COASTAL PROCESSES WORKBOOK

Evaluating the Risks of Flooding and Erosion for Great Lakes Coastal Property

J. Philip Keillor and Allen H. Miller

University of Wisconsin Sea Grant Institute WIS-SG-87-431

COASTAL PROCESSES WORKBOOK

Evaluating the Risks
of Flooding and Erosion
for Great Lakes Coastal Properties

J. Philip Keillor and Allen H. Miller

University of Wisconsin Sea Grant Institute

This work was funded by the University of Wisconsin Sea Grant Institute under grants from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and from the State of Wisconsin. Federal Grant No. NA84AA-D-00065, Projects A/AS-1 and A/AS-2.

Support was also provided by the Division of State Energy and Coastal Management, Wisconsin Department of Administration, and the Coastal Zone Management Improvement Act of 1980, as amended, administered by the Office of Ocean and Coastal Resource Management Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

DISCLAIMER

The contents of this workbook are intended only to help reduce the uncertainties of evaluating future changes to coastal properties. The authors, the University of Wisconsin and the State of Wisconsin accept no responsibility, financial or otherwise, for losses resulting from misuse of this publication in the purchase, sale, appraisal, design, siting or construction of any coastal property or structure, including but not limited to misrepresentations of the contents of this publication, the use of portions of the publication out of context, and reliance on the materials beyond the limited intended use.

UW Sea Grant Advisory Services Report No. WIS-SG-87-431

Authors * J. Philip Keillor and Allen H. Miller
Publication Coordinator * Peyton Smith
Editing * Stephen Wittman
Graphics * Christine Kohler and Wendy Schorr
Production Assistance * Cathy Catanzaro

Additional copies of this publication are available from:

Communications Office
UW Sea Grant Institute
1800 University Avenue
Madison, WI 53705

Phone (608) 263-3259

COST: **$1.00** (for postage and handling)
Make checks or money orders payable to "UW Sea Grant Institute."
Payment must be in U.S. currency and drawn from a U.S. bank.

First Printing: September 1987
Printed in the USA

Contents

Lists of Tables and Figures

TABLES

FIGURES

Glossary of Terms

Bank	The lakeward edge of land, generally less than 10 feet high, containing a few simple soil layers and no groundwater.
Beach Ridges	A series of elongated sand ridges parallel to the shoreline formed during past periods of high lake levels.
Bluff	The lakeward edge of land, generally higher than 10 feet high, that is high enough to contain complex, multiple layers of soil and groundwater.
Recession	The landward movement of a shoreline caused primarily by erosion of the shore.
Revetment	A sloped structure of stone or concrete designed to protect a bluff or bank from recession.
Riprap	A layer of stones or concrete rubble on an embankment slope to prevent erosion; a type of revetment.
Seawall	A vertical structure -- usually made of concrete, steel or wood beams -- installed to protect a bluff or bank from recession.
Seiche	A small rise or drop in water level caused by oscillations (a sloshing) of the water back and forth in the lake bed as a result of strong winds, storms and atmospheric pressure changes.
Setback	The distance a building should be back from the edge of a bluff or bank to be reasonably safe from shore recession and to be relocated if necessary.
Shoal	An offshore sandbar that creates an area of shallow water.
Slump Block	A large block of earth that has broken off or slid down a bluff face.
Stable Slope	The natural angle to which a coastal bluff or bank will erode even when unaffected by other forces, such as shoreline recession or heavy loads like buildings.

Still Water Level	The normal level of a lake when it is unaffected by winds, storms or seiches.
Storm Surge	A temporary rise in water levels along downwind coasts caused by the drag of storm winds on the lake's surface.
Toe	The lake-level base of a bluff, bank or shore protection structure.
Wave Runup	The vertical distance storm or wind-driven waves will rise upon encountering a beach or sloped shore protection structure.

Preface

The University of Wisconsin Sea Grant Institute is part of the the National Sea Grant College Program, a network of 30 university-based marine research and public service programs supported by federal, state and private grants. Headquartered on the UW-Madison campus, the UW Sea Grant Institute is a statewide program with Advisory Services field offices located in Milwaukee, Green Bay, Sister Bay and Superior/Ashland. At present, more than 150 faculty, staff and students are involved in Sea Grant projects on campuses throughout the state -- at UW-Green Bay, UW-Extension, UW-Madison, UW-Milwaukee, UW-Parkside, UW-Stevens Point, UW-Superior and Lawrence University in Appleton. Its major research areas include Great Lakes fisheries, environmental contaminants, cool-climate aquaculture, diving physiology, Great Lakes management policy and a comprehensive Green Bay research program.

For more information, contact the Communications Office, UW Sea Grant Institute, 1800 University Ave., Madison, WI 53705, or one of UW Sea Grant's four Advisory Services field agents:

* Lynn Frederick, Sea Grant Advisory Services, The Walkway Mall, 522 Bay Shore Dr., Sister Bay, WI 54234, phone (414) 854-5329.

* Cliff Kraft, Sea Grant Advisory Services, ES-105, University of Wisconsin, Green Bay, WI 54301-7001, phone (414) 465-2795.

* James Lubner, Sea Grant Advisory Services, University of Wisconsin Great Lakes Research Facility, 600 E. Greenfield Avenue, Milwaukee, WI 53204, phone (414) 227-3291.

* Scott Chase, Sea Grant Advisory Services, 104 Sundquist Hall, University of Wisconsin, 1800 Grand Avenue, Superior, WI 54880, phone (715) 394-8472. (Also available Wednesdays and Thursdays at Ashland City Hall, Ashland, WI 54806, phone (715) 682-7071, Ext. 24.

The Wisconsin Coastal Management Program was established in 1978 to direct comprehensive attention to the state's 820 miles of Lake Michigan and Lake Superior coastline. The WCMP analyzes and develops state policy on a wide range of Great Lakes issues, coordinates the many governmental programs that affect the coast, and provides grants to stimulate better state and local coastal management. Its overall goal is to preserve, protect and develop the resources of Wisconsin's coastal areas for this and succeeding generations.

For more information about the program, contact the Wisconsin Department of Administration, Division of State Energy and Coastal Management, P.O. Box 7868, Madison, WI 53707.

Introduction

This workbook describes how to evaluate the likely effects of changing lake levels, storm surges, wave runup and shoreline recession on Great Lakes coastal property. These procedures can help:

* Lenders and prospective buyers make informed decisions about investing in Great Lakes coastal property;

* Realtors make better disclosures to prospective buyers of the possible hazards to lakeside property posed by flooding and shore erosion; and

* Local administrators and citizen members of planning and zoning commissions and boards of appeal make better decisions on the zoning and development of coastal properties.

Though tailored to Wisconsin's Great Lakes shores, the procedures described in this workbook can also be applied to other areas of the Great Lakes.

Each reach of Great Lakes shoreline has a unique set of geological features, however, and a site-specific coastal engineering study is the only way to minimize the uncertainties involved in estimating the effects of erosion, flooding and shore protection on the long-term value of a parcel of coastal property.

In many cases, though, the cost of an engineering study is out of proportion to the property investment or impractical for other reasons. This workbook is designed to help fill the gap between mere guessing and a detailed engineering study.

Choosing to use the generalized procedures presented here in lieu of a site-specific engineering study involves certain trade-offs, however, as generalization and simplification increase the uncertainties involved. Even in the case of on-site studies, coastal engineering is the practice of applying incomplete information to an environment that has storms, water level changes and recession rates that do not observe design limits.

Despite the complexities of these coastal processes, it does not take an expert to estimate the relative risks of investments in Great Lakes coastal property. A reasonable evaluation of most coastal property can be performed by using readily available and easily understood information.

It is not possible, however, to anticipate all possible site conditions. Uncertainties about future water levels, the date of the next big storm, future rainfall amounts, erosion rates, bluff stability, and the effectiveness and durability of shore protection are a fact of life for coastal living.

The evaluation process described in this workbook is applicable to coastal sites without special complicating factors requiring professional evaluations by an engineer or geologist. Typical complicating factors include:

* Exposed locations on points of land subject to wave action from several directions;
* Locations inshore of large shoals, and
* Evidence that recession occurs in infrequent episodes of massive bluff slumping, rock falls or large retreats of sandy ridges and terraces.

The step-by-step evaluation process described in this workbook is intended only to help <u>reduce</u> the uncertainties of investing in coastal property. When in doubt, consult an engineer or geologist about the need for an on-site inspection.

Information You Will Need to Use This Workbook

Before you can use the step-by-step methods described in this workbook for evaluating the risks of flooding and erosion for Great Lakes coastal properties, you will need a topographic map of the property that indicates the property's elevation. In most cases, you will also need to make an inspection of the property to:

* Assess the erosion history and stability of its lakeside bluff or bank;

* Measure or estimate the horizontal distance covered between the toe and the top of the bluff;

* Measure how far any buildings on the property are from the top edge of the lakeside bluff or bank, and

* Determine whether the property has any of the special complicating factors described in the introduction that may require professional evaluations by an engineer or geologist.

For properties with shore protection, you will need to assess the condition and effectiveness of the shore protection structure and to measure the current slope of the lakeshore. Slope measurements can be performed simply with a measuring tape and a yardstick: First, select a area of slope typical for the shoreline, secure the tape to the ground, and, holding the tape level, move down the slope until you are three feet (yardstick height) below the starting level of the tape; then divide the distance (in feet) shown on the tape by 3 to determine the slope ratio in terms of horizontal feet per vertical foot. For long slopes, repeat the measurement two or three times on other parts of the slope and use the average value.

Other sources of information you will need to have on hand are:

* The U.S. Army Corps of Engineers' Monthly Bulletin of Lake Levels for the Great Lakes, available from the Detroit District Office, U.S. Army Corps of Engineers, P.O. Box 1027, Detroit, MI 48231.

* The U.S. Army Corps of Engineers' 1978 brochure, Help Yourself: A Discussion of Erosion Problems on the Great Lakes and Alternative Methods of Shore Protection, available from the North Central Division Office, U.S. Army Corps of Engineers, 536 S. Clark Street, Chicago, IL 60605-1592.

The equivalent Canadian sources for this information are:

* The Canadian Hydrographic Service's Monthly Water Level Bulletin, Great Lakes and Montreal Harbour, available from the Department of Fisheries and Oceans, Canadian Hydrographic Service, P.O. Box 5050, Burlington, Ontario L7R 4A6, Canada.

* The Ontario Ministry of Natural Resources' 1986 booklet, How to Protect Your Shore Property, available from MGS Publications Services Section, 5th Floor, 880 Bay Street, Toronto, Ontario M7A 1N8, Canada.

How to Evaluate the Risks of Flooding

The risks of flooding are greatest when Great Lakes water levels are high. Flooding caused extensive damage throughout the region during 1985-86, when all of the Great Lakes except Lake Ontario set new 20th century highs. Besides high lake levels, flooding can also result from storm surges and wave runup (Figure 1). Estimating the risk of flooding for a Great Lakes coastal property, therefore, requires three steps:

1. Estimating the lake's highest still water level.

2. Estimating the height of the local storm surges, temporary rises in water level that occur when storm winds blow towards shore.

3. Estimating how high storm waves will run up on the property.

The sum of these three factors is the height that water can be expected to reach on the property.

Estimating Still Water Levels

The available water level information for the Great Lakes is based on data from little more than a century of record-keeping. Recent evidence of prehistoric lake levels obtained from old beach ridges indicate Lake Michigan's water levels during the last 1,000 years have at times been several feet higher and several feet lower than the levels recorded during the last 100 years. This may also be true for the other Great Lakes, so it would be wise to increase estimates of lake level elevations accordingly to hedge against the possibility of higher levels in the future. The 20th century record high and record low water levels for each of the Great Lakes are listed in Table 1.

Determining the still water level for a property involves selecting the 20th century record high water level (as of June 1987) for the lake in question from Table 1, or the highest recorded or projected monthly mean lake level from the most recent U.S. or Canadian Great Lakes water level bulletins. Note that the highest monthly mean is an average level for the lake over the entire month and therefore is lower than the highest daily lake level.

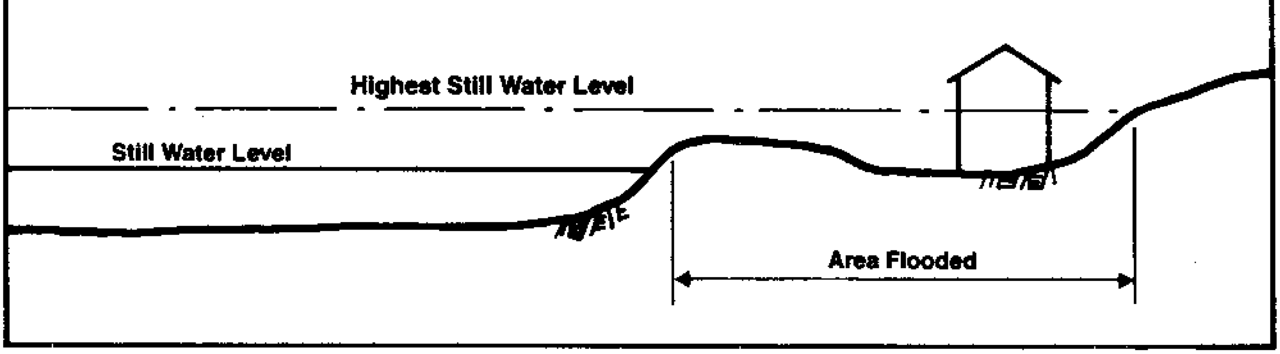
Estimating Storm Surge Heights

As storm winds blow across the many miles of open water on the Great Lakes, they push water towards the downwind side of the lakes, causing a build-up in water level along the downwind shore. This temporary rise in water level is called a storm set-up or storm

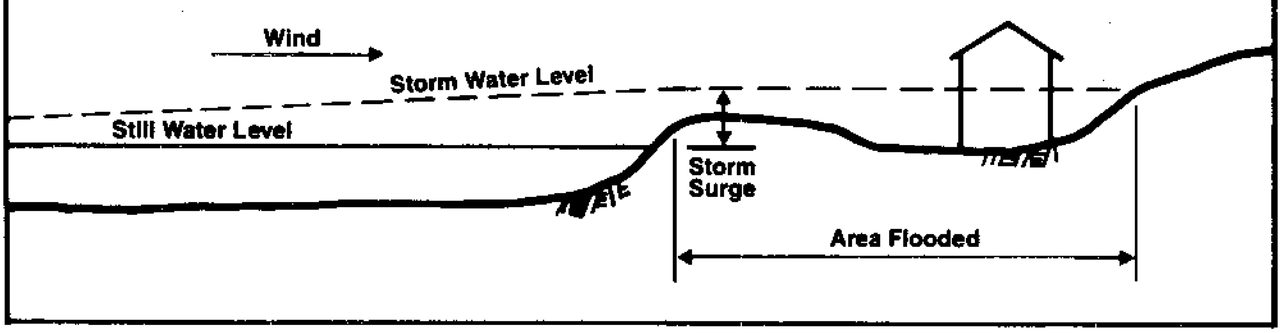
Figure 1

Types of Coastal Flooding

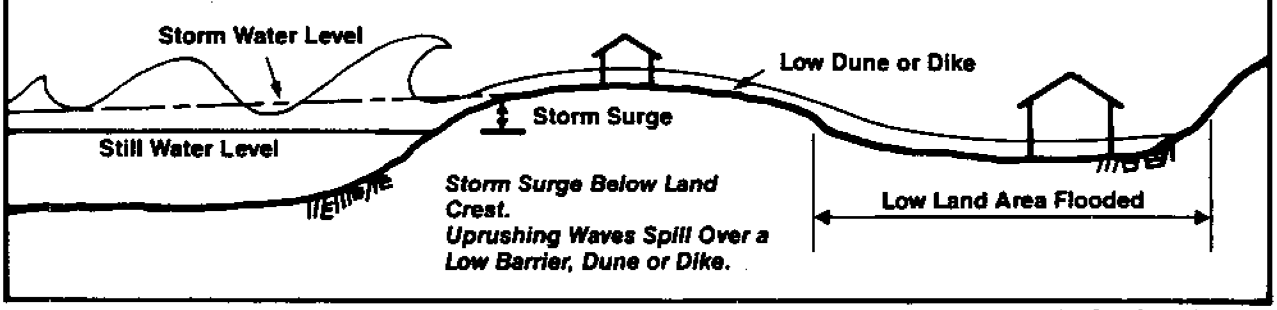
Flooding Due to High Water Levels



Flooding Due to Storm Surge



Flooding Due to Wave Runup



UW Sea Grant Institute

surge, and the corresponding drop in water level on the upwind side of the lakes is called a set-down.

Storm surges last about as long as the storm winds do, rising rather quickly with wind velocity and dropping when wind velocity falls or the wind switches direction. One or more small rises in the water level may occur up to 8 hours after a storm due to a back-and-forth sloshing of the water in the lake bed called seiches. Seiches following a storm may cause repeated flooding of low-lying property, but they usually have less of an effect on coastal erosion because they are not accompanied by waves as high as those accompanying a storm surge.

Figure 2 shows the height of typical storm surges for most of the U.S. and Canadian Great Lakes coastline. The surge height is presented in feet above the still water level. These storm surge values are not maximum values, however. Storm surge records indicate that storm surges in some locations can be twice the values indicated in Figure 2. Extreme storm surges affect coastal property along shallow bays where the wind can blow long distances across the water.

Complex calculations are required to determine extreme storm surges and storm surges for coastal waters confined by bays, islands or large shoals. Extreme storm surge information can only be obtained by engineering calculations or from long-term water level records. In the U.S., long-term water level records can be obtained from the Great Lakes Acquisition Unit, National Ocean Service, National Oceanic & Atmospheric Administration, Rockville, MD 20852. In Canada, such records are available from the Canadian Hydrographic Service, Department of Fisheries & Oceans, 867 Lakeshore Road, Burlington, Ontario L7R 4A6.

Estimating Storm Wave Runup

A complete assessment of the risks of flooding from high water levels and storm surges also requires an estimate of the extent of wave runup on a coastal property. Wave runup is the vertical distance reached by a wave as it washes up a beach or on a shore protection structure (Figure 3). This distance depends not only on the size of the wave but on the slope and make-up of the beach or shore protection structure as well. Wave runup is generally higher on beaches and shore protection structures with steep slopes and lower on those with gentle slopes. Because they are more porous, cobble beaches and rubble revetments will absorb more of a wave and have less runup than sandy beaches or concrete slab revetments with similar slopes.

Calculating actual wave runup is a complicated process best left to a professional engineer. The minimum wave runup values for beaches, revetments and vertical seawalls along open coasts of Wisconsin are provided in Table 2. Lake waves can be expected to run up to at least these values anywhere along the coast: In most cases, actual runup will exceed these values. For other Great Lakes coasts, wave runup can be inferred by looking at suggested crest elevations for shore protection structures in the U.S. Army Corps of Engineers Help Yourself brochure.

Estimating Storm Wave Runup Elevations

The elevation of storm wave runup for a coastal property is the sum of the preceding estimates for still water level, storm surge and wave runup. The result will not be a precise elevation: The combined uncertainties for all three factors will total more than a foot.

Figure 2

Generalized Storm Surges in the Great Lakes

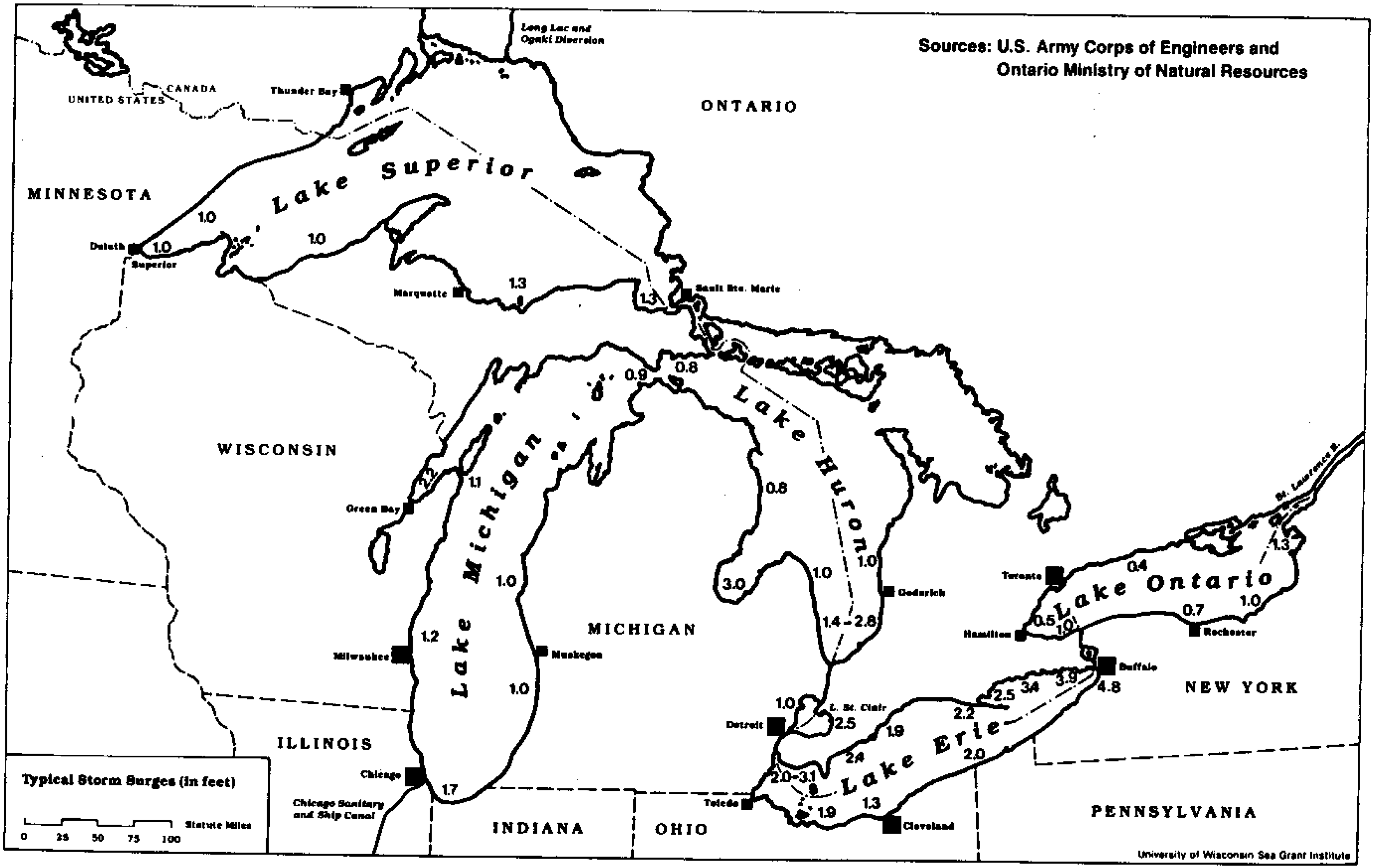
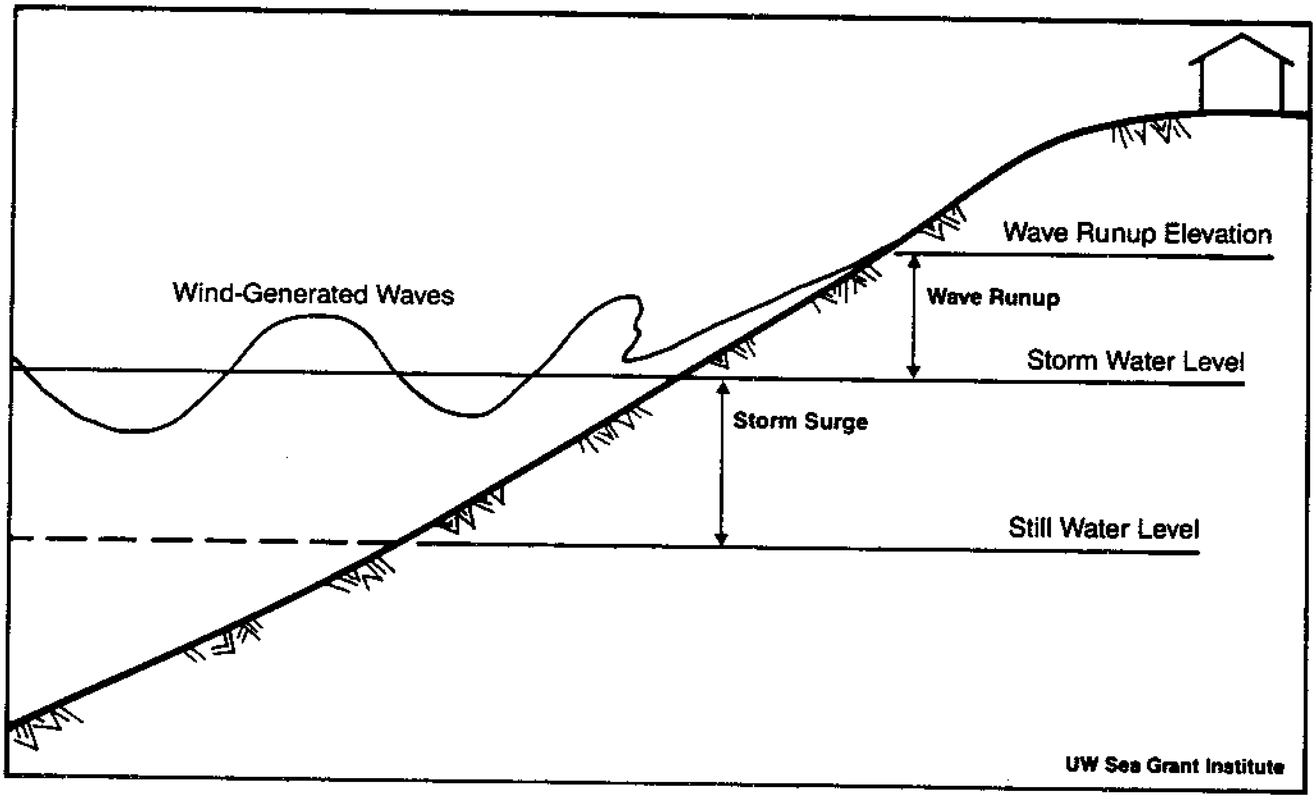


Figure 3

Storm Surge and Wave Runup



An evaluation of the property's susceptibility to erosion and/or flooding requires a comparison of the estimated storm wave runup elevation to the elevation of the land or the crest elevation of a shore protection structure. In sheltered waters where waves are not a significant factor, this requires only a comparison of the land elevation and the elevation of the highest still water level and typical storm surge.

Suitable land elevations can usually be obtained from topographic maps for the area and by estimating on-site variations in elevation. In cases where it is difficult to estimate land elevations, a site survey may be necessary. The currently recommended U.S. datum is the National Geodetic Vertical Datum (NGVD 1929), but many topographic maps show elevation in terms of feet above Mean Sea Level (MSL 1929, or simply MSL). NGVD and MSL are different terms for the same datum. Canadian land elevations are referenced to Geodetic Datum as determined by the Geodetic Survey of Canada.

Great Lakes water levels, on the other hand, are referenced to a completely different datum. The U.S. Army Corps of Engineers' Monthly Bulletin of Lake Levels for the Great Lakes and the Canadian Monthly Water Level Bulletin give lake level information in terms of feet and meters, respectively, above or below a reference level, or chart datum, for each lake -- the International Great Lakes Datum (IGLD 1955). For example, the chart datum for Lake Superior is equal to 600 feet (182.9 meters) above the IGLD.

Table 3 provides the equivalent NGVD and Geodetic Datum elevations for the IGLD of each of the Great Lakes. Coastal property within city limits will have elevations referenced to city datum. For example, the City of Milwaukee Datum (CMD) is 579.30 feet above IGLD. For other cities, contact the city engineering department to get the proper conversion of water level elevations to local city datum.

How to Evaluate the Risks of Coastal Erosion

Besides determining the likelihood of flooding, it is equally important to determine if an existing or proposed lakeshore building is set back far enough from the lake to prevent damage to or loss of the building due to erosion during the life of the mortgage or the projected life of the structure. This is called "construction setback."

It is important to recognize the signs of severe, rapid coastal erosion and to evaluate the stability of the ground along the lakeside edge of a coastal property. Some ways in which coastal bluffs and banks erode are shown in Figure 4.

The most obvious way to recognize a stable bluff or bank is to examine whether the slope above the beach has mature vegetation or not. If the vegetation is mature shrubs or trees and if there are no signs of slump blocks, the slope has probably been stable for as long as the vegetation has been there. However, sometimes slump blocks are so large and thick that, as they sink below the bluff top, they carry along the mature vegetation intact. Generally speaking, stable slopes have fairly uniform faces and are likely to remain stable as long as the toe of the bluff or bank is protected from wave attack and the surface of the slope is protected from erosion by vegetation. A raw bluff face is a sure sign of bluff erosion and instability, especially if it shows evidence of groundwater seepage.

Coastal properties with rock terraces and bluffs can also recede. The ceaseless wash of gravel and cobbles against rocky ramparts of the coast undercuts the rock, and storm waves drive water into crevices with great force, enlarging the fissures. In cold weather, water draining into rock crevices from overlying topsoil freezes and expands, applying large separation forces to the rock along the sides of the cracks, eventually causing blocks of rock to fall from the face of the bluff.

Estimating Construction Setback

Three factors are involved in estimating construction setback:

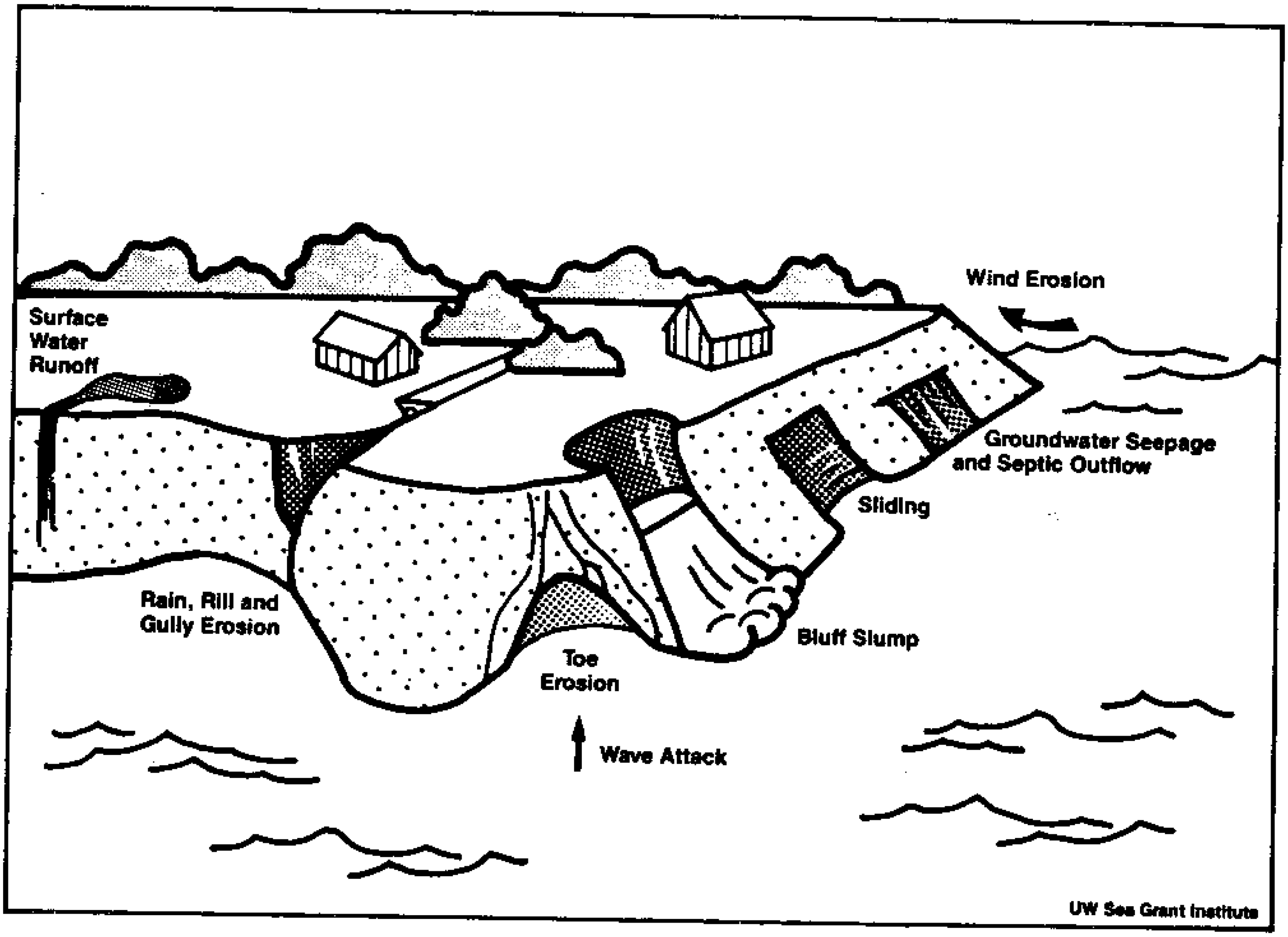
1. The distance the bank or bluff edge is expected to recede during the life of the building or mortgage (recession setback);

2. The distance necessary for the bluff face to recede to a stable slope (stable slope setback), and

3. The distance needed to allow house movers to safely relocate the building if necessary (relocation setback).

Figure 4

Coastal Erosion Problems



Estimating Recession Setback. An estimate of recession setback is used to determine whether an existing or proposed building is located far enough from the edge of the bank or bluff so that it is unlikely to be endangered by coastal erosion during its useful life (or the life of a mortgage on it). This is simply a matter of determining the property's recession rate and multiplying it by the desired number of years. While the arithmetic is easy, the information on recession rates is limited and picking a prudent recession rate requires considerable personal judgment.

The rates of shoreline recession along Wisconsin's Great Lakes coasts over long periods of time (from decades to a century or more) vary by location from less than a foot to 15 feet per year. Recession of the Great Lakes coastline is most rapid during periods of high water because high lake levels enable larger waves and more wave energy to attack the toes of coastal bluffs and banks. During the present high water period, for example, some terraces with no protection from storm waves and storm surges have receded 20 or more feet in a single storm.

Long-term recession rates for some Wisconsin coastal counties are presented in the appendix. A reasonable estimate of long-term recession rates can also be made for shoreline section corners from old land survey records. Well- documented recession on similar property nearby is another good source to use. Consult a local or regional planning agency regarding the availability of more information on local recession rates.

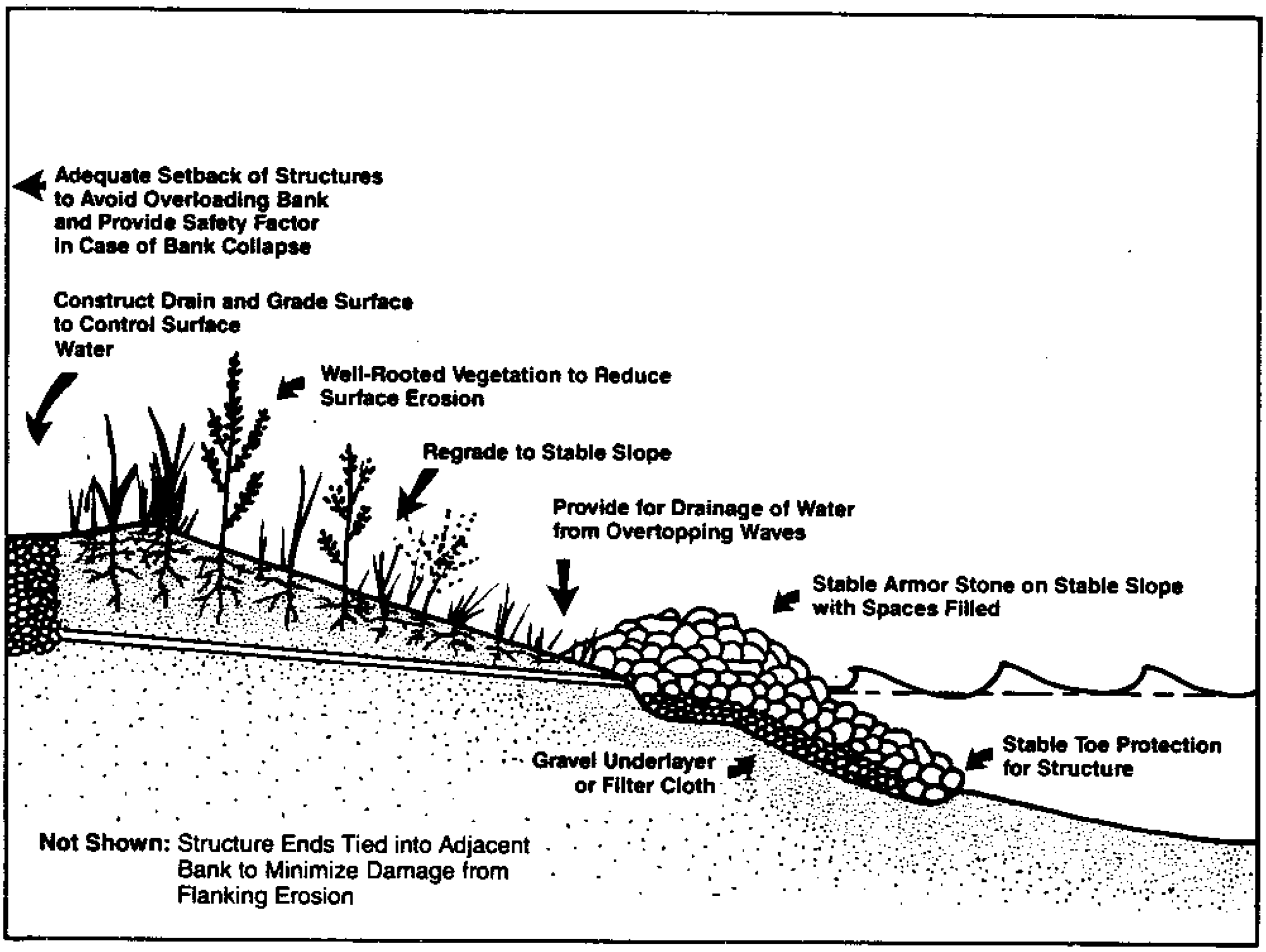
Estimating Stable Slope Setback. A stable slope is the angle to which a coastal bluff or bank would erode even if its toe were protected from recession. Such protection occurs naturally when lake levels are low enough to create a broad beach between the bluff toe and the water's edge. Stabilization of the toe of a bluff or bank can also be achieved by building and maintaining an effective shore protection structure at the toe. A bluff with a protected toe and stable slope is unlikely to fail by slumping.

A survey of 180 slopes along Wisconsin's Lake Michigan and Lake Superior shores in the mid-1970s by University of Wisconsin Sea Grant geotechnical engineers indicated that a slope was stable if it has a fairly uniform grade not steeper than those described in Table 4. These "stable slope angles" are conservative, but they depend on assumptions made about the maximum elevation of groundwater in the bluff or bank. Some bluffs may have stable slopes steeper than those indicated in Table 4, but making this determination requires a detailed investigation by a technical expert.

As a rule of thumb, a stable slope angle for Wisconsin's Lake Michigan coastal bluffs is 2.5 feet horizontal for each vertical foot (2.5:1). For the Wisconsin coast of Lake Superior, use 3 feet horizontal for each foot vertical (3:1).

Figure 5

Example of a Well-Designed Shore Protection System



UW Sea Grant Institute

Evaluating Shore Protection

The key to estimating the appropriate construction setback for properties with shore protection is to correctly estimate the effectiveness of the shore protection structure. Each element of a shore protection system has strategic importance. Forget one element and the whole system is in danger of failure. Figure 5 shows an example of a well-designed shore protection system.

The adequacy of a planned or existing shore protection structure can be estimated by comparing it to actual structures that have successfully survived severe storms. An alternative is to compare the structure to similar designs in the U.S. Army Corps of Engineers Help Yourself brochure or the Ontario Ministry of Natural Resources' booklet, How to Protect Your Shore Property. Even if the shore protection is well designed, it can fail and will need to be replaced unless it receives periodic maintenance. A complete and accurate evaluation of the effectiveness of any existing or proposed shore protection structures requires a professional coastal engineering analysis.

Step-by-Step Summary

Estimating the Risk of Flooding for a Coastal Property

Step 1: Estimate the highest still water lake level by (1) selecting the maximum 20th century water level from Table 1, or (2) use the highest recorded or projected monthly mean level for the lake from the most recent U.S. Army Corps of Engineers or Canadian monthly bulletins of lake levels. Keep in mind that new record high levels may be possible in the future.

Step 2: Find the typical storm surge for the area on Figure 9. Remember that storm surges at some locations can be twice the values shown in Figure 9. If the property is on a shallow bay and subject to extreme storm surges, contact the local city engineer's office or a professional coastal engineer for more precise storm surge information.

Step 3: Select the appropriate minimum wave runup value from Table 2. Keep in mind that the actual runup on a property is likely to exceed these values.

Step 4: Select the equivalent land elevation for Great Lakes chart datum from Table 3. If the property is within city limits, check with the local city engineer's office for the proper number for converting city datum to NGVD or MSL.

Step 5: Add the highest still water level, typical storm surge value and minimum wave runup value to the equivalent NGVD elevation to estimate the storm wave runup elevation. Remember that the uncertainties involved in these factors are likely to total more than a foot.

Step 6: Compare the storm wave runup elevation to the property or building's elevation as determined from a topographic map or a site survey. If the property has shore protection, also compare the storm wave runup elevation to the elevation of the crest of the shore protection structure.

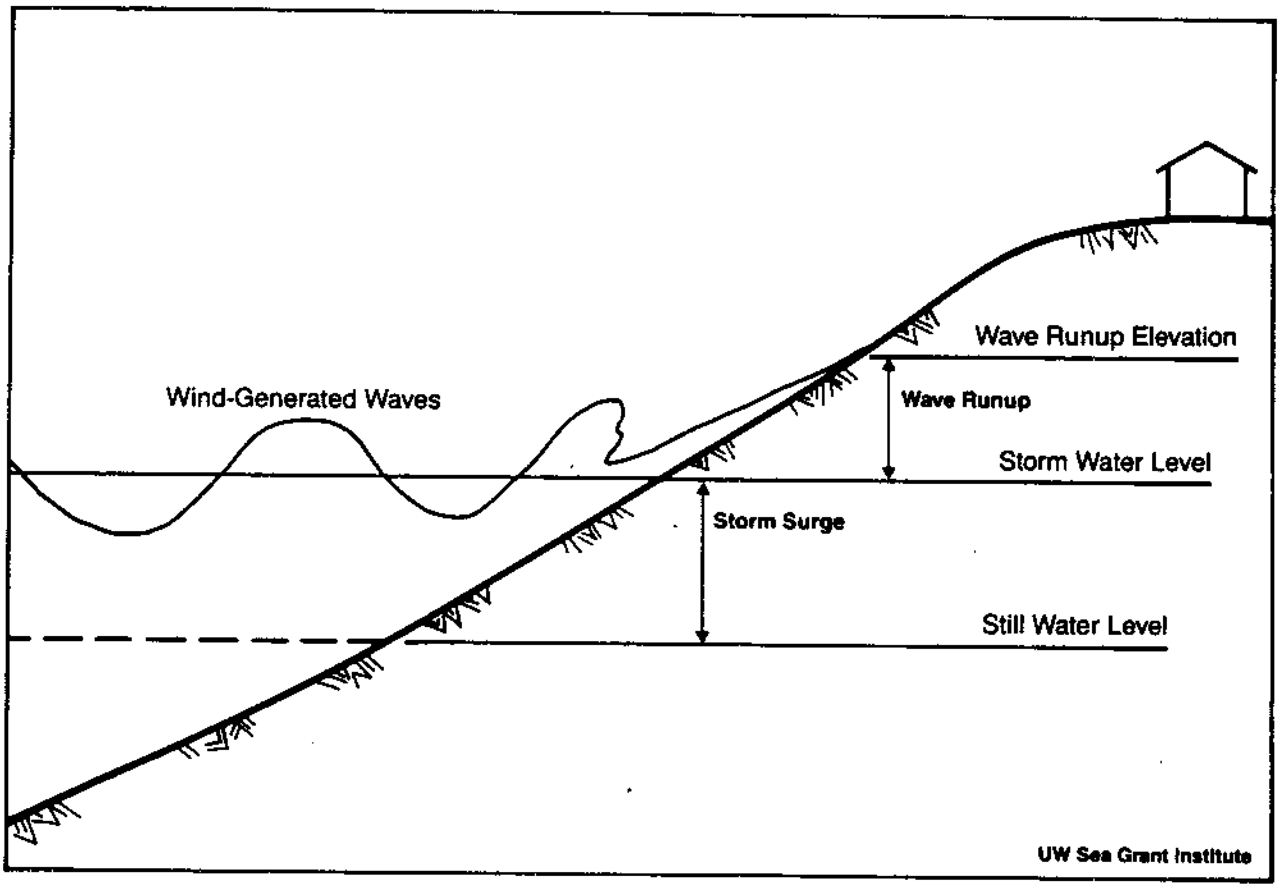
(Figure 6)

Step 1:	Highest Still Water Level	______	feet above IGLD chart datum
Step 2:	Typical Storm Surge	+______	feet
Step 3:	Minimum Wave Runup	+______	feet
Step 4:	Equivalent NGVD Elevation	+______	feet above NGVD
Total:	Storm Wave Runup Elevation	=______	feet above NGVD
Step 5:	Elevation of Property and/or Crest of Shore Protection	-______	feet above NGVD (or MSL)
Difference:		=______	feet

If the storm wave runup elevation is nearly equal to or greater than the property's elevation (a positive number), the property is likely to be flooded. A negative difference of a foot or more indicates the property is likely to be safe from flooding unless the lake rises to new record high levels or the property is subject to extreme storm surges or wave runup that is significantly greater than the minimum value used.

Figure 6

Worksheet for Estimating Storm Surge and Wave Runup



Estimating Construction Setback Distance for Property Without Shore Protection

Step 1: Select a recession rate for the property from the appendix and/or consult local or regional planning agencies for information on local recession rates. Well-documented recession on similar property nearby is another good source to use. If long-term recession rate data are unavailable, an engineering analysis is necessary for this estimate.

Step 2: Determine the number of years of protection needed to cover the life of the mortgage on the property and/or the useful life of the house. In some areas, a minimum number of years or a minimum setback distance is mandated by ordinance: Check with the city or county planning and zoning administrator.

Step 3: Determine the recession setback by multiplying the recession rate (step 1) by the required number of years of protection (step 2).

Step 4: Determine the construction setback by adding a relocation setback to the the recession setback (step 3) to preserve the option of relocating the house. Check with a house mover for the minimum distance needed to safely bring in house moving equipment. In many locations, a relocation setback distance of 25 feet is adequate.

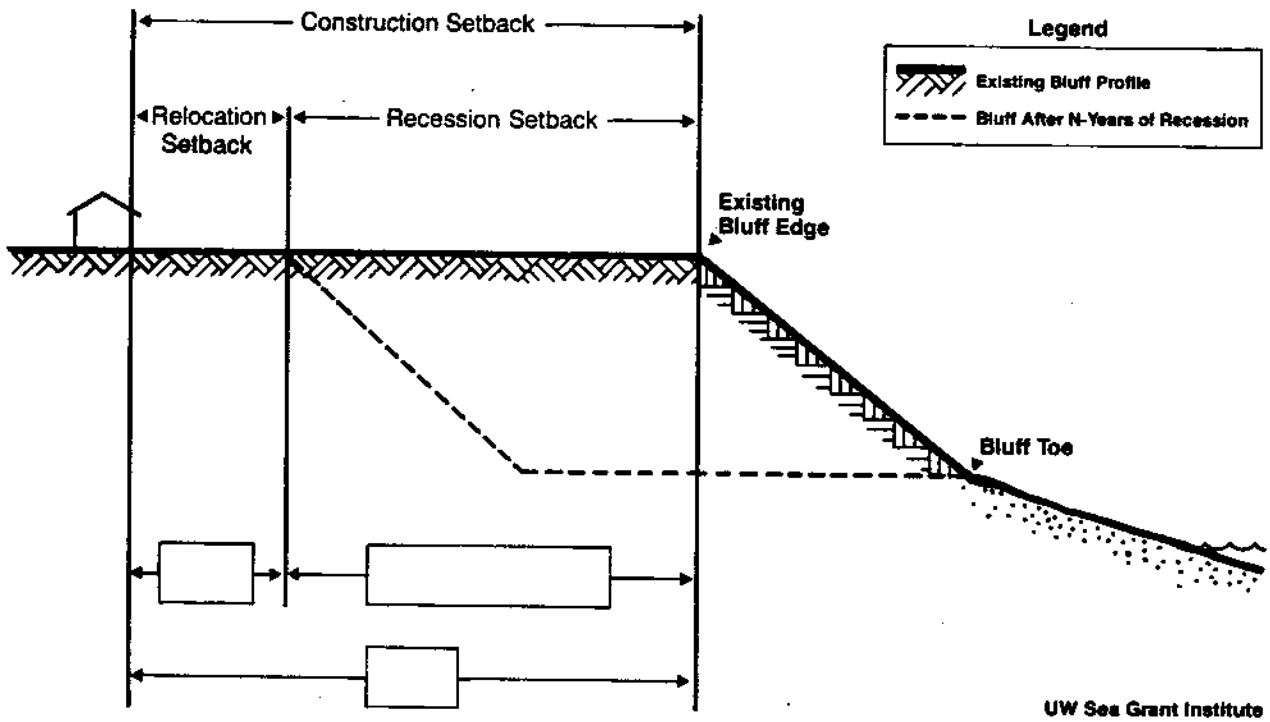
(Figure 7)

Step 1:	Recession Rate	______	feet per year
Step 2:	Time Period	x______	years
Step 3:	Recession Setback	=______	feet from bluff edge
Step 4:	Relocation Setback	+______	feet
Sum:	Construction Setback	=______	feet from bluff edge

If the selected recession rate is an accurate indicator of future recession, the construction setback distance will provide adequate protection of the property for the desired period of time. If possible, also calculate the construction setback using other documented recession rates for the area. To be safe, always use the largest calculated construction setback distance.

Figure 7

Worksheet for Estimating Construction Setback Distance for Property Without Shore Protection



UW Sea Grant Institute

Estimating Construction Setback Distance for Property With Shore Protection

Step 1: First, evaluate the effectiveness of the shore protection structure. One way to do this is to compare it to the designs shown in the Corps of Engineers Help Yourself brochure or the Ontario Ministry of Natural Resources How to Protect Your Shore Property booklet. If you are uncertain of its effectiveness, assume it is inadequate or have the structure professionally evaluated by an engineer.

If the shore protection structure has not been well maintained or it shows any of the signs of failure depicted in the Help Yourself brochure, assume the structure will soon fail. In either case, since the property essentially has no shore protection, its construction setback should be calculated as if it were a property without shore protection.

Step 2: Measure or estimate the height of the property's lakeside bluff or bank and also the horizontal distance ("A" in Figure 8) between the top edge of the bluff or bank and its toe. Note the relative (fractional) height of any evidence of groundwater in the bluff.

Step 3: Select the appropriate stable slope ratio for Wisconsin coasts from Table 4 (outside Wisconsin, consult the state or provincial department of natural resources or the local planning agency). Calculate the stable slope distance inland from the toe of the bluff ("B" in Figure 8) by multiplying the stable slope ratio by the height of the coastal bluff or bank as measured in step 2.

Step 4: Estimate the stable slope setback from the top edge of the bluff by subtracting the horizontal bluff distance ("A") from the stable slope distance ("B") calculated in step 3.

Step 5: Estimate the construction setback by adding the stable slope setback calculated in step 4 and a relocation distance (25 feet is usually adequate) for the option of moving the house later.

(Figure 8)

Step 2:	Height of Bluff	______	feet
Step 3:	Stable Slope Ratio	x______	feet/foot
Product:	Stable Slope Distance (B)	=______	feet from toe of bluff
Step 4:	Horizontal Distance (A)	-______	feet from toe to top edge
Difference:	Stable Slope Setback	=______	feet from bluff top edge
Step 5:	Relocation Setback	+______	feet
Sum:	Construction Setback	=______	feet from bluff top edge

Given the uncertainties involved in making this estimate, always consider the construction setback to be the minimum distance a building should be located from the top edge of a coastal bluff or bank.

Figure 8

Worksheet for Estimating Construction Setback Distance for Property With Maintained Shore Protection

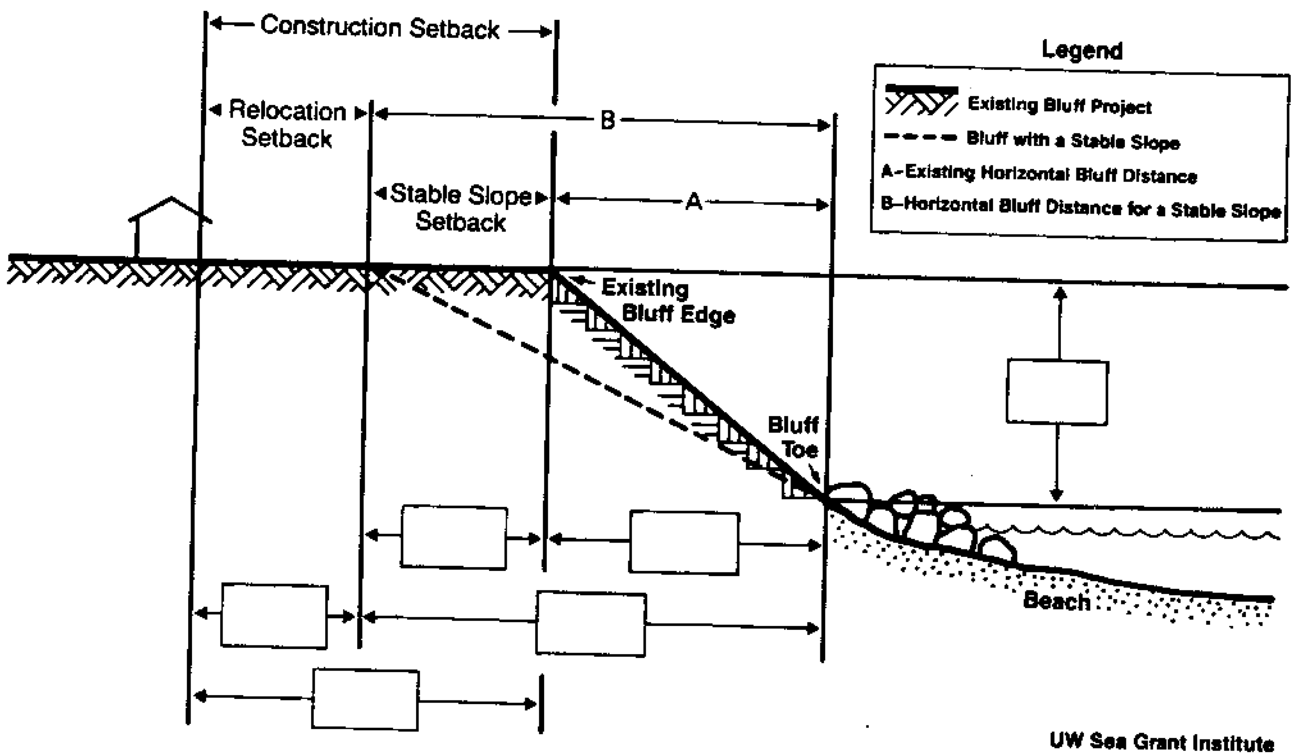


TABLE 1

Twentieth Century Record High and Record Low Great Lakes Water Levels

(Monthly Mean Levels Relative to International Great Lakes Datum 1955)

Lake	Record High Levels (above datum)			Record Low Levels (below datum)		
	Feet	Meters	Year	Feet	Meters	Year
Superior	+2.2	+0.7	1985	-1.8	-0.5	1926
Huron	4.8	1.5	1986	1.4	0.4	1964
Michigan	4.8	1.5	1986	1.4	0.4	1964
St. Clair	5.0	1.5	1986	1.8	0.5	1964
Erie	5.1	1.6	1986	1.1	0.3	1936
Ontario	5.2	1.6	1952	1.4	0.4	1934

SOURCES: June 1987 lake level bulletins, Canadian Hydrographic Service and U.S. Army Corps of Engineers.

TABLE 2

Minimum Wave Runup Values for Wisconsin's Great Lakes Coasts

Type of Shore	Runup (Vertical Height)
Beach	2.0 feet
Riprap Revetment	1.0 foot
Vertical Seawall*	2.0 feet (45 gpm/ft) 3.0 feet (4.5 gpm/ft)

* Wave runup on seawalls is treated differently than runup on beaches or revetments. These are the heights of the seawall crest above storm water levels (freeboard) that are estimated to be adequate for acceptable storm wave overtopping rates of 45 and 4.5 gallons per minute per foot of shoreline. The 45 gpm/ft rate requires a large-capacity drainage system behind the seawall. The 4.5 gpm/ft rate is more appropriate for residential properties with seawalls with drainage systems.

TABLE 3
Land Elevation Equivalents for International Great Lakes Chart Datums

Lake	Chart Datum (IGLD 1955) Feet	Chart Datum (IGLD 1955) Meters	Equivalent Land Elevation* (NGVD 1929)** Feet	Equivalent Land Elevation* (Geodetic Datum-Canada) Meters
Superior	600.0	182.9	601.0	183.0
Michigan	576.8	175.8	578.1	N/A
Huron	576.8	175.8	578.1	176.0
St. Clair	571.7	174.2	573.1	174.4
Erie	568.6	173.3	570.1	173.5
Ontario	242.8	74.0	244.0	74.1

* These conversions are inadequate for survey purposes.
** Same as Mean Sea Level (1929) elevations.

SOURCES: National Ocean Service, National Oceanic & Atmospheric Administration, U.S. Department of Commerce, and the Canadian Hydrographic Service.

TABLE 4
Suggested Stable Slope Ratios for Wisconsin Great Lakes Coastal Bluffs

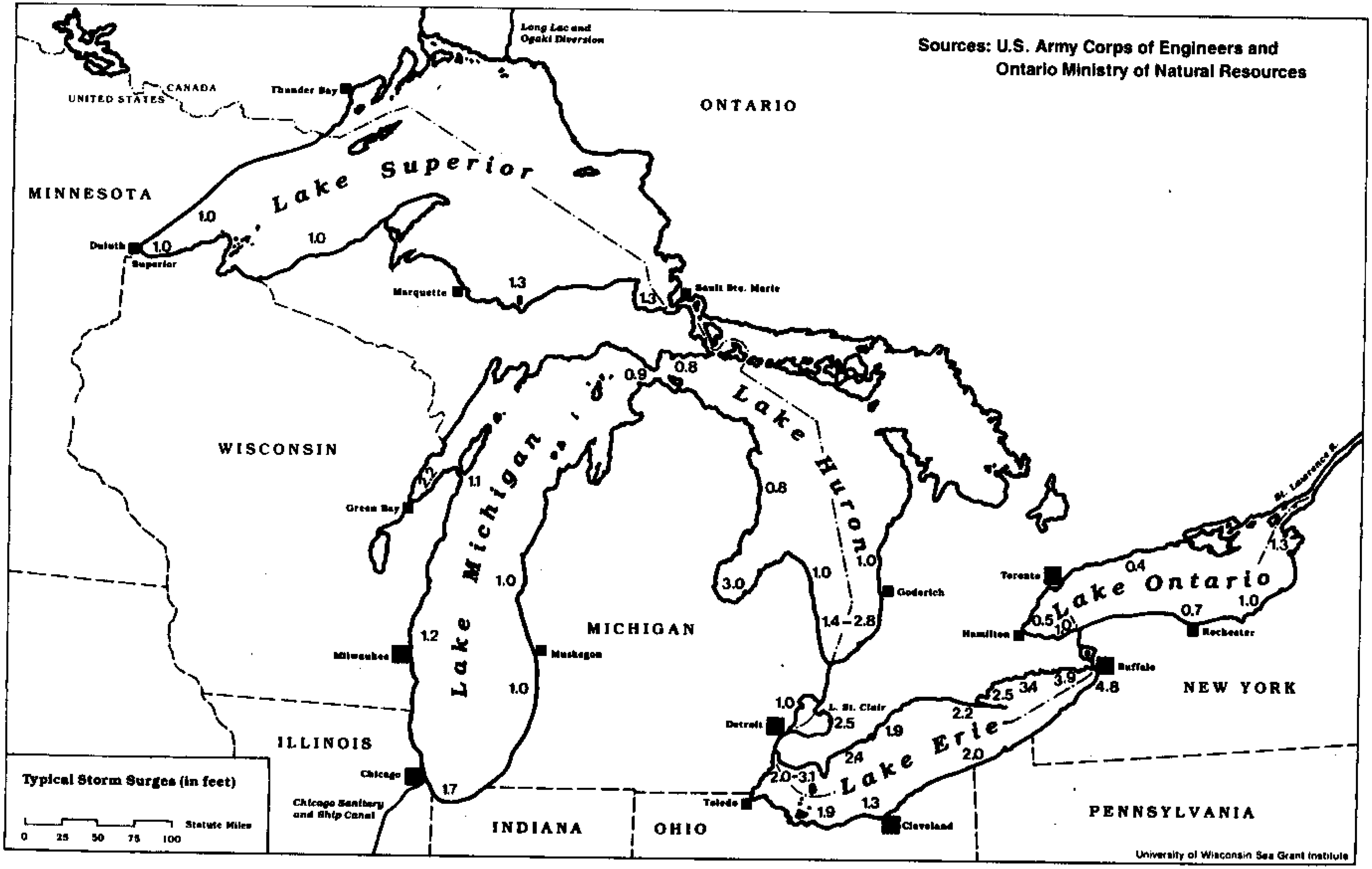
Location on Wisconsin Great Lakes Coastlines	Maximum Height of Groundwater in Bluff (H = bluff height)	Ultimate Stable Slope Ratio in Feet per Foot (horizontal:vertical)
Lake Michigan	0	1.7:1
	1/4 H	1.8:1
	1/2 H	3.0:1
	3/4 H	3.5:1
	Unknown	2.5:1
Lake Superior		
Douglas County	1/2 H	3.4:1
W. Bayfield County	1/2 H	3.6:1
E. Bayfield County	0	2.2:1
Madeline Island	0	2.6:1
Ashland/Iron counties	1/2 H	3.7:1
	Unknown	3.0:1

SOURCES: Luis E. Vallejo and Tuncer B. Edil. 1979. Design charts for development and stability of evolving slopes. Journal of Civil Engineering Design 1(3):231-52.

M.N. Schultz, T.B. Edil and A. Bagchi. 1984. Geomorphology and stability of southwestern Lake Superior coastal slopes. In: Proceedings of the International Symposium on Landslides. Toronto: University of Toronto Press.

Figure 9

Generalized Storm Surges in the Great Lakes



APPENDIX

Estimated Long-Term Recession Rates for Some Wisconsin Great Lakes Counties

(All measurements are in feet per year. N/A = not available.)

COUNTY Township	Range	Section	Long-Term Recession Rate
BAYFIELD COUNTY			
T49N	R9W	6	0.3
		5	1.4
		4	N/A
T50N	R6W	6	N/A
T50N	R7W	8	0.0
		7	0.0
		6	N/A
		5	1.6
		4	+1.1
		1	+0.3-0.9
T50N	R8W	30	2.1
		22	0.4
		21	0.0-12.7
		20	11.0-22.0
		19	N/A
		15	N/A
		14	N/A
		12	N/A
		11	0.0
T50N	R9W	36	0.1
		35	N/A
		34	1.5
		33	1.5
		25	0.0
T51N	R5W	--	N/A
T51N	R6W	34	3.3
		33	9.9-14.0
		32	2.0
		31	1.9-3.4
		29	3.8-3.9
		27	N/A
		24	0.6-1.4
		23	N/A
		22	N/A

COUNTY Township	Range	Section	Long-Term Recession Rate
BAYFIELD COUNTY (continued)			
T51N	R7W	36	+0.3-0.9
		35	+1.2-1.8
		34	0.4
		33	0.0
		27	1.7-1.8
		26	0.0-0.1
		25	N/A
		24	2.0-2.6
T52N	R5W	36	2.5
		35	0.0
		34	N/A
DOOR COUNTY			N/A
DOUGLAS COUNTY			
T49N	R10W	18	6.6
		17	N/A
		10	7.2
		9	N/A
		8	N/A
		3	6.0
		2	1.2
		1	1.3
T49N	R11W	30	N/A
		29	1.7-7.4
		28	0.4
		23	0.7
		22	1.3
		21	N/A
		14	2.7
		13	2.7

COUNTY Township	Range	Section	Long-Term Recession Rate
DOUGLAS COUNTY (continued)			
T49N	R12W	36	N/A
		35	1.6-1.9
		34	N/A
		33	N/A
		32	N/A
		31	5.9
		28	N/A
		27	3.2
		25	0.8
T49N	R13W	36	0.9
		35	0.5-1.2
		34	N/A
		28	0.7
		27	0.7
KENOSHA COUNTY			
T1N	R23E	32	9.0-12.0
		29	7.0-12.0
		20	3.0-7.0
		17	2.0-5.0
		8	4.0
		5	4.0-6.0
T2N	R23E	30	2.0-4.0
		19	2.0-3.0
		18	3.0
		5	2.0-3.0
KEWAUNEE COUNTY			
T22N	R24E	36	0.5-2.2
		25	N/A
		24	N/A
T22N	R25E	18	1.7
		7	0.4
		6	0.4-0.5
T23N	R25E	31	0.4-0.5
		30	0.6
		19	2.6

COUNTY Township	Range	Section	Long-Term Recession Rate
KEWAUNEE COUNTY (continued)			
(T23N)	(R25E)	17	1.1
		8	0.6-1.1
		5	0.6
T24N	R25E	32	N/A
		29	N/A
		28	0.3
		21	0.2-0.3
		16	0.2-0.7
		10	0.7
		9	0.7
		3	1.1
T25N	R25E	34	N/A
		26	0.5
		24	0.5
		23	0.5
		13	N/A
T26N	R26E	18	N/A
		7	N/A
		6	N/A
MANITOWOC COUNTY			
T17N	R23E	34	0.7
		27	0.3-0.7
		22	0.3-0.5
		14	0.5-2.0
		11	N/A
		1	0.3
T18N	R23E	36	0.3
		25	N/A
		24	N/A
T18N	R24E	18	0.2
		7	2.0
		5	1.0
T19N	R24E	32	1.0
		29	N/A
		20	N/A
		17	N/A
		16	N/A
		11	2.0

COUNTY Township	Range	Section	Long-Term Recession Rate
MANITOWOC COUNTY (continued)			
(T19N)	(R24E)	10	N/A
		1	N/A
T20N	R25E	--	N/A
T21N	R24E	31	N/A
		30	2.0
		25	3.0
		24	3.0
		13	3.0
		11	2.0
		2	2.0-4.0
MILWAUKEE COUNTY			
T5N	R22E	36	3.0
		25	2.0-3.0
		24	0.7-2.0
		13	0.7
		12	0.7-1.0
		1	1.0
T5N	R23E	31	3.0
T6N	R22E	36	0.3-1.0
		25	0.3-1.0
		24	1.0
		14	1.0
		10	1.0-2.0
		3	2.0
T7N	R22E	33	Harbor Breakwater
		28	Harbor Breakwater
		22	2.0
		15	2.0
		10	2.0
		3	2.0-3.0
T8N	R22E	34	3.0
		33	2.0-3.0
		28	2.0
		21	0.6-2.0
		16	0.6-1.0
		10	1.0
		4	0.2-1.0
		3	1.0

COUNTY Township	Range	Section	Long-Term Recession Rate
OZAUKEE COUNTY			
T9N	R22E	33	0.2
		28	2.0
		20	2.0
		17	2.0-3.0
		8	3.0
		5	3.0
T10N	R22E	33	3.0
		28	3.0
		21	N/A
		16	2.0
		10	2.0
		3	2.0
T11N	R22E	36	0.1
		33	N/A
		28	N/A
		25	0.1
		22	N/A
		15	N/A
		14	N/A
		11	1.0
		2	1.0
		1	1.0
T12N	R23E	30	N/A
		19	N/A
		18	0.1
		7	0.1
		6	0.2
RACINE COUNTY			
T3N	R23E	32	2.0-3.0
		28	2.0
		21	2.0
		16	2.0-4.0
		9	5.0
		8	4.0
		4	1.0-5.0
T4N	R23E	33	1.0-3.0
		27	1.0-3.0
		21	0.9-2.0

COUNTY Township	Range	Section	Long-Term Recession Rate
RACINE COUNTY (continued)			
T5N	R23E	17/16	1.0-2.0
		8/7	0.8-3.0
		6	3.0-4.0
SHEBOYGAN COUNTY			
T13N	R23E	31	0.4
		30	0.4
		20	N/A
		19	N/A
		17	0.4
		9	0.6
		8	N/A
		4	0.6
T14N	R23E	34	N/A
		33	N/A
		27	N/A
		23	0.6

COUNTY Township	Range	Section	Long-Term Recession Rate
SHEBOYGAN COUNTY (continued)			
(T14N)	(R23E)	22	N/A
		14	0.6
		11	1.0
		2	1.0
T15N	R23E	35	1.0
		26	1.0
		24	N/A
		14	N/A
		11	N/A
		3	2.0
		2	N/A
T16N	R23E	34	1.0
		27	1.0
		22	1.0-2.0
		15	1.0-2.0
		10	1.0
		3	N/A
T17N	R23E	34	N/A
		27	0.7-1.0

SOURCES: Data from Wisconsin Coastal Management Program's Shore Erosion Study Technical Report: Appendix 1, Kenosha County, February 1977; Appendix 2, Racine County, February 1977; Appendix 3, Milwaukee County, February 1977; Appendix 4, Ozaukee County, February, 1977; Appendix 5, Sheboygan County, April 1977; Appendix 6, Southern and Central Manitowoc County, April 1977; Appendix 7, Northern Manitowoc, Kewaunee and Door County Shorelines of Lake Michigan in Wisconsin, July 1980; and Appendix 9, Douglas and Western Bayfield Counties, Wisconsin Point to Bark Bay, July 1980.