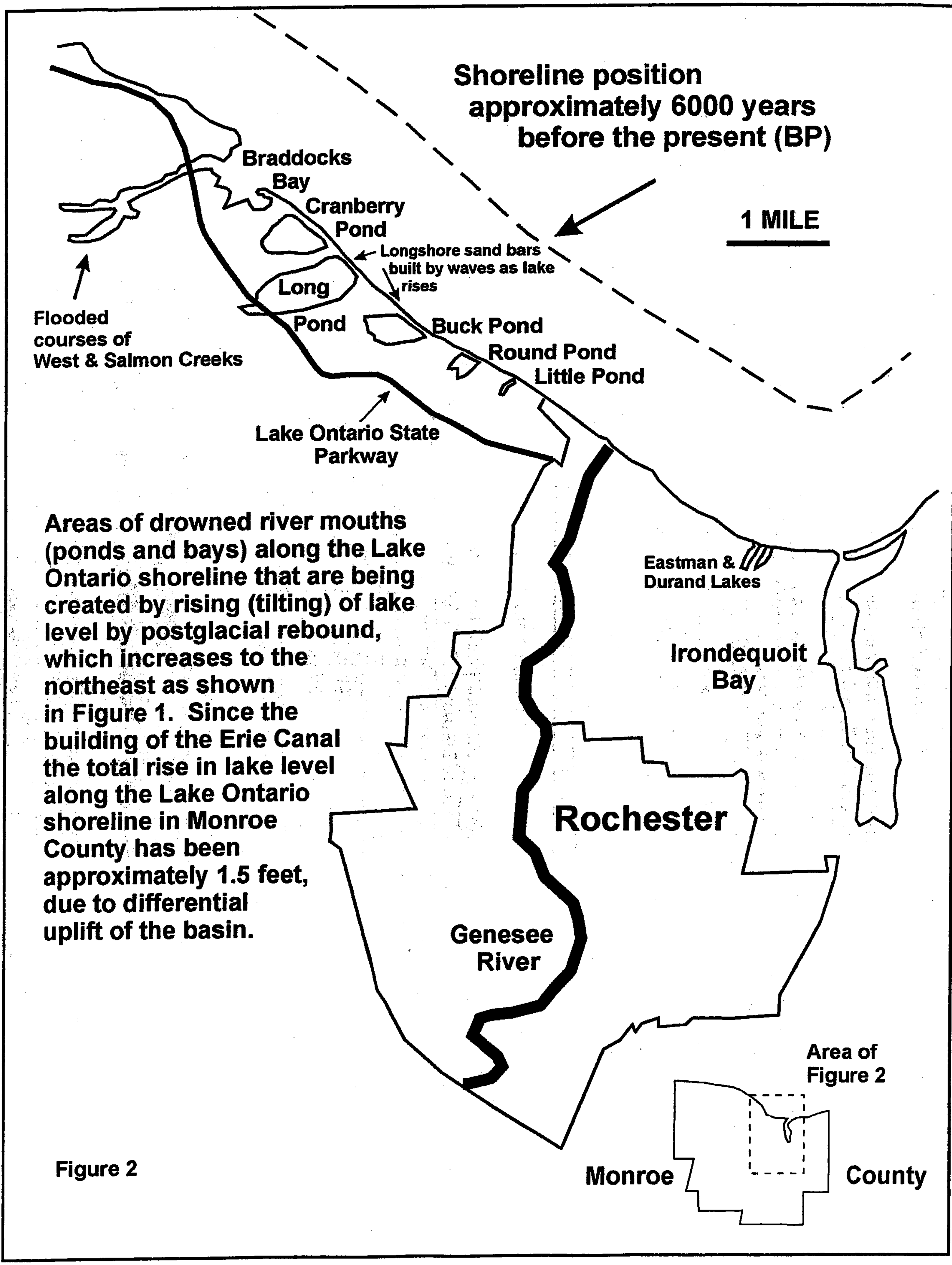
Shoreline position approximately 6000 years before the present (BP)
1 MILE
Braddocks Bay
Cranberry Pond
Longshore sand bars built by waves as lake rises
Long Pond
Buck Pond
Round Pond
Little Pond
Flooded courses of West & Salmon Creeks
Lake Ontario State Parkway
Areas of drowned river mouths (ponds and bays) along the Lake Ontario shoreline that are being created by rising (tilting) of lake level by postglacial rebound, which increases to the northeast as shown in Figure 1. Since the building of the Erie Canal the total rise in lake level along the Lake Ontario shoreline in Monroe County has been approximately 1.5 feet, due to differential uplift of the basin.
Eastman & Durand Lakes
Irondequoit Bay
Rochester
Genesee River
Area of Figure 2
Monroe
County

Figure 2

LAKE ONTARIO HISTORIC WATER LEVELS 1918 TO 1998

Modified from Great Lakes Information Network Website (http://superior.lre.usace.army.mil/levels/hlevont.html) 1998

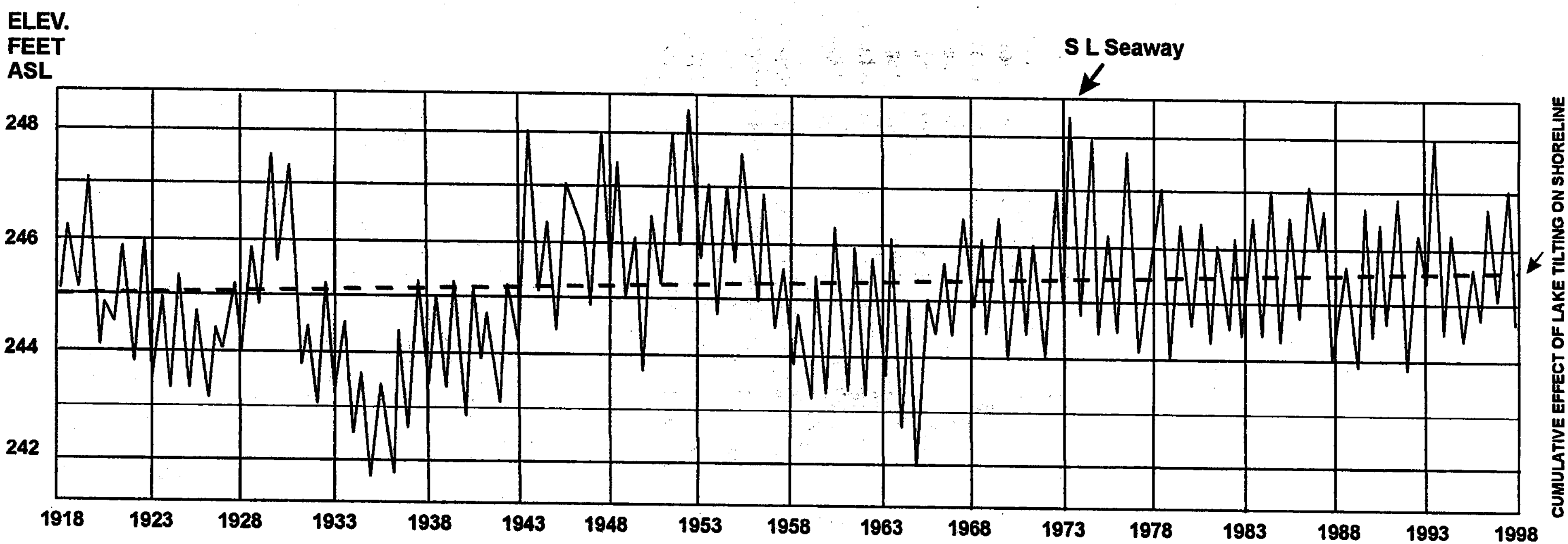

Figure 3. Dashed line represents the cumulative, relative effect of a 0.6-foot differential uplift at Monroe County superimposed on 80-year record of lake level fluctuations. Each point on the historic lake level curve includes a component of change caused by the tilting of the lake basin that is approximately equal to the magnitude of the dashed line as it increases through time. In other words, the actual lake level changes are the result of a combination of annual climate, man-made controls, and cumulative lake basin tilting. Note start of St. Lawrence Seaway impact.

IMPACTS OF RISING WATER LEVELS ON THREE COMMON TYPES OF SHORELINES

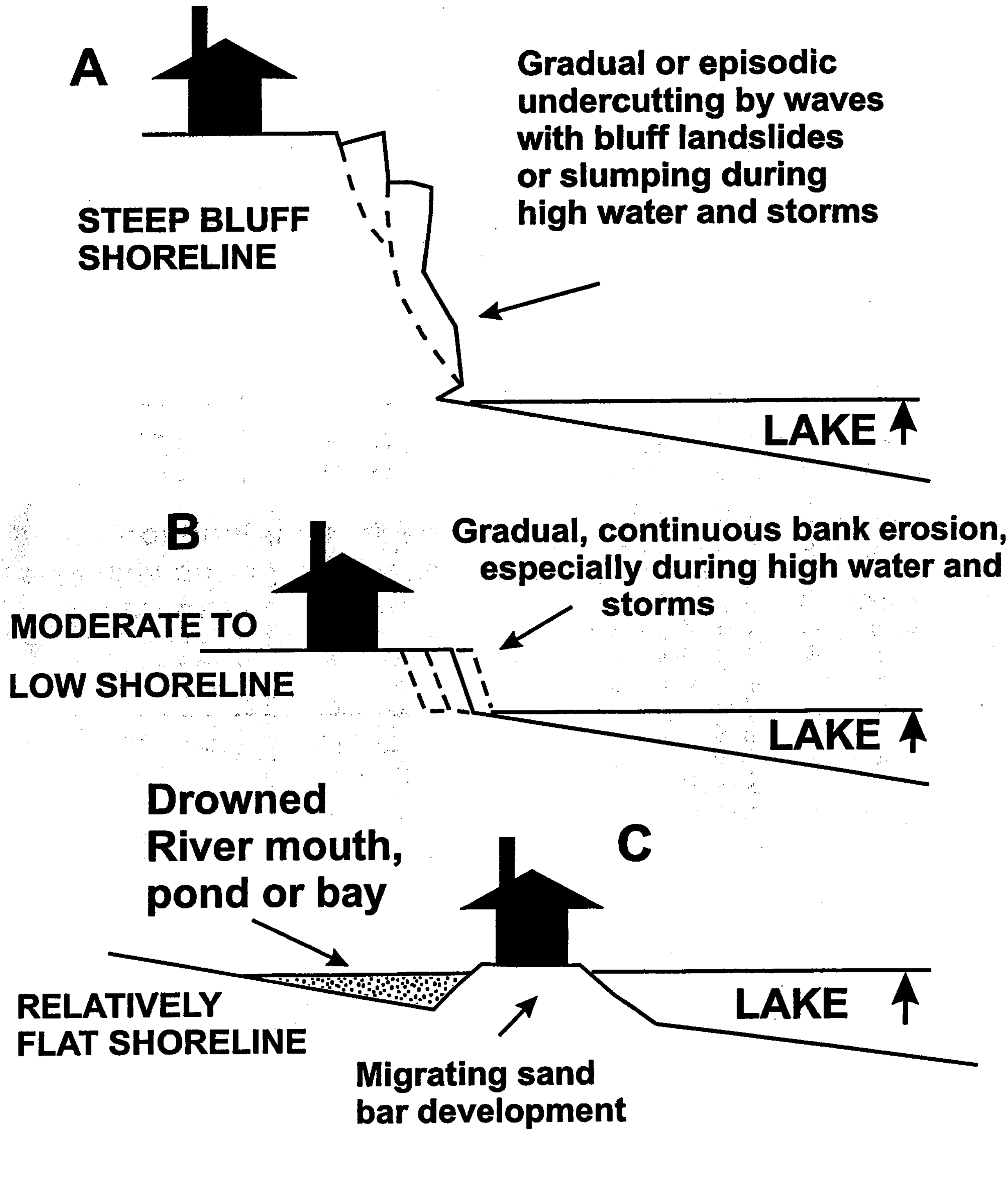

Figure 4