

Bluff Slumping & Stability

a consumer's guide

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a consumer's guide

BLUFF SLUMPING AND STABILITY: A CONSUMER'S GUIDE

by

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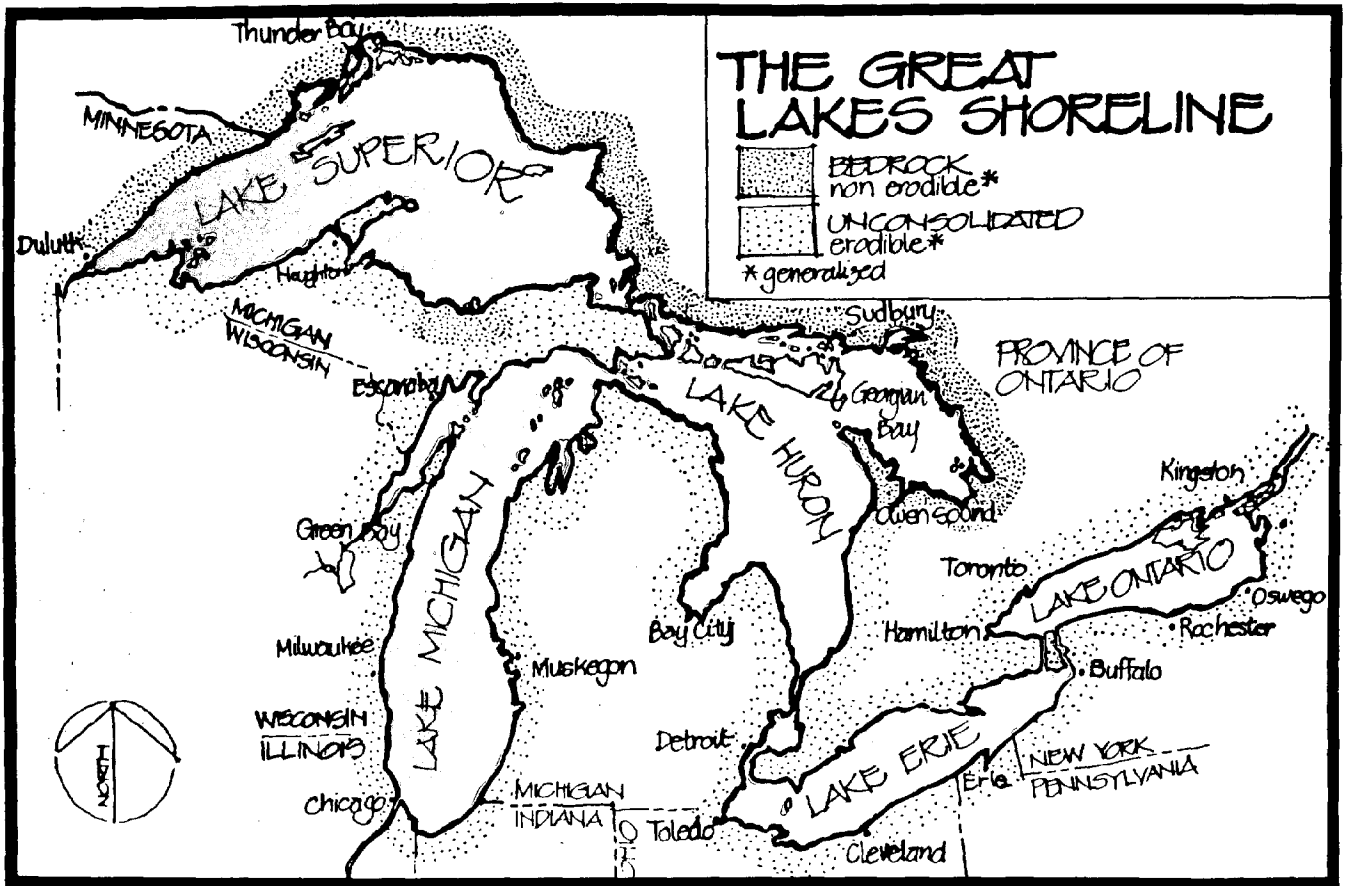
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ABSTRACT

This booklet presents issues and options in bluff stability problems for the current or prospective shoreline property owner, as well as community officials, agricultural landowners, park managers, and shore community residents. Natural forces (erosion) and human activities which contribute to bluff instability are defined. While instructions for construction of protective devices are not included, interventions which could enhance bluff stability are suggested. Land use controls, protection against wave attack, reshaping the bluff face, subsurface drainage, surface water control, and vegetation planting are explored, along with examples and case studies. A guide for assessing property is offered, and an extensive list of resources for professional help and additional annotated reading material are provided.

Getting Started



Where This Publication Came From

In 1981, the Great Lakes Basin Commission began developing information on bluff stability problems for Great Lakes shoreland owners. When the GLBC was terminated in 1981, Michigan Sea Grant, with funding from the U.S. Geological Survey, took on this attempt to help property owners along the Great Lakes shores cope with their bluff retreat problems.

So rarely is bluff stabilization a do-it-yourself proposition, that we have not tried to prepare any blueprints for installing bluff protection. Rather, the goal of this booklet is to acquaint property owners with the issues and options in bluff stability problems so that they can deal knowledgeably with professional help on these matters.

A state-of-the-art conference on bluff stability problems was the first step in the preparation of this material. This publication uses the proceedings of that conference and draws liberally from the following publications which are now difficult to obtain. Harmony With the Lake: Guide to Bluff Stabilization, Lake Michigan, Illinois, produced by the Illinois Coastal Zone Management Program for Illinois Lake Michigan coastal residents, includes extensive material on vegetation suitable to that region, and detailed drawings of surface drainage diversions. The Role of Vegetation in Shoreline Management, a Guide for Great Lakes Shoreline Property Owners is produced by the Great Lakes Basin Commission, and Help Yourself is a shore erosion pamphlet from the Corps of Engineers. In addition to these publications there are many other useful materials listed under MORE READING.

Although the information in this publication may not include any startling new advances in the state-of-the-art in erosion control, especially of bluffs, the booklet does pull together for the individual property owner all the major considerations and some applications and limitations of control measures.

Who Should Use This Publication

This information is directed primarily to the individual Great Lakes shoreline property owner interested in a permanent residence or vacation home on the property.

The discussion is also useful to:

- o community officials
- o agricultural land owners
- o park managers
- o shore community residents, who in a sense all own pieces of the shoreline and are responsible for use of public lands

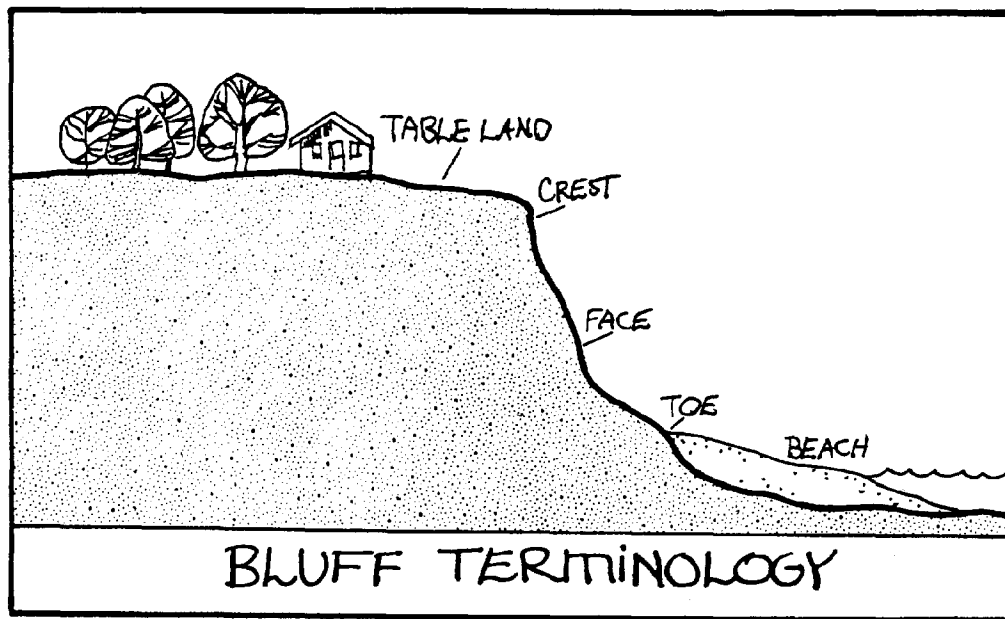
If you haven't yet developed or purchased your property, you have many more options and may save yourself a lot of heartbreak -- let alone money -- if you consider the forces at work on coastal bluffs and your land use alternatives.

If you are merely contemplating the uses you will make of your shore property, this discussion will provide a good basis for judging the suitability of various uses and what management is necessary to maintain shore property for those uses.

What This Publication Will and Won't Do

For undeveloped lands, there are guidelines based on recession rates and setback ordinances which could help people avoid problems. For more information on these types of approaches to bluff stability problems see MORE READING.

For developed lands, approaches to bluff stability problems range from relocation of the buildings to aggressive interventions such as toe protection, drainage, surface diversions, and vegetation. Intervention measures should often be used in combination with one another.



This publication will acquaint you with:

- o terminology of bluff problems and protection
- o natural forces causing instability
- o range of intervention necessary to stabilize Great Lakes bluffs

It will prepare you to work with natural forces to cope with bluff retreat.

This publication will not:

- o explain wave protection options
- o substitute for professional help in:
 - determining soil composition of your bluff
 - slope modification
 - designing and installing drainage
 - landscaping
 - designing and installing a shoreline protection system

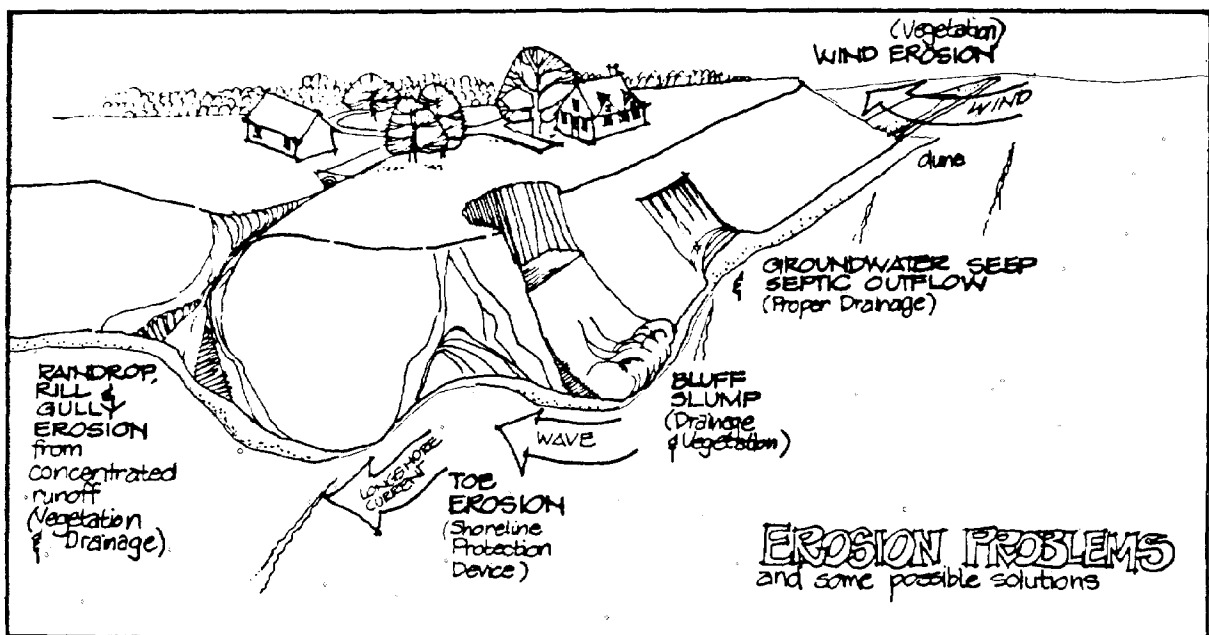
What's Happening . . .

What's Happening in the Bluff

Wind, waves and running water continue to shape the shores of the Great Lakes. Considered in a geologic time frame, the Great Lakes shore is a recent development. Erosion is a process of reshaping begun before we were here which will continue, despite our best efforts, after we are gone.

Erosion, broadly defined, is a process of degradation or wearing down of the land surface. Both surficial erosion and mass erosion are at work on the coastal bluffs around the Great Lakes. Surficial erosion is a process of particle detachment and transport by wind and water. Wind can pick up and remove fine sand and silt provided they are relatively dry. Water can carry away sand, silt, and clay particles. Mass erosion, on the other hand, involves the movement of relatively large, intact blocks of soil and/or unconsolidated sediments. Mass erosion is driven by gravity forces in conjunction with a weakening effect from the presence of water in a slope or bluff. Slumping is a particular form of mass erosion which tends to occur in clay.

Bluff erosion manifests itself in several ways. Waves can eat at the toe of a bluff undermining the upper layers. Mud may flow down the face of the bluff. Whole layers of the bluff soil may slide down the surface. In a bluff slump, a large chunk of the bluff moves down along a concave failure surface. The type of erosion likely to occur in a bluff largely depends on the bluff material and structure (e.g., stratification). This publication is concerned mainly with the landslides and slumps which tend to occur in the bluff regions characterized by clay materials.



Glacial sediments of unconsolidated deposits of clays, silts, sands, gravels, and boulders constitute shores which are prone to erosion. Left in many forms by advancing and retreating glaciers, the shoreline has considerable variety. Erosion tends to be site specific. What's happening on your stretch of the shore may differ from what's happening on adjacent property.

The key to maintaining a stable bluff or prescribing a remedial program is to recognize the factors which affect stability at a particular site and the interplay between these factors and natural forces acting on the bluff. Successful plans should answer all of the following questions:

- o Is the bluff toe protected from wave attacks?
- o What materials comprise the bluff?
- o How are soil types distributed within the bluff?
- o What is happening to soil moisture and groundwater in the bluff?
- o How is runoff water handled on the bluff top?
- o What is the angle of the bluff?
- o How is the bluff being used?
- o What vegetation grows on the toe, face, and top surface (table land)?

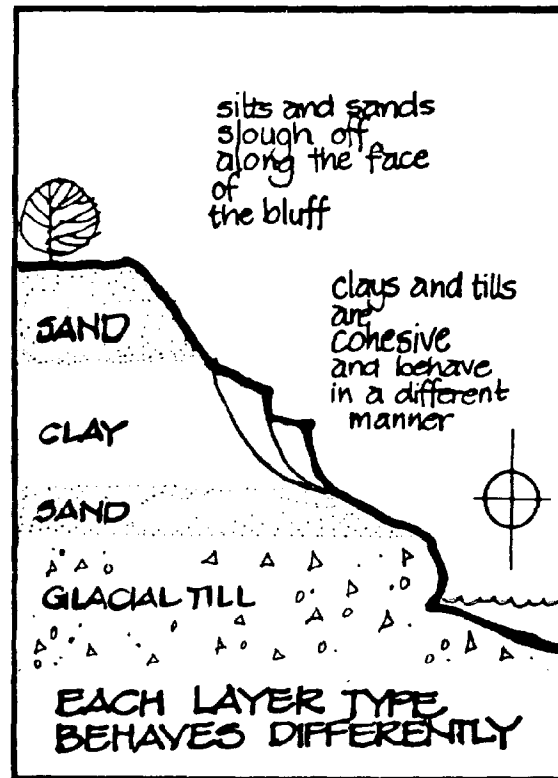
Bluff stability is a balancing act between forces within the bluff and acting on the bluff, and the resistance of bluff materials to those forces.

Gravitational and climatic forces act upon the bluff. Gravity acts via the natural weight of the soil and water in the soil and the additional weight of structures on the bluff.

Climate acts on the bluff directly and indirectly. Climate generates the storms and water levels which allow the waves to run up on the beach and attack the bluff toe. Climate provides the rain which loosens and saturates soil in the bluff.

The bluff's resistance to these forces is provided mainly by the so-called shear strength of the soil itself and by vegetation.

Shear strength is a measure of the ability of a soil to resist the forces trying to shear away pieces of a bluff or detach individual particles. Shear strength in granular soils, such as sand, is governed mainly by particle gradation and porosity. Dense, well graded sands are strongest. Shear strength of clays is more complex, but in general the lower the water content and plasticity, the stronger the clay. The stability of clay slopes is governed by shear strength, slope angle, and height. The stability of a sand slope, on the other hand, is independent of height. Quite often the stability of an entire slope will depend on the strength and location of a weak zone or layer in the slope. It is important to be on the lookout for such localized zones.



Soil moisture and groundwater conditions are critical to the stability of a bluff. Soil moisture which saturates a soil reduces shear strength and increases shear stresses. Pockets of water pressure which can develop in a slope will greatly weaken it. Seepage through a slope which emerges at the face can lead to a piping failure. This occurs in stratified slopes with water bearing seams of sand and silt--a fairly common occurrence in Great Lakes bluffs.

Water management is essential for bluff stability. Water should be diverted or prevented from entering the bluff by use of appropriate drainage measures. Water pressure within the bluff can be relieved and seepage intercepted by using horizontal drains, vertical relief wells, and drainage trenches. Planting vegetation, such as willows, also helps.

Human uses affect bluffs by altering natural resistances to the forces of gravity and climate.

Some human interventions work against the natural forces which stabilize the bluff. By building near the bluff edge, property owners add additional weight and water to the bluff, requiring additional shear strength in the soil.

By clearcutting vegetation on the face of the bluff, property owners lose vegetation benefits. Plants no longer remove soil moisture. Forces of raindrops are no longer dissipated before they slam into the soil. Nothing remains to trap moving sediments. Roots which formerly helped to bind and reinforce the soil die and become zones of weakness.

Bluff recession seldom occurs uniformly or continuously. After each slide, the slope temporarily stabilizes until the net effect of the interacting factors causes another slope failure.

A slope may appear stable, grow vegetation, and remain stationary for some time only to have a major slump many years later. In soils prone to bluff slumps, failures such as these are likely to occur within the useful lives of most buildings.

One large slump can take 50 to 100 feet of bluff with it. These slides can be dangerous as well as costly, taking lives as well as property with them.

Factors in Bluff Stability

The following factors all play a role in the stability of any particular bluff.

Wave attack -- is a major cause of bluff erosion. Waves eat at the toe of the bluff, undermining higher layers of bluff material. Eventually the force of gravity pulls the material down, sometimes bringing vegetation and buildings with it. Waves also attack beaches carrying away the protective beach material. Other publications go into the beach relationships in much greater detail than is possible here. Devices to provide protection from wave attack are discussed in these publications as well. All these devices work on the principle of dissipating the wave energy so that it cannot carry away the shoreline materials. See MORE READING.

Off shore lake depths -- help determine the size of the waves likely to run up on a particular beach, and thus whether they are likely to reach the bluff toe.

Beach width -- affects whether waves can reach the bluff toe.

Soil composition of beach and bluff -- in the beach, helps determine its resistance to the erosive forces of the waves; in the bluff, whether the bluff is clay, silt, sand, or rock determines to a great extent its natural shear resistance.

Stratification within the bluff -- is another major factor in bluff stability. Stratification is the arrangement of types of soil within the bluff, and dictates the bluff's susceptibility to groundwater problems.

Groundwater table -- The height or elevation of the groundwater table determines, in combination with the stratigraphy, slope angle, and height the stability of the bluff.

Soil moisture -- Saturated soil is much less stable because its shear resistance is greatly reduced.

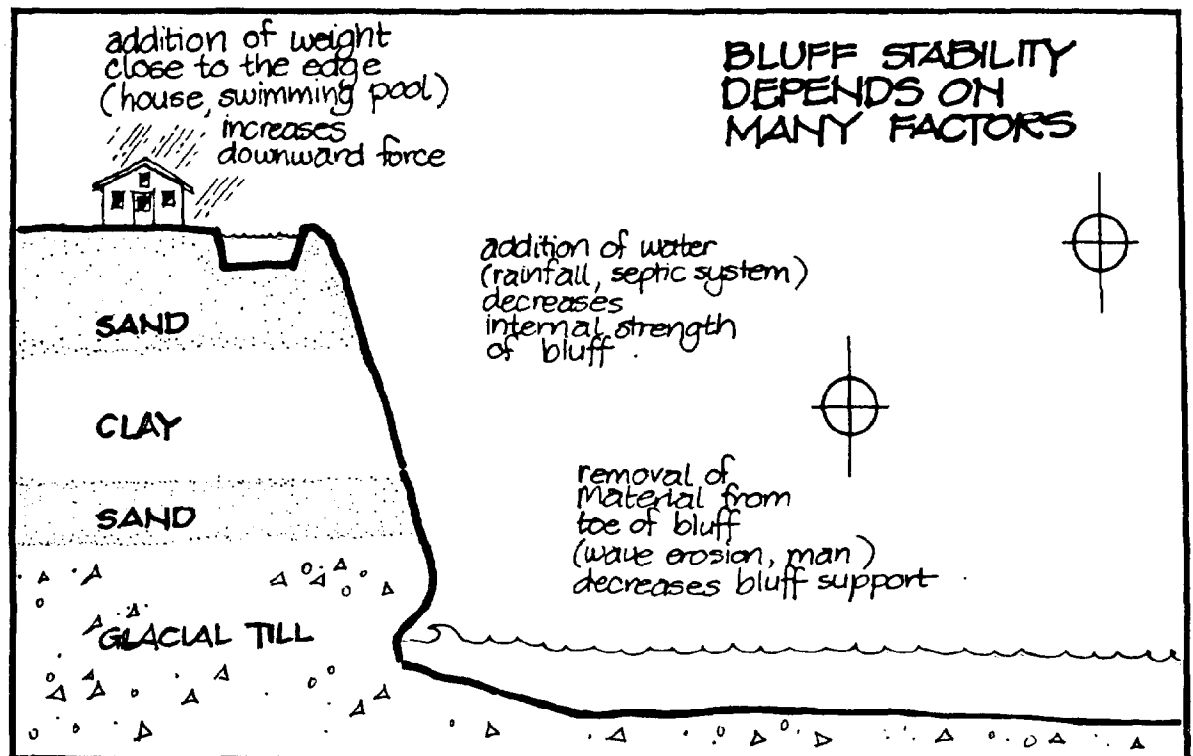
Surface drainage -- can help determine how much water seeps into the bluff. This may lead to the soil and groundwater problems outlined above; or excess water may run over the surface of the bluff carrying along bare soil and eroding gullies and rills into the bluff surface.

Use of property -- Some uses, such as traffic, compact the soil, increasing runoff problems. Lawn sprinkling can increase soil moisture problems, as can septic systems and swimming pools. Some uses destroy protective vegetation.

Vegetation -- increases bluff stability four ways. It directly removes water from the soil layers. The root systems hold soil in place. Vegetation softens the impact of raindrops which otherwise could jar loose soil particles. Vegetation slows runoff and filters out suspended sediment.

Bluff angle -- helps determine how strong an influence gravity will have on the bluff. Angle is a function of height and distance from the lake. The higher the bluff, the more materials it contains, and the more mass gravity can act upon it. The soils in high, steep bluffs must have great shear resistance to overcome this gravitational force and resist slumping.

Frost action -- includes freezing and thawing which can break up the bluff material, and solifluction which occurs in spring when frozen clays begin to melt and the thawing soil flows down the face of the slope.



Your Options . . .

• • • Erosion Damage Prevention

You are reading this publication because you are concerned about the damage that can be caused by bluff retreat.

The two major approaches to erosion problems are 1) to prevent damages and loss of life by controlling uses of erosion-prone land; or 2) to prevent erosion itself. Focus on erosion reduction leads towards emphasis on structural solutions; a land use control approach permits greater flexibility of options.

To use this publication, read through the options in damage prevention. Get a feel for what each option entails. Then use the property assessment checklist to measure your own situation. Finally, weigh the damage prevention options against your own situation.

Land Use Controls

The land use controls work better for undeveloped than for already developed lands. Tools for preventing erosion losses include: zoning, building codes, public disclosures, and land acquisition by government bodies.

Zoning

Zoning in high risk erosion areas prevents inappropriate use of these lands for human activities. Most approaches allow some uses for open space or recreation unless the risk to life is very great. A related approach is to make all developments subject to review; then such developments typically have to meet certain criteria such as setbacks or bond requirements.

Building Codes

Standards such as moveability could be required for any building located in erosion prone areas.

Public Disclosure

A public disclosure system would warn buyers of potential hazards.

Land Acquisition

Government bodies could acquire title to lands deemed most hazardous.

We have assumed that most readers of this publication already have developed property which needs protection. If, however, you are fortunate enough to have more options, consult Regulations to Control Shore Erosion listed in MORE READING for suggestions on non-structural controls of erosion damage.

Stopping Wave Attack

THE SLOPE CANNOT BE STABILIZED UNLESS
THE TOE IS PROTECTED
FROM WAVE ATTACK.

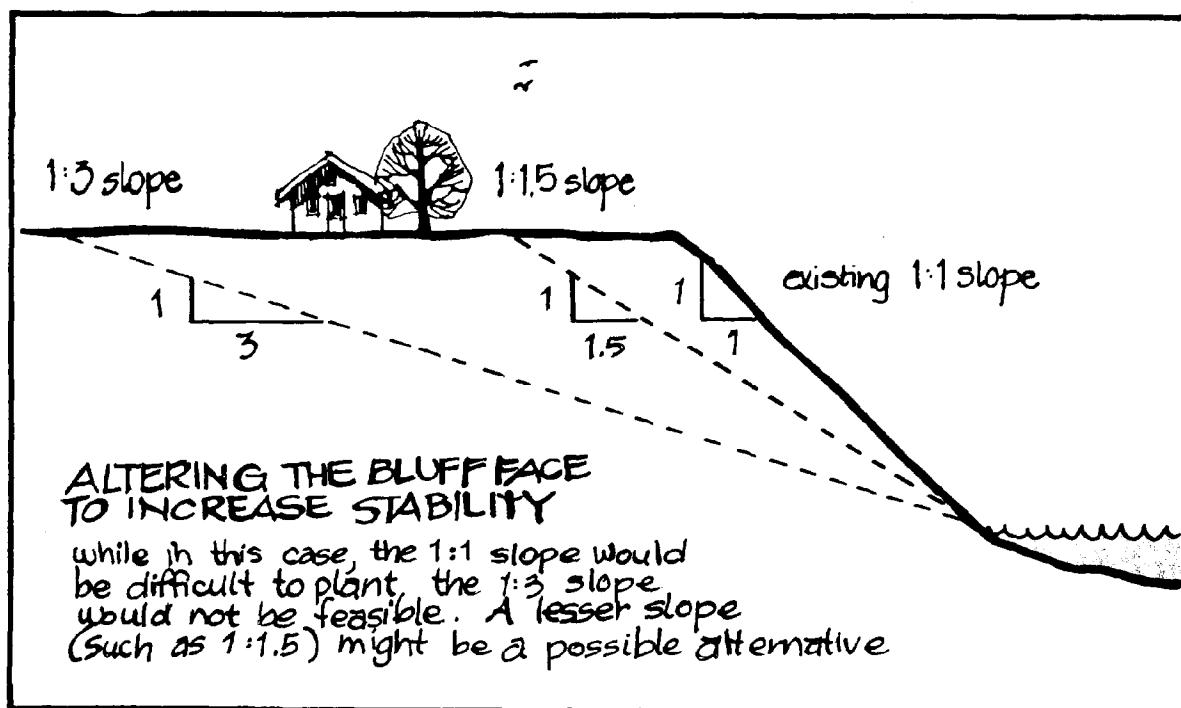
Wave attack is a major cause of bluff retreat and shore erosion around the Great Lakes, and should not be overlooked in any plan for erosion control. Other, easily obtained publications do a very thorough job of explaining wave protection options. Accordingly, individual wave protection devices won't be examined here. See MORE READING for a list of these publications.

The concept behind all wave protection options is to dissipate the energy of the waves so that they can't carry away beach and bluff material. Sea walls and revetments do this directly. Devices known as groins and beach nourishment programs either preserve existing beaches or cause the buildup of a protective beach which lets the wave energy spread itself over the beach without attacking the bluff. Wave attack problems are site specific, and individual situations must be evaluated on a case-by-case basis. Any devices must receive proper maintenance.

Reshaping the Bluff Face

Bluff stability depends to some extent on the slope of the bluff face. The degree to which any particular angle is stable depends on the soil types and the amount of water in the soils that make up the bluff.

In this publication slope angles are given in terms of rise in feet for a given horizontal distance in feet. For example, a bluff slope of 1:2 means the bluff face rises one foot over a distance of two feet. The slopes in this publication are all given in a vertical: horizontal ratio. The accompanying figure shows examples of various slopes.



To make a bluff stable, the soil and water content of the bluff material must be determined. Again, the slope angle which is stable will depend on the type of soil materials and the amount of water in the materials.

For example, a predominantly clay bluff with a high water content may not be stable even at a $1:2\frac{1}{2}$ angle. Yet the same soil, if it is dry, may be stable at slopes as steep as 1:1. Some experts use a rule of thumb of a slope of $1:1\frac{1}{2}$ as the dividing line between a bluff which can be readily stabilized and one which cannot. It depends on your particular site. On a $1:1\frac{1}{2}$ slope it is possible to establish vegetation without resorting to sophisticated professional land reclamation services. However, before wheeled equipment can be used the slope would have to be 1:3.

In many clay areas such as the red clay shores of Lake Superior, a stable slope is even flatter, about 1:3. Cutting back a bluff to that angle would mean the loss of a lot of table land. In some areas, and to many property owners, that would be totally unacceptable. In other areas, the land value and use would make the cost prohibitive.

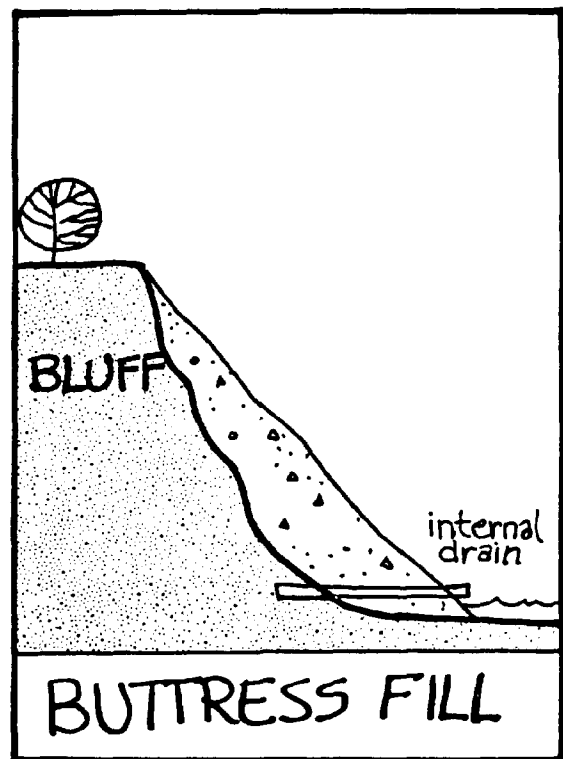
Reshaping is expensive and difficult. However, if this approach is viable for your site, there are three basic methods to recasting the slope.

All these methods work on the principle of counterbalancing forces of gravity in the slope. The methods also incorporate subsurface drainage controls. Additionally, in areas where the toe is subject to wave attack, the new bluff face needs adequate toe protection.

Buttress Fill

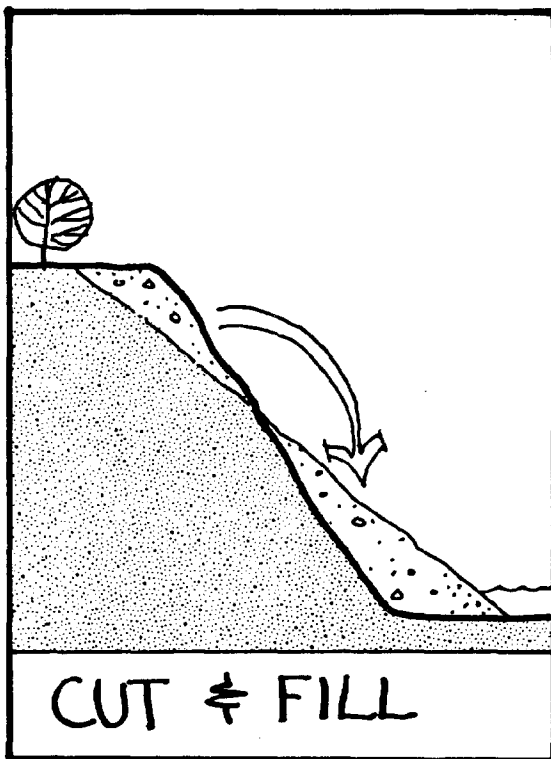
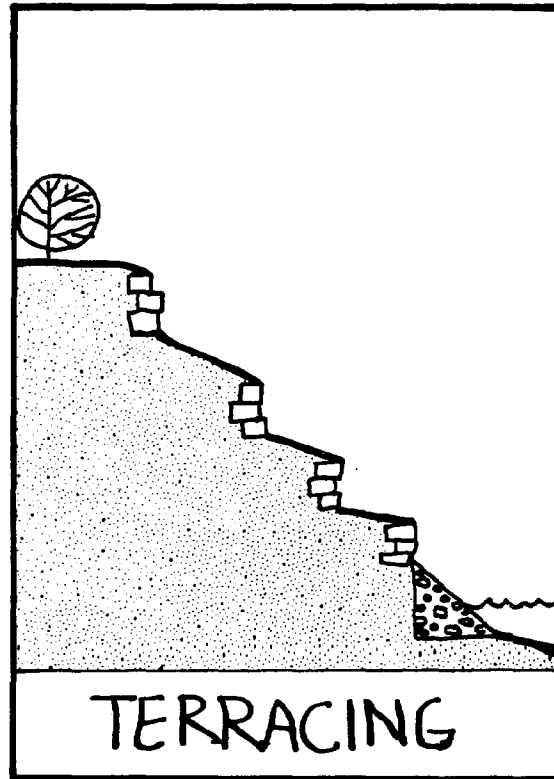
This method brings in soil, preferably select granular material, from an outside source and adds it to the base of a steep bluff so that the angle is modified. First the natural bluff must be drained, and, of course, the toe of the new slope must be protected. The fill itself must also be free draining or incorporate internal drains so as not to impede drainage from the face of the bluff.

The advantage of this method is that there is an increase in the amount of property. The disadvantage is that fill has to be available and the drainage is costly. Furthermore, in some places there is not room enough to add material to the base without having to dump some of it into the lake. That means permits will be required from the Corps of Engineers and appropriate state officials.



Terracing

A modification of the fill method is to create a series of terraces down the face of the slope with the new fill. This requires building some retaining walls, but the terraces between the walls, created with the fill, could have a slope of 1:3 which would be very stable. Again the underlying bluff must have a drainage system, and the terrace fill should allow water to percolate through the bluff to the drainage system. The terraces could support vegetation.

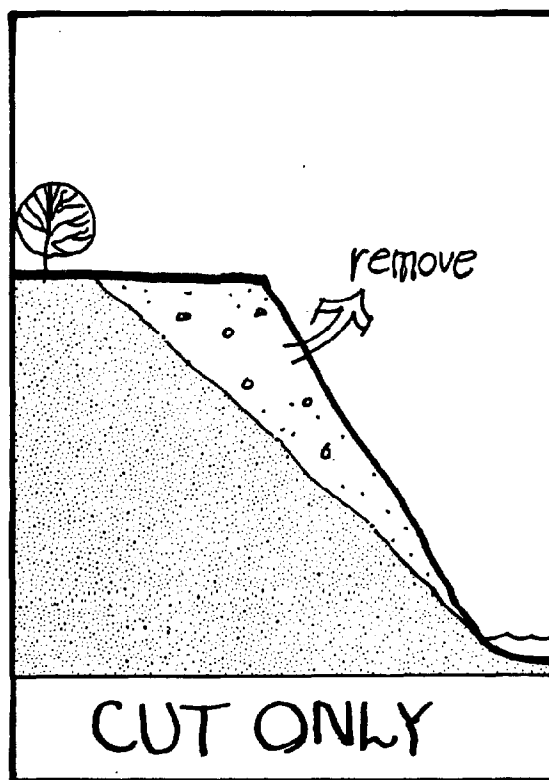


Cut and Fill

The upper unstable portion of the bluff is cut away, and that material is used as fill which is compacted at the bottom of the bluff so that the overall angle is more stable than the original face. The advantage of this method over the fill method is that the fill material is at hand. The disadvantage is that some table land will be lost.

Cut Only

Here, the bluff is excavated to a new stable angle. A large amount of material can be removed which is an advantage or disadvantage depending on whether you have a use for it, or a buyer. Otherwise its disposition can be expensive. A large amount of table land can be lost in this method. Again, subsurface drainage is usually incorporated into the method.



EXAMPLES of how these methods could be done are suggested for bluffs along the Illinois shore of Lake Michigan. Cost data is from 1979. Examples and figures are from Harmony With the Lake.

Fill Method

The natural bluff will be drained by placement of a plastic filter cloth and gravel, an 8-inch perforated collector pipe, and a 12-inch outlet pipe installed as described for the cut and fill method. An alternate method of stabilizing the bluff consists of the construction of a series of 6 to 9-foot high retaining walls (cribs or gabions) separated by a fill graded to a 1:3 slope. The horizontal distance between the walls should be 21 feet. The fill to be placed to the rear of the lower walls can be used as a working surface from which the next upper wall and section of drainage can be constructed. The areas to be filled can be filled with materials consisting mostly of sand and gravel or crushed rock to provide for drainage through the fill to the drainage system. The surface may be filled with soil to a depth sufficient to support vegetation. This method is not difficult to construct and will drain the existing slope, stop groundwater seepage, and provide stable, gradually sloping terraces which will resist erosion and support plant life. This method is particularly

useful for those bluffs with overall stable slopes, with the exception of the immediate upper bluff area. The estimated first cost for this method may be \$1,000 to \$1,700 per lineal foot if treatment of the entire bluff face is needed. If only the upper bluff wood cribbing walls are needed, these will cost some \$15 to \$45 for each linear foot depending upon the height of the wall.

Cut and Fill Method

Fill from the upper portion of the unstable bluff is excavated and compacted in the lower portion. This method drains the natural slope of the lower portion of the bluff (after it has been cleared of vegetation) by placing a maximum of four feet of coarse gravel on the filter cloth. The cloth and gravel can be placed as the lots of the fill are added. Groundwater drained from the bluff strata will be transmitted downward through the gravel layer to an 8-inch diameter perforated drain pipe to be installed parallel to the base of the bluff. Water collected in the perforated pipe will be drained to the lake by 12-inch diameter drain pipes at a slope of approximately 1:100. These outlet pipes, which are perpendicular to the bluff face, can be spaced approximately 400 feet apart. If sand and silt lenses with seepage problems occur above the fill area, a drainage method to control these, such as a horizontal drain system, may be advisable. The collection pipes for these drains may be connected to the collector pipe located at the base of the bluff. Care in compaction is a necessary engineering concern. The amount of compaction per lift and thickness of each lift of soil depends on the type of soil used for the fill. The estimated first cost for this method is approximately \$350 per linear foot.

Cut Only Method

This method of bluff stabilization consists of excavating an unstable slope to a recommended slope of $1:1\frac{1}{2}$. Any seepage zones may be eliminated by a dewatering system. In this case perforated horizontal drains are recommended. Water collected in the perforated drains should be carried in an 8-inch collector pipe to the bluff face. The water should then be carried down to the toe of the bluff through outlet pipes whether buried or carried on the surface. The estimated first cost of this method is approximately \$600 per linear foot.

Subsurface Drainage

GROUNDWATER PROBLEMS

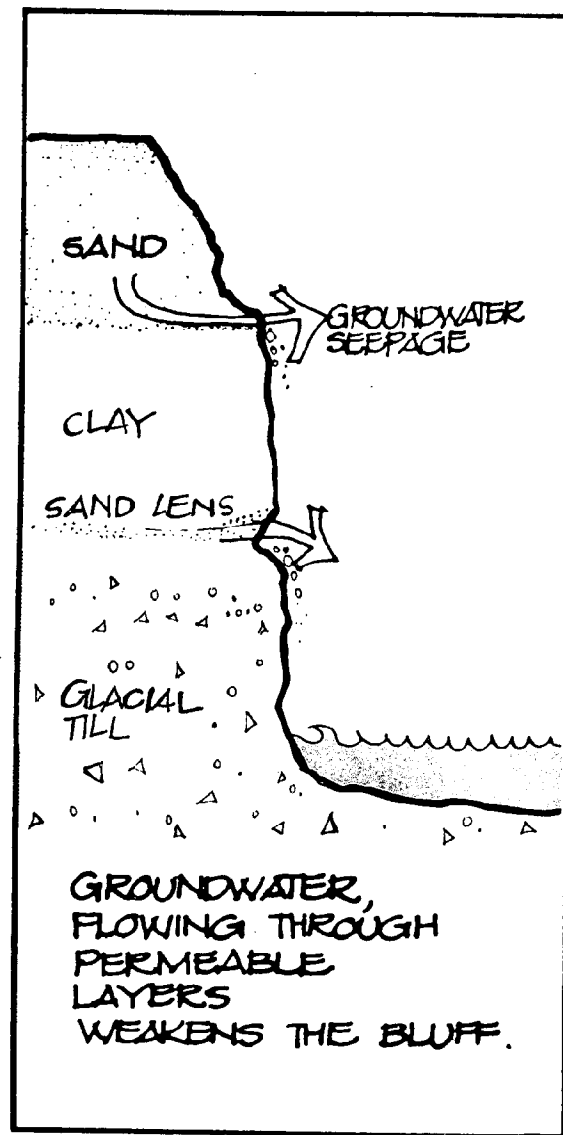
Water is the major culprit in bluff stability problems in the Great Lakes region. Many bluff stabilization efforts are a matter of managing the water.

Lake water is generally recognized as the most serious threat to stability. The erosive energy of waves and currents can be controlled, however, by toe protection.

Soil moisture and seepage can also pose a problem. The amount of soil moisture is an important determinant of shear strength and a soil's ability to resist the forces of erosion. High groundwater tables in a bluff result in high pore water pressures and seepage forces which greatly reduce stability.

Seepage is one of the most recalcitrant problems confronting shore property owners, particularly in stratified clay till bluffs. In the Great Lakes region clay strata comprising the shoreline bluffs are often interbedded with lenses of sand or silt that allow water to collect above less permeable clay layers. The water then moves laterally toward the lake and seeps out the face of the bluff. This seepage will destabilize the soil above it, and chunks of the bluff may slide down the face.

Sometimes seepage zones in a bluff are easy to detect. There may be an obvious wet spot or spring. Vegetative indicators can also be used to spot a potential problem. Plants such as horsetails (equisetum), cottonwoods, willows, and even cattails tend to grow in wet or moist zones in a bluff.



GROUNDWATER CONTROL METHODS

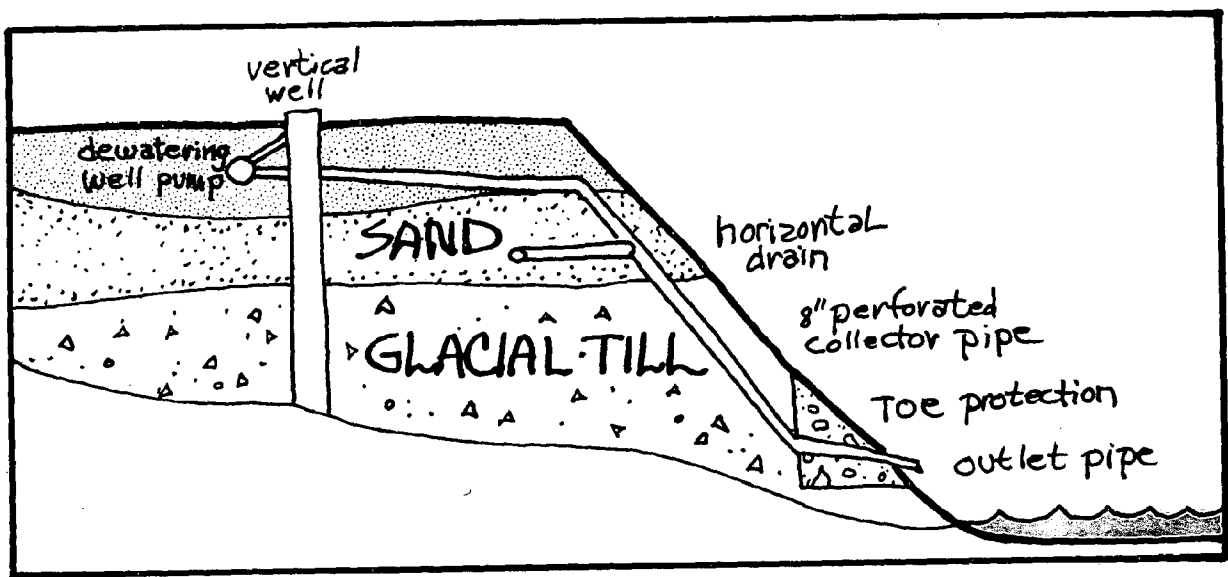
To make a bluff more stable, groundwater has to be drained out of and conveyed away from the bluff. There are several ways of achieving this goal.

Vegetation is one means of managing water on the bluff. Plants intercept raindrops and help to prevent surficial rilling and gullying. Vegetation also removes water from the soil and releases it into the atmosphere via roots, stems, and foliage.

More mechanical means of controlling groundwater in a bluff can also be employed. These include horizontal drains, vertical wells, and drainage trenches.

1. Horizontal Drain Systems

A small-diameter pipe is drilled nearly horizontally into the face of the bluff, extending back into the bluff, especially into lenses of silt or sand. A system of collector pipes, outlet pipes or ditches is usually needed to safely carry away the seepage water without further face erosion. In most horizontal drains, installation of the initial drains is merely exploratory to locating areas where additional drains should be installed. Finished projects usually space drains across the face of the bluff at 20 to 50-foot intervals. Determining the natural spacing of each drain is a lengthy, complicated process. If a substrata or sand lens drainage system is necessary, a professional geotechnical engineer is recommended.



2. Vertical Well Systems

Vertical well systems are used to improve groundwater conditions. A pump moves water to the bluff surface, and collector pipes, outlet pipes, and ditches carry the water away to some location where it can be discharged without danger of reentering the slope. Some well systems can bypass impervious soil layers, allowing seepage to drain vertically down into permeable sand and gravel at the base of the well.

3. Drainage Trenches

Drainage trenches or so called French drains can be employed to intercept and divert shallow seepage. A drainage trench consists of a narrow trench dug parallel to the edge of a bluff which is backfilled with graded aggregate. In some instances a pervious filter cloth is placed around the aggregate to prevent washout of fines into the trench. A perforated or slotted pipe can also be laid in the bottom of the trench to improve its hydraulic efficiency. Drainage trenches are effective in intercepting shallow seepage in water-bearing sands or silts which cap an underlying clay till.

A Caveat

While the drains and wells mentioned above can make a difference in layered soil, many bluff stability experts take a dim view of the capability of any engineering devices to sufficiently dewater the solid clay bluffs found along many Great Lakes shores.

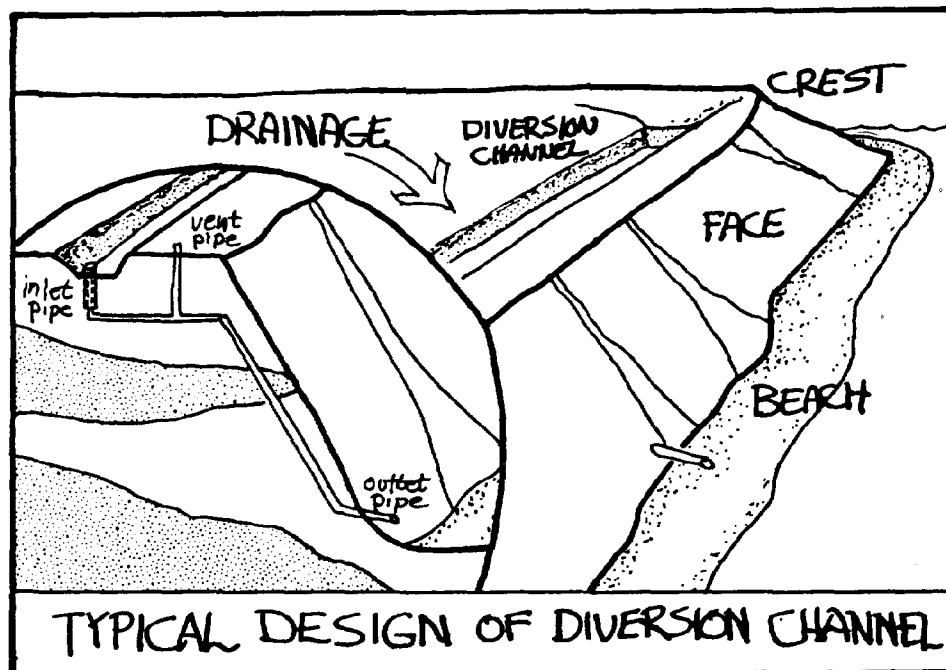
Surface Water Control

Land areas along the lake shores tend to drain toward the lakes. Unless controlled, runoff from major storms will flow over the top of the bluff and down the face carrying soil and vegetation with it.

Another problem common along Great Lakes shores is that the soil in the upper layers of the bluffs is relatively permeable, but several feet down an impermeable clay layer forms a barrier. In an intense rain storm, or after long lawn watering periods, the water saturates the soil; and above the usual groundwater aquifer, a perched water table forms. This water moves through the soil toward the lake, seeping out the bluff face. A surface drainage system can help control this problem.

Such systems usually consist of a surface water retention area (diversion channel) on top of the bluff to intercept and temporarily hold surface runoff. An outlet pipe carries the stored runoff water down the bluff face to the lake. An underground tile system or drainage trench along the bluff face is necessary to intercept the perched groundwater flow (see **SUBSURFACE DRAINAGE**). The underground system can discharge into the same outlet needed for the diversion channel.

This diagram shows a diversion/drainage system developed for Illinois shoreland areas to accommodate the excess water from a 24 hour storm likely to occur once every 10 years.



This is but an indication of the type of drainage system installed in the region. Individual conditions dictate site specific solutions. Property owners should seek professional advice before installing such systems.

The typical diversion channel design takes into consideration the area to be drained and the likely amount of water to be handled, and then specifies: 1) the required bottom width of the diversion, 2) the required size of the channel outlet pipe, 3) a choice of plastic or metal pipes to be used, 4) the depth at which the pipes should be buried to be safe from frost, and 5) support for the outlet pipe to protect it from wave attack at the lake level.

Another way to control surface water is to regrade the surface so that it slopes away rather than toward the lake, or to build a berm to divert surface water away from the bluff face.

Vegetation

Vegetation may be the last step in an erosion control program, but it is still very important because it has several critical erosion control functions and because it improves the appearance of a shore site. Vegetation also provides food and cover for wildlife.

Vegetation alone is of little use against wave attack or slumping of a bluff crest because of deep groundwater problems. Before initiating vegetation work, be sure the bluff is protected from wave attack and the slope is stable.

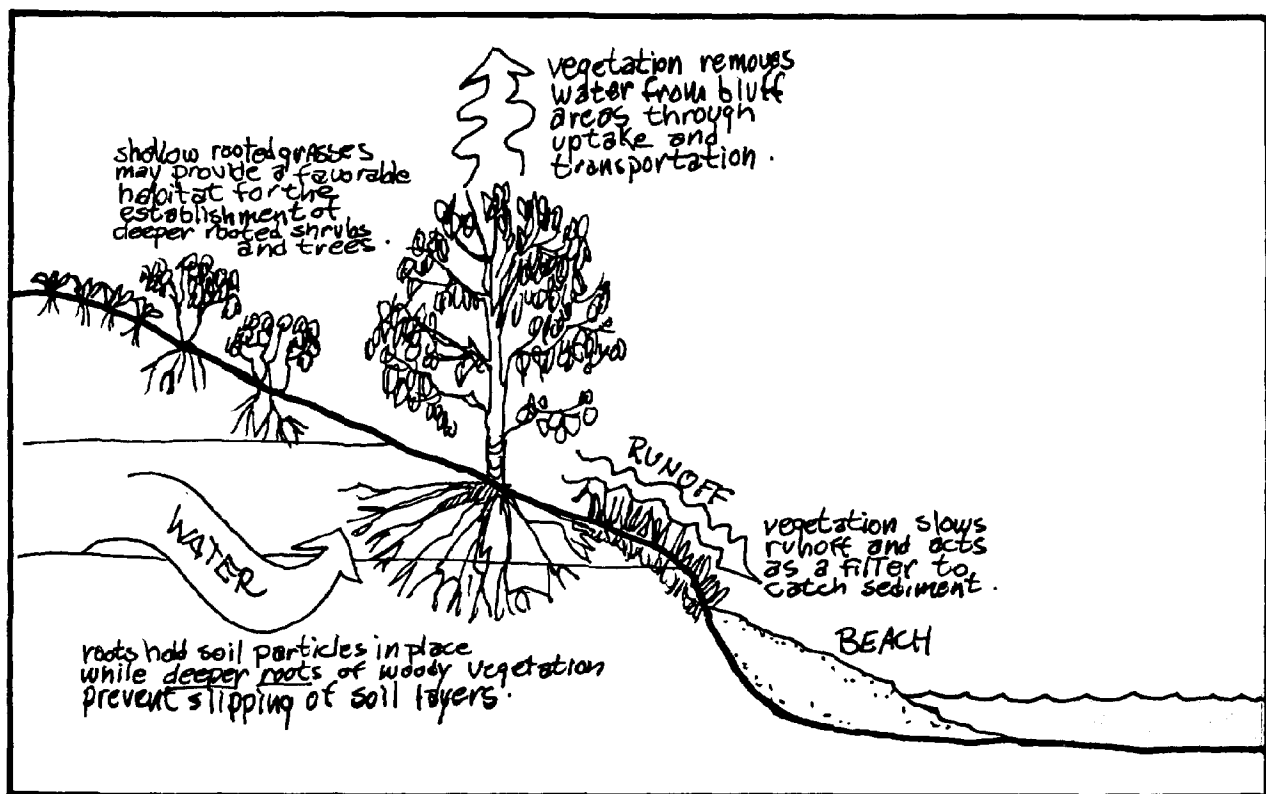
The presence or absence of vegetation is a good indicator of the stability conditions of the slope. Vegetation is extremely difficult to maintain on very steep, unstable slopes. Slopes steeper than 1:1 rarely have vegetation since the soil is not stable at such steep angles. Slumps often carry large trees to the beach along with all the grasses and other covering vegetation. If there are large seeps in the bluff face, vegetation will not establish itself readily.

Compared with the structural means of controlling erosion, establishing vegetation is inexpensive. However, when planning an erosion control program it is important to budget sufficient money for seed, nursery stock, fertilizer and mulch. Sometimes it is necessary to use professional services such as hydroseeding.

How Plants Control Erosion

Vegetation is useful in the battle against surface erosion caused by runoff and spring thaws and raindrops. Grasses trap moving soil particles and intercept raindrops.

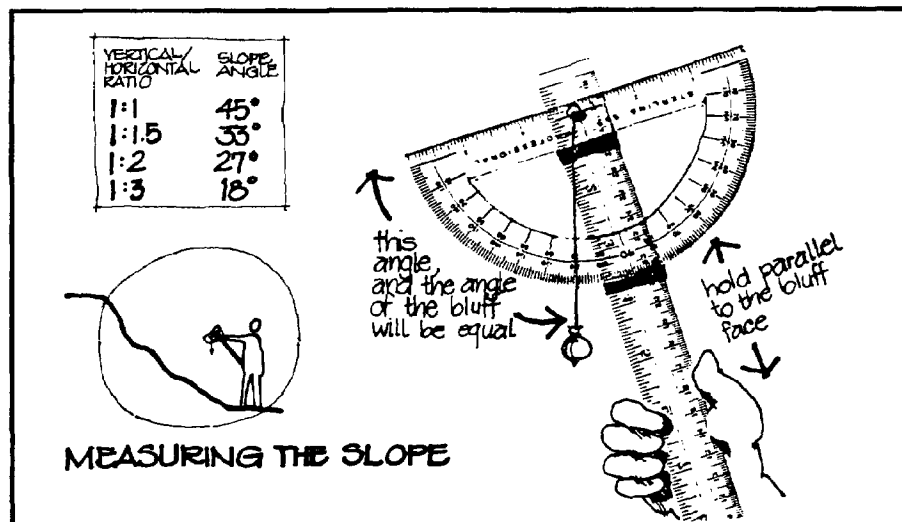
Plant root systems hold soil particles in place, and deep roots can penetrate lower soil layers where water is drawn up by the roots, through the tree to the leaves and reused into the atmosphere. This moisture removal can help stabilize the soil.



<u>Role of Vegetation</u>	<u>Type of Vegetation</u>		
	<u>Herbs</u>	<u>Shrubs</u>	<u>Trees</u>
intercept rainfall	good	good	good
retard runoff	good	poor	poor
filter surface soil particles	good	poor	poor
root penetration	very shallow to medium	shallow to medium	shallow to deep

Slope Angle

The vegetation which can be established on a slope depends on the slope angle. If that angle is steeper than 1:1, the soil is likely to be unstable and it will be practically impossible to establish vegetative cover. Slopes steeper than 1:1½ are likely to require specialized professional planting services. On slopes flatter than 1:3 it is possible to use lawn mowers so it is feasible to plant a lawn. On slopes between 1:1 and 1:3, vegetation will grow providing groundwater and wave attack problems have been corrected.



Climate

The climate of the Great Lakes coastal regions is modified by the large water mass of the lakes. Thus the hardiness zone for vegetation along the shore may be at least one zone more tolerant than adjacent inland areas. But remember that the bluff face is going to be exposed to winds and water runoff, making tough conditions for plants.

The Great Lakes region covers several latitudes and takes in several hardiness zones for plants. Your best guidance for establishing vegetation is to rely on the expertise of local people such as your county cooperative extension agent or soil conservation service. They will know which species of particular plants do well in your location.

Often you can get a clue to the type of vegetation likely to thrive in your area by looking at what thrives naturally in unmanaged areas.

Soil Limitations

Droughtiness, fine textures, claypan soils, wetness, alkalinity, acidity, shallow depth, toxicity, and nutrient imbalance all affect how well any particular species will grow in your soil.

Existing Vegetation

Survey the slope to determine what healthy vegetation currently exists on your shore property. Is it compatible with your preferred uses of the property? Often your slope will have bare patches even though the rest of the area is well vegetated. You can use selective planting to fill those areas.

Aesthetics

Plants have different colors, sizes, shapes, and textures. These characteristics can be taken into consideration for pleasing combinations of living material.

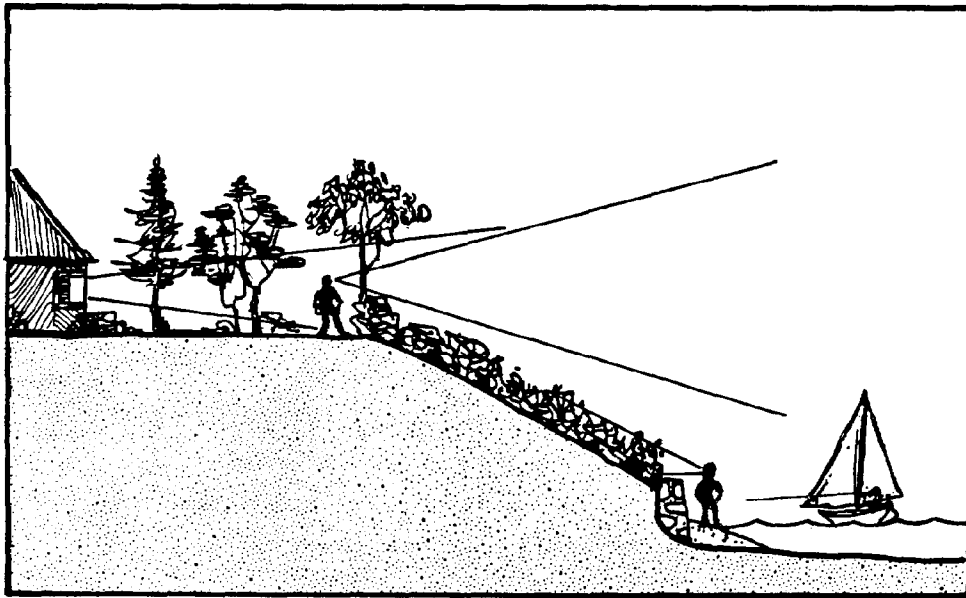
Functions

Plants can help you achieve desired effects. If a view of the lake is desired, consider the eventual height of the plants you choose. Some vegetation can help you attract wildlife, for example, chokecherry. Other vegetation can help you control traffic. Thorny brambles will discourage foot traffic over your bluff. If top soil is your goal, a fast growing species with a wide spreading root system should be chosen.

Human Activity

Success or failure of vegetation depends on the human activity to which it is subjected. Choose plants that are appropriate for the use you intend to make of your property. You might consider altering your uses to better allow the vegetation to establish itself. For example, you may need to control traffic over the bluff face with a stairway so that the plants can get started.

One major reason for living along the Great Lakes shore is to have a view of the lake. Clearcutting the trees for a better view of the lake may lead to slope failure as those roots no longer hold the soil or provide other water-removing functions. Vegetation largely determines the overall effect of the view. It is possible to use vegetation in creative ways to enhance the views you want while screening out undesirable sights and blocking the view from the beach of your house.

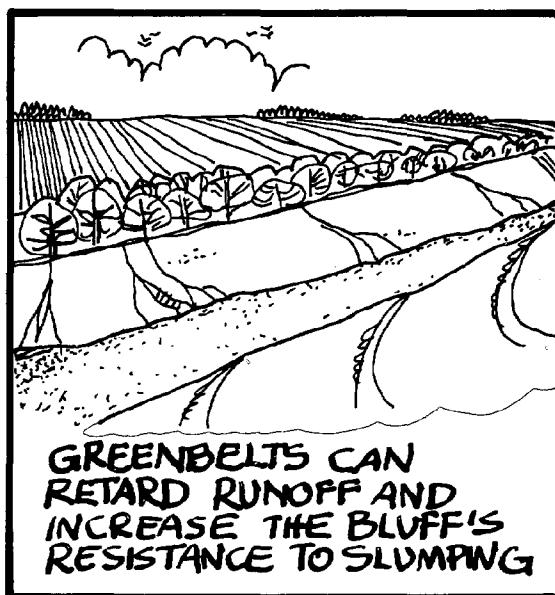


Location

Bluff Top

Vegetation on the bluff top forms a protective buffer for the bluff face. A greenbelt should be maintained along the bluff edge. Much of the Lake Michigan and Lake Erie shore is used for agriculture; for these lands, it would be too costly to reshape the bluff to a stable slope. Farmers can maintain wide strips of dense, natural vegetation along the edge. These strips control traffic, keeping it far enough away from the edge and retard runoff from plowed fields. If the bluff edge is currently cleared you should consider leaving the strips undisturbed. Shrubs and trees will naturally invade the area and reestablish the greenbelt; or you can speed the process with your own plantings.

Very large trees near the edge of a steep bluff can be a mixed blessing. If the roots are showing on the bluff side, the tree is probably unstable. When the tree topples, it may carry away a large chunk of the bluff top with it. If you have such trees, you may wish to cut them down so that they don't fall down during a storm. You can leave the roots in the bank to hold the soil temporarily until new vegetation becomes established.



Bluff Face

Vegetation traps sediment, controls runoff, and holds soil in place on the slope face. Trees, shrubs and grasses can all be used on the bluff face. If the slope is too steep to mow, consider ground covers other than a lawn.

Cottonwoods and willows can be planted as cuttings or saplings and are particularly good for seep zones and other wet areas of the slope face. However, avoid planting willows near drainage systems because the roots seek water and may eventually clog or break up your drains.

Bluff Toe

If you have sufficient beach, it is possible to establish vegetation at the bluff toe. It provides additional anchoring and some protection from all erosive processes. Willows may root in the wet soil at the bluff toe.

Native Versus Introduced Species

Both native and introduced species thrive in the Great Lakes region. Some people prefer to plant only native species; others like a combination of native and introduced plants. Some people believe native species do better than introduced species. In fact, many introduced species do very well in the region and some are free of natural enemies. Whether you should plant native or introduced species depends on the effect you are trying to achieve. If you want a "natural" look, then you may want to consider only native species. Combinations of native and introduced plants are appropriate in landscaped settings. Whichever you choose, be sure the plants meet your requirements for appearance and maintenance, and grow well under the conditions on your property.

Species Selection

Often for the same type of plant, you will have a choice of species. One species may do better than another for the particular conditions on your slope. Take into consideration the following factors:

- o ultimate size
- o rate of growth
- o ease of establishment
- o suitability to soil type and moisture levels
- o susceptibility to insect and disease problems
- o longevity
- o appearance
- o cost
- o habits such as dropping limbs in storms
- o compatibility with other vegetation

Maintenance Requirements

Some plants are carefree once established; others require constant attention for shaping, watering, fertilizing, and the like. Select plants which require no more maintenance than you are willing to give them.

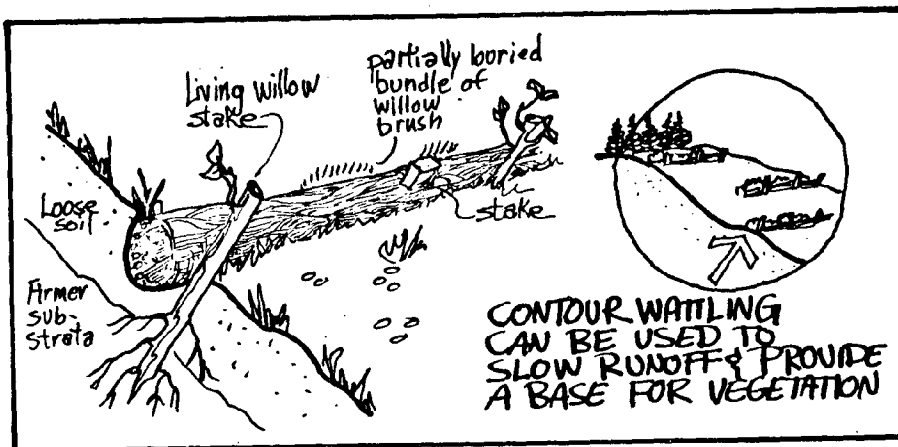
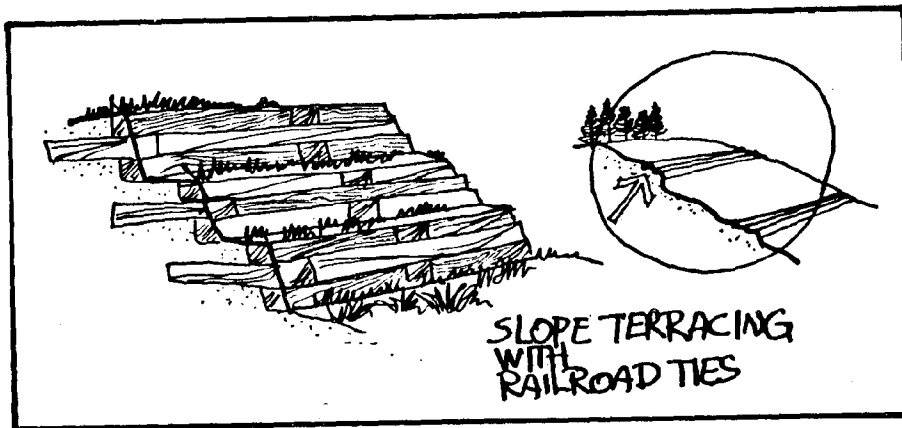
PREPARING YOUR SITE

Slope Stability

Is the slope presently stable or will it be when you add the plantings? If not, look at earlier sections of this publication for ideas on how to make it stable.

If regrading is too costly, consider gentle slope modifications which will allow vegetation to get established. One such idea is terracing discussed in the section on slope angle.

A terracing idea that uses vegetation is contour wattling. Cigar-shaped bundles of live willow cuttings are anchored into the bluff face with either construction or live willow stakes. This bundle traps surface runoff and soil particles and lets vegetation get a hold. Furthermore, the willow stakes are capable of rooting in the bluff soil if there is enough moisture. See MORE READING for details of this method including a Soil Conservation Service field trial on Lake Michigan bluffs.



Soil Tests

Before you select vegetation or plant it, find out what kind of soil you have. Is it clay? Sand? Silt? Does it tend to dry out? Or stay wet? Is it acid or alkaline? Does it need fertilizer? See HELP for soil and crop experts.

Surface Preparation

Proper surface work is essential to successful planting. Remove all debris that could smother vegetation.

Smooth out all rills and gullies. Be sure surface drainage is being controlled.

Based on your soil tests, add fertilizer and other soil conditioners.

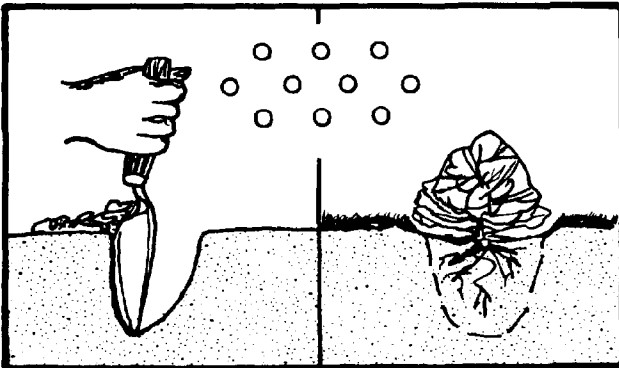
PLANTING GRASSES AND GROUNDCOVER

Seeding and Planting

Once the area is prepared, seeding and planting also should be carefully handled.

In many cases grass mixtures can be seeded by scattering the seed along the bluff face by hand.

For large scale planting and steep slopes, machines called hydroseeders which spray mixtures of seed, water, and mulch are recommended. These are generally used by the Soil Conservation Service.



Groundcovers are usually available as small container grown plants, and must be individually planted. Dig small holes with a trowel, forming a staggered pattern. The number of plants required depends on the variety of groundcover used.

Watering

Even though excess soil moisture problems can lead to a slope disaster, initial plantings and seeding often will require some judicious sprinkling and watering to get the plants going.

Mulching

Mulching is particularly important for slope plantings. Mulch protects against rain and wind while seeds are germinating and plants are reestablishing roots. Mulches also reduce moisture loss during dry spells.

The accompanying table lists common mulch materials and methods for anchoring the mulch. For more information consult references in MORE READING.

<u>Mulch Material</u>	<u>Anchoring Method</u>
Hay or Straw (1½-2 tons/acre)	peg and twine network punched into slope with spade
Jute Netting	staked according to manufacturer's specifications
Plastic Netting	staked according to manufacturer's specifications
Manure or Compost	no anchoring necessary
Glass Fiber	follow manufacturer's instructions

Timing

The Great Lakes region has a typical pattern of precipitation/dry spells which affect plant success. Your efforts to establish vegetation should take this into consideration. Seeding of grasses and legumes should be avoided in July and August because long dry periods are most likely to occur then. Legume-based mixtures should be planted as early as possible, but no later than mid-June. Grass-based mixtures can be seeded before and after July and August.

PLANTING TREES AND SHRUBS

Handling

Trees and shrubs are available four ways: as seedlings, bare-root, balled and burlapped, and container-grown. Easily transplanted species can be handled as seedlings and bare rooted. More sensitive species need to have undisturbed roots. Balled and burlapped and container-grown plants are expensive, but the plants suffer less shock from being moved and the roots are better protected from drying out. The root ball can be heavy. Thus, on a steep slope it is usually impossible to plant a balled and burlapped tree with a root ball larger than 18 inches in diameter. In any transplanting, always be careful to prevent the roots from drying out.

Spacing

For maximum erosion control, trees and shrubs should be planted after grass has been established. Plants should be spaced to prevent dense shade. Trees should be planted at least 50 feet apart and shrubs, 15 to 25 feet apart. If trees and shrubs are going to be mass planted to achieve total ground cover, then the trees can be 6 feet apart and shrubs, 3 to 4 feet apart.

Timing

Evergreens, shrubs, and small trees are best planted in spring before they have begun new growth. Plant them after the ground thaws and the air temperature exceeds 35° F. You can also plant in late autumn after the plants are again dormant, but before the ground freezes.

Fertilizer

It is not absolutely necessary, but fertilizer can be added when planting trees and shrubs. Use a small amount and be careful to prevent it from coming into direct contact with the roots. It's best to mix it into the backfill for the hole.

For information on specific formulations for particular species, consult local vegetation experts.

For more information on planting, consult any good gardening or landscaping book. Cooperative Extension Service offices, libraries, and bookstores all carry such planting guides. Also, plants are often sold with planting instructions.

This table gives suggested vegetation which is suitable throughout the Great Lakes region. For more detailed information, consult with a local vegetation expert such as your county extension or soil conservation service agent.

This information comes from **The Role of Vegetation in Shoreline Management** produced by the Great Lakes Basin Commission.

Species	Soil Moisture Types			
	Droughty	Well-Drained Good Moisture	Imperfectly Drained	Poorly Drained
Autumn Olive* (<i>Elaeagnus umbellata</i>)	X	X		
Bearberry (<i>Arctostaphylos uva-ursi</i>)	X	X		
Chokecherry (<i>Prunus virginiana</i>)		X		
Gray Dogwood (<i>Cornus racemosa</i>)	X	X	X	
Red-Osier Dogwood (<i>Cornus stolonifera</i>)			X	X
Wild Grape (<i>Vitis riparia</i>)	X	X	X	
Common Juniper (<i>Juniperus Communis</i>)	X	X		
Staghorn Sumac (<i>Rhus typhina</i>)	X	X		
Sandbar Willow (<i>Salix interior</i>)		X	X	X
Heartleaved Willow (<i>Salix cordata</i>)		X	X	X

Species				
Cottonwood (<i>Populus deltoides</i>)		X	X	
Black Locust (<i>Robinia pseudo-acacia</i>)		X		
Silver Maple (<i>Acer saccharum</i>)		X	X	X
Willow (<i>Salix spp.</i>)			X	X
Red Maple (<i>Acer rubrum</i>)		X	X	
Box Elder (<i>Acer negundo</i>)		X	X	

*Indicates introduced species

Grass and Legume Seed Mixtures

Species	Lbs/Acre
Perennial Rye Grass*	5
(<i>Lolium perenne</i>)	
Redtop*	4
(<i>Agrostis alba</i>)	
Smooth Bromegrass*	12
(<i>Bromus inermis</i>)	
Orchard Grass*	8
(<i>Dactylus glomerata</i>)	
Canada Bluegrass	8
(<i>Poa compressa</i>)	
Sweet Clover	4
(<i>Melilotus alba</i>)	
Red Clover*	6
(<i>Trifolium pratense</i>)	
	<u>47 lbs/acre</u>

This mixture can be planted in well-drained soils.

Creeping Red Fescue*	10
(<i>Festuca rubra</i>)	
Kentucky Bluegrass*	2
(<i>poa pratensis</i>)	
Redtop*	1
(<i>Agrostis alba</i>)	
Tall Fescue*	20
(<i>Festuca arundinacea</i>)	
Timothy*	2
(<i>Phleum pratense</i>)	
Birdsfoot Trefoil*	10
(<i>Lotus corniculatus</i>)	
	<u>45 lbs/acre</u>

This mixture can be planted in well-drained soils.

Reed Canarygrass	15
(<i>Phalaris arundinaceus</i>)	
Garrison Creeping Foxtail	5
(<i>Alopecurus arundinaceus</i>)	
Redtop*	5
(<i>Agrostis alba</i>)	
Birdsfoot Trefoil*	10
(<i>Lotus corniculatus</i>)	
	<u>35 lbs/acre</u>

This mixture can be planted in imperfectly drained soils.

*Indicates introduced species

SOURCES

Local nurseries will have many plant materials you can use for erosion control on bluffs.

Some state, provincial, and federal programs offer substantial discounts on obtaining materials for erosion control programs. See HELP at the end of this publication.

MAINTENANCE

Lawns

Healthy, vigorous grass will be maintained only with annual fertilizer applications. Light applications will keep an established lawn healthy. But don't overdo it or water quality problems may result. Use care to prevent fertilizer from reaching the lake.

Trees and Shrubs

Newly planted trees and shrubs require care until they are established, usually one to two years after planting. Slopes are often very dry in summer, so water the trees about twice a month. Keep competing vegetation cleared away from the base of the tree. Many plants are susceptible to insects and diseases. Healthy, vigorous plants are seldom bothered, but declining plants may be attacked. A yearly inspection and a little maintenance can keep plants vigorous. When short-lived species have been established for several years, you may wish to introduce some long-lived species.

Selective Topping and Thinning

A dense, heavily wooded slope effectively controls erosion. However, such woods often block the lake view. Selective pruning, topping and removal of some trees opens up the view without endangering slope stability. Thinning will also allow more sunlight into the existing trees which will strengthen them. Handle thinning gradually, a little bit each year. Leave brush and shrubs undisturbed. Never cut down all the vegetation at once. Clearcutting the slope will rob the slope of all the benefits of the vegetation, and make it vulnerable to erosion.

Debris

Remove all debris that is covering the soil to be vegetated. Cut down dead trees, cutting them so that they fall across rather than up or down the slope, leaving the trunk and roots in place. Remove dead shrubs. Don't use your slope as a dumping ground. Leaves, grass clippings, or other debris dumped over the edge of the slope will smother the vegetation you are trying to establish.

• • • **Checklist**

Property Management Checklist

Now that your bluff has been stabilized, what measures do you need to take to keep it that way? Here is a checklist.

- _____ Maintain toe protection. Prevent toe scour; repair damaged sections.
- _____ Keep septic system and drain field unclogged.
- _____ Maintain any drainage devices, keeping drains free of debris.
- _____ Establish suitable traffic patterns (stairs, fences, shrubbery) to protect vegetation; keep weight off the bluff edge; and prevent soil compaction.
- _____ Keep surface, face, and toe well vegetated.
- _____ Use sprinkling with care.
- _____ Consider effects on bluff stability of changes before undertaking new activities.

NOTES

Know Your Situation

Know Your Situation

Some 80 percent of the Great Lakes shoreline is privately owned. About half the private shore which is susceptible to erosion is used for residences. This means the responsibility for controlling erosion is in your hands.

How do you approach an erosion problem?

First use the site assessment checklist to learn what is happening on your bluff site. By the time you have finished filling out the assessment sheet, you will know most of the relevant information for determining what erosion problems you have.

Then you can match the natural factors you are up against with your options in erosion protection.

Finally, when you've made a decision on what to do, you can make a detailed plan of how to go about it.

Assessing Your Property - A Checklist

1. WHAT IS YOUR BLUFF SITE LIKE?

Dimensions

___ height above the water

___ width of beach between water and bluff toe

___ slope angle

Composition

Of what materials is the beach made?

___ sand ___ gravel ___ cobbles

Of what materials is the bluff made?

___ sand ___ silt ___ glacial till ___ clay ___ combinations

Make a diagram of your bluff showing the relative vertical location, depth, and thickness of the materials in the bluff.

2. WHAT PROBLEMS ARE YOU ENCOUNTERING?

Wave Action

___ waves eroding the beach ___ waves eroding the bluff toe

Are there any shore protection devices nearby?

___ on your property ___ on adjacent property

Are these devices protecting the beach?

Are neighbors having problems?

Surface Drainage

Is water running over the face of the bluff after rainfall or sprinkling?

What are your contributions to surface runoff?

___ sprinkling ___ downspouts/rain gutters

Subsurface Drainage

Do you have a septic system drain field?

Are there seep areas on the bluff face?

Are there wet areas?

Is the soil saturated during heavy rains?

Are any drains installed in the bluff? If so, do they operate correctly and is the drain outlet correctly situated to cause no further face or toe erosion?

3. WHAT VEGETATION IS AT YOUR SITE?

Toe

___ grasses ___ shrubs ___ trees

Face

___ grasses ___ shrubs ___ trees

Top

___ grasses or lawn ___ green belt ___ trees

___ no roots exposed
___ roots exposed

If there used to be vegetation on the toe, face, or top of the bluff, but it is no longer there, what happened to it?

4. WHAT USES WILL YOU MAKE OF THE PROPERTY?

Access to the beach

___foot path ___stairs ___roadways

A place from which to view the lake

Building site

5. WHAT LOCAL, STATE, AND FEDERAL RESTRICTIONS APPLY TO YOUR PROPERTY?

Once you have identified the type of property you have and the problems you may encounter, then you can determine how to handle your problems.

You Don't Have To Go It Alone

To most effectively treat shore and bluff stability problems, join together with your neighbors. Such an approach considers an entire reach of shoreline which may be subject to erosion and retreat, and avoids trying to handle a major problem with spot treatments.

There are many real savings in joining together. Property owners with shore erosion problems are rarely alone. Usually adjacent landowners have similar problems. With wave protection devices it is necessary to tie the device back into the shore or eventually the erosion problems will retreat around the outside edge of the protection causing additional problems. With groundwater problems, often the water carrying strata extends under a considerable stretch of the shoreline. Runoff water on property far removed from your own may travel along that layer of soil, seeping out the face of your bluff.

Thus, sometimes it is essential to work together to handle problems. Geological structures rarely conform very well to property lines.

Experience has shown that when property owners have tried to go it alone, the result has often been ineffective protection. Devices frequently fail because of continued erosion on adjacent properties.

Working together also may create some economies of scale in shore protection.

One effective way to band together is to create a property owners' association. Your organization's plan for shore protection should include:

- o hiring consultants
- o administration
- o site assessment
- o alternatives to be considered, both structural and non-structural
- o preconstruction planning
- o engineering considerations
- o maintenance

In non-structural approaches to shoreline coping strategies, such as zoning for appropriate uses or other creative approaches, often it is all the more important to have community-wide support to make the political institutions function for you.

For hints on how to organize for shore protection, see MORE READING and HELP.

Weigh Your Alternatives

Shore protection options range from doing nothing to a full scale, multifrontal attack on the problem.

Decisions on what actions to take should always be made by weighing the alternatives.

Do Nothing

The first alternative is to do nothing. What is the cost of letting the erosion and retreat continue? This depends to a great extent on the use of the property. In the case of home development, this is usually too costly unless a building is adequately set back from the bluff. However, alternative land uses are very viable options for lands which have not yet been developed. Over the years, the do nothing option is often the low cost option.

The do nothing option is often, psychologically, the most difficult decision to make, although sometimes economics dictates it.

Alternative Use

If you can make alternate uses of the property, despite erosion, you may wish to opt for this idea rather than invest in protective devices. Nature preserves and park lands are often compatible with erosion-prone property.

Land Management Changes

This option is one that lets you continue your original use with some small changes in practice. These practices may not stop major retreats, but they might slow erosion and they can prevent some damages. For example, many Wisconsin clay bluffs are agricultural lands. A small change in practice, such as leaving a greenbelt along the bluff edge, rather than plowing all the way to the edge, may help to slow bluff retreat at minimal cost.

It is often essential to incorporate land management changes into major erosion intervention strategies.

Relocation

The next option is to move the building. You should seriously consider this alternative because erosion is a natural process that is extremely difficult to curtail. If your erosion protection fails, you have lost your investment and you may still lose your house or cottage.

The relocation of your structure requires that there be enough land between the bluff edge and your house to move in the necessary heavy equipment. Between 15 and 20 feet of clearance are required.

You must have land which will safely accomodate your home or cottage. Thus, your lot must be deep or you must have property elsewhere, outside the erosion area.

Your building must be constructed in a way that allows it to be moved. Buildings built on slabs can rarely be moved.

Moving homes is rarely a do-it-yourself proposition. Moving your house can range in cost from a modest amount to almost as much as the cost of a new structure. Also to be considered is the cost of preparing the new site -- building a foundation, installing gas, water, and other utilities, etc.

To make a sound decision about moving a structure, you need to know the recession rate and the stable slope angle for your property so that you can determine how far back to place your structure.

Calculating Erosion Hazard Setbacks

Some Great Lakes states have adopted voluntary or mandatory setback regulations for properties. These guidelines dictate minimum distances from the lake where buildings can be located. They are set to try to prevent damage from erosion.

Recession Rates

Most setbacks are based on the recession rate. This is the rate at which the property could be expected to retreat over a given period of time. Rates are best calculated over a long term, 20 to 100 years. The rate is determined by looking at historical measurements of where the shore was in some distant, previous year and comparing that with the bluff line today. Then, you can calculate how far the bluff has retreated in the intervening years. By dividing distance by the number of years, you learn how fast the bluff may be expected to retreat. For example, if the bluff has retreated 200 feet in 100 years, the recession rate is 2 feet per year. If the setback regulation calls for a 50 year safety margin, you would want to locate any building at least 100 feet from the lake or bluff edge undergoing active erosion.

The problem with calculating recession rates in the clay bluffs susceptible to major slumps is that it is extremely difficult to determine when a major portion of the bluff could give way. For example, a Milwaukee, Wisconsin slope well protected from wave attack for at least 20 years, suddenly gave way in 1979. A major slump can take 100 feet of bluff at one time. Thus, clay bluff setbacks need to have a considerable margin of safety built into them, or a stable slope setback (see below).

Stable Slope Setback

The stable slope setback considers the angle that is stable for a particular shoreline. For example, in Wisconsin the Coastal Zone Management program recommends 1:2½ as a stable slope along the Lake Michigan shore, and 1:3 for the Lake Superior shore. The number of feet back from the base of the bluff where that angle intersects the bluff top is the minimum safe setback. For example, a 50 foot high Lake Michigan bluff would require a 125 foot setback ($50 \times 2\frac{1}{2}$). The stable angle (2½) would intersect the bluff top (50 feet high) 125 feet from the bluff toe (base).

The Erosion Hazard Setback

The erosion hazard setback takes into consideration both the recession rate and the stable slope setback. For beach areas, the recession rate determines the setback. For bluff areas, the erosion hazard setback is determined by adding the recession setback to the stable slope setback. Again, consider the 50-foot high Lake Michigan bluff with a recession rate of 2 feet per year. If the setback requires a useful building life of 50 years, then the safe minimum distance from the lake at which a building could be located would be 225 feet, 100 feet to cover the recession rate and 125 feet to account for the stable slope setback.

Active Intervention

If you have determined that the best course of action is to intervene in the shore erosion process to halt bluff retreat, consider attacking the problem in this order:

1. **Protect the toe against wave attack.**
2. **Reshape the angle of the bluff.**
3. **Drain excess groundwater and soil moisture.**
4. **Divert runoff.**
5. **Revegetate toe, face, and bluff top.**
6. **Maintain devices and vegetation, vigilantly.**

Inspect your property, using the site assessment checklist and then:

1. **Select the type and combination of controls needed to correct each specific problem.**
2. **Make a detailed plan of operations for installation of the system of controls.**
3. **Install the system starting at the toe of the slope, working to the top. Controls in the upper portion of the slope are dependent on the lower controls.**
4. **Revegetate.**
5. **Maintain.**

More Information

More Information

The following listings are suggested places where you can obtain additional help with your bluff erosion questions.

Help

UNITED STATES

U.S. Army Corps of Engineers

North Central Division

Division Engineer
U.S. Army Engineer Div., North Central
536 South Clark Street
Chicago, IL 60605

District Offices

Buffalo District

District Engineer
U.S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

Detroit District

District Engineer
U.S. Army Engineer District, Detroit
P.O. Box 1027
Detroit, MI 48231

Chicago District

District Engineer
U.S. Army Engineer District, Chicago
219 South Dearborn Street
Chicago, IL 60604

St. Paul District

District Engineer
U.S. Army Engineer District, St. Paul
1210 U.S. Post Office and Custom House
St. Paul, MN 55111

Illinois

Coastal Zone Management Program
Department of Transportation
Marina City Office Building
300 North State St., Room 1010
Chicago, IL 60610

Soil Conservation Service
Federal Building
P.O. Box 678
Champaign, IL 61820

Bureau of Soil and Water Conservation
State Dept. of Agriculture
Emerson Bldg., State Fair Grounds
Springfield, IL 62756

Indiana

Coastal Zone Management Program
State Planning Services Agency
143 West Market Street
Harrison Building
Indianapolis, IN 46204

Soil Conservation Service
Atkinson Square West
5610 Crawfordsville Road
Indianapolis, IN 46224

Indiana State Soil & Water
Conservation Committee
Rm. 7, Agriculture Administration Bldg.
Purdue University
West Lafayette, IN 47907

Michigan

Great Lakes Shorelands Section
Division of Land Resource Programs
Michigan Dept. of Natural Resources
P.O. Box 30028
Lansing, MI 48909

Soil Conservation Services
U.S. Dept. of Agriculture
1405 S. Harrison Road
East Lansing, MI 48823

Michigan State Soil
Conservation Commission
Lewis Cass Building
P.O. Box 30017
Lansing, MI 48909

Michigan Sea Grant
University of Michigan
2200 Bonisteel Blvd.
Ann Arbor, MI 48109

Local County Drain Commission
Local County Extension Director

Minnesota

Coastal Zone Management Program
Minnesota State Planning Agency
100 Capitol Square Building
St. Paul, MN 55101

Soil Conservation Service
200 Federal Bldg. & U.S. Court House
316 North Robert Street
St. Paul, MN 55101

Minnesota Soil & Water
Conservation Board
300 Centennial Building
St. Paul, MN 55155

Minnesota Sea Grant Program
Director, Sea Grant Extension Program
109 Washburn Hall
University of Minnesota, Duluth
Duluth, MN 55812

New York

New York Coastal Zone
Management Program
Department of State
162 Washington Avenue
Albany, NY 12231

Soil Conservation Service
U.S. Courthouse & Federal Building
100 S. Clinton Street
Syracuse, NY 13202

New York State Soil & Water
Conservation Committee
Box 1, 142 Emerson Hall
Cornell University
Ithaca, NY 14853

Ohio

Shoreland Management
Division of Water
Ohio Dept. of Natural Resources
Building E, Fountain Square
Columbus, OH 43224

Soil Conservation Service
311 Old Federal Building
3rd & State Streets
Columbus, OH 43215

Ohio Soil & Water
Conservation Commission
Fountain Square, Building B
Columbus, OH 43224

Office of the Chief Engineer
Department of Natural Resources
Fountain Square
Columbus, OH 43224

Division of Geological Survey
Ohio Dept. of Natural Resources
P.O. Box 650
Sandusky, OH 44870

Pennsylvania

Coastal Zone Management Program
Dept. of Environmental Resources
Bureau of Resources Programming
Third & Reilly Streets
Harrisburg, PA 17120

Soil Conservation Service
Route 19
R.D. 5
Waterford, PA 16441

Agriculture Stabilization
and Conservation
County Committee
Route 19
R.D. 5
Waterford, PA 16441

Pennsylvania State University
Cooperative Extension Service
850 E. Gore Road
Erie, PA 16509

Wisconsin

Coastal Zone Management Program
101 S. Webster
Madison, WI 53702

Soil Conservation Service
4601 Hammersley Road
P.O. Box 4248
Madison, WI 53711

Wisconsin Board of Soil & Water
Conservation Districts
Room 346
1815 University Avenue
Madison, WI 53786

Wisconsin Sea Grant College Program
Advisory Services
1815 University Avenue
Madison, WI 53706

William S. Haras
 Shore Property Studies
 Research and Development Division
 Ocean and Aquatic Affairs
 Central Region
 Fisheries & Environment Canada
 867 Lake Shore Road
 P.O. Box 5050
 Burlington, Ontario L7A 4A6
 (416) 637-4338

D. L. Strelchuk
 Engineering Services Branch
 Ontario Ministry of Natural Resources
 Whitney Block, Room 5620A
 Queen's Park
 Toronto, Ontario M7A 1W3
 (416) 965-1271

Ontario Ministry of Agriculture and Food

County	Agricultural Representatives	Soils & Crops Specialists
Essex	Essex (519) 776-7361	N. C. Laing (519) 674-5456 c/o R.C.A.T. Ridgetown
Kent	Box 726, 435 Grand Ave. W. Chatham, Ont. (519) 354-2150	
Lambton	Box 730, Petrolia (519) 882-0180	
Elgin	594 Talbot St. St. Thomas (519) 631-4700	David Norris (519) 674-5456 c/o R.C.A.T. Ridgetown
Wentworth	R.R. 1, Ancaster (416) 527-2995	Harvey Wright (519) 824-4120 Ext. 2513 c/o Crop Science University of Guelph
Huron	Box 159, Clinton (519) 482-3428	Patrick Lynch (519) 271-8280 Box 398, 478 Huron St., Stratford
Norfolk	19 Kent St. S. Simcoe (519) 426-0680	E. B. Pridham (519) 426-0680 19 Kent St. S., Simcoe
Haldimand	Cayuga (416) 772-3381	
Niagara, North	Vineland Station (416) 562-4142	
Niagara, South	574 South Pelham St. Welland (416) 732-7552	
Bruce	Box 1330 Walkerton (519) 881-3301	R. A. Upford (519) 881-3301 Box 1330, Walkerton
Gray	181 Toronto St. S. Markdale (519) 986-2040	

Halton	181 Main St. Milton (416) 453-9866	J. P. Fish (416) 895-4519 Newmarket Plaza
Peel	3 Elizabeth St. S. Brampton (416) 451-5474	
York	Newmarket (416) 895-4519	
Simcoe, North	Box 340, Elmvale (705) 322-2231	C. H. Kingsburg, (705) 435-5521 Box 370, Alliston
Manitoulin	Box 326, Gore Bay (705) 282-2043	Walker Riley (705) 474-3050 222 McIntyre St. W., North Bay
Muskoka & Parry Sound	Box 130, Huntsville (705) 789-5491	
Sudbury	1414 LaSalle Blvd. Sudbury (519) 566-1638	Walker Riley (705) 474-3505 222 McIntyre St. W., North Bay
Thunder Bay	Ontario Gvt. Bldg. 435 James St. S. Thunder Bay (897) 475-1631	
Durham	234 King St. E. Bowmanville (416) 623-3348	Neil Moore (705) 324-6125 322 Kent St. W., Lindsay
Northumberland	Box 820, Brighton (613) 395-3393	W. E. Hurst (613) 475-1630
Hastings	Box 340, Stirling (613) 395-3393	
Lennox & Addington	41 Dundas St. Napanee (613) 354-3371	G. J. Smith (613) 476-3224
Prince Edward	Box 470, Picton (613) 476-3224	
Frontenac	Box 657, 1055 Princess St. Kingston	
Leeds	Box 635, Brockville (613) 342-2124	J. C. Shelhaut (613) 258-3411 Box 2004, Kemptville
Grenville	Box 2004, Kemptville (613) 258-3411	
Dundas	Box 488, Winchester (613) 774-2313	
Stormont	Box 655, 109 11th St. W. (613) 933-1581 Cornwell	
Prescott	Box 110, Plantagenet (613) 673-5115	P. E. Beaudin (613) 673-5115 Box 110 Plantagenet
Glengarry	Box 579, Alexandria (613) 525-1046	

Sea Grant Network* Agents

Ron Kinnunen
Michigan Sea Grant Extension Agent
U.P. Extension Center
1850 Presque Isle
Marquette, MI 49855

John McKinney
Michigan Sea Grant Extension Agent
Governmental Center
400 Boardman Avenue
Traverse City, MI 49684

Chuck Pistis
Michigan Sea Grant Extension Agent
County Extension Office, Rm. 101
Ottawa County Building
Grand Haven, MI 49417

John Schwartz
Michigan Sea Grant Extension Agent
P.O. Box 599
County Building Annex
Tawas City, MI 48763

Steve Stewart
Michigan Sea Grant Extension Agent
Cooperative Extension Service
County Building, 9th Floor
Mount Clemens, MI 49043

Dale Baker
Minnesota Sea Grant
109 Washburn Hall
University of Minnesota
Duluth, MN 55812

Stephen Brown
New York Sea Grant Extension Program
129 Merritt Hall
S.U.C. Potsdam
Potsdam, NY 13676

Robert Buerger
New York Sea Grant Extension Program
66 Sheldon Hall
S.U.C. Oswego, NY 13126

David Greene
New York Sea Grant Extension
Home & Farm Center
2100 S. Grove Street
E. Aurora, NY 14052

Christine Hagerman
New York Sea Grant Extension
Cooperative Extension Regional Office
412 E. Main St.
Fredonia, NY 14063

Mike Voiland
New York Sea Grant Extension Office
Morgan III
Brockport, NY 14420

David O. Kelch
Area Extension Agent
Ohio Sea Grant Program
1575 Lowell Street
Elyria, OH 44035

Frank R. Lichtkoppler
Area Extension Agent
Ohio Sea Grant Program
99 East Erie Street
Painesville, OH 44077

Fred L. Snyder
Area Extension Agent
Ohio Sea Grant Program
1401 Walter Avenue
Fremont, OH 43240

Kim Bro
Wisconsin Sea Grant Program
University of Wisconsin
P.O. Box 505
Washburn, WI 54891

Lynn Frederick
Wisconsin Sea Grant Extension
The Walkway Mall
Sister Bay, WI 54234

Cliff Kraft
Wisconsin Sea Grant Advisory Service
E.S./105
University of Wisconsin-Green Bay
Green Bay, WI 54302

James Lubner
Wisconsin Sea Grant
Great Lakes Research Facility, 600 E. Greenfield
University of Wisconsin-Milwaukee
Milwaukee, WI 53204

More Reading

Many of these listings were gleaned from an annotated bibliography prepared by Susan Prinz as part of the original Great Lakes Basin Commission proposal for this project.

GENERAL

Dorr, John A. Jr. and Eschman, Donald 1970. **Geology of Michigan**. Ann Arbor: University of Michigan Press. Standard reference to geology of Michigan.

Environment Canada 1975. **Canada/Ontario Great Lakes Shore Damage Survey: Technical Report**. Includes methods and criteria of survey, causes of erosion, magnitude of erosion (comparing different areas and different techniques).

SHORE PROTECTION WITH EMPHASIS ON WAVE ATTACK

Fisheries and Oceans Canada/Ontario Ministry of Natural Resources 1979. **Shore Property Hazards**. Coping with the Coast Series. Available from Marine Information Center, Bayfield Lab, Box 5050 Burlington Ontario. A brochure for shore and property owners which includes a section on shore processes, a list of potential hazard indicators and descriptions of possible solutions. Also federal/provincial policy and programs.

Hanson, S. N.; Wallace, W.; and Chenoweth, R. 1978. **Great Lakes Shore Erosion Protection: Structural Design Examples**. Owen Ayres and Associates for Wisconsin Coastal Management. A report focusing on structural responses to shore erosion. Includes a general discussion of structural methods, design drawings and process, and a number of site examples in Wisconsin.

Michigan Sea Grant Program 1980. **Shoreline Erosion: Questions and Answers**. Ann Arbor, Michigan. A question and answer format brochure for property owners which includes information on shore protection structures, their effectiveness and relevant permits and laws. A glossary and sources of further information.

Michigan Sea Grant 1980. **Shore Erosion: What To Do**. Eight page brochure with the basics of how wave attack erosion occurs, and devices for preventing erosion from wave attack.

Strelchuk, D. L., ed. 1981. **Canada/Ontario Great Lakes Shore Processes and Protection**. Toronto, Ontario: Ontario Ministry of Natural Resources. Public Information Centre, Whitney Block, Queens Park, Toronto.

Strelchuk, D. L., ed. 1981. **Canada/Ontario Great Lakes Shore Management Guide**. Toronto, Ontario: Ontario Ministry Natural Resources. Public Information Centre, Whitney Block, Queens Park, Toronto.

- U.S. Army Corps of Engineers, North Central Division 1978. **Help Yourself.** A property owner's brochure which includes a map of generalized shore types, a guide for selecting shore protection, permit requirements, and the advantages and disadvantages of various solutions, primarily structural in orientation.
- U.S. Army Corps of Engineers 1982. **Low Cost Shore Protection.** An overview of the various low cost shore protection devices tested in a nationwide demonstration project.
- U.S. Army Corps of Engineers 1982. **Low Cost Shore Protection: A Guide for Property Owners.** Detailed information to prepare the property owner to cope with shore erosion problems. Booklet covers the various protection devices and pros and cons of various systems. To obtain this publication, get the one above from any Corps of Engineers office and send in the postcard in the back.
- U.S. Army Corps of Engineers 1982. **Low Cost Shore Protection: A Guide for Engineers and Contractors.** To obtain this publication, get the overview publication from any Corps of Engineers office and send in the postcard in the back.
- U.S. Army Corps of Engineers 1982. **Low Cost Shore Protection: A Guide for Public Officials.** To obtain this publication, get the overview publication from any Corps of Engineers office and send in the postcard in the back.

BLUFF RETREAT

- Berg, Richard C. and Collison, Charles 1976. **Bluff Erosion, Recession Rates, and Volumetric Losses on the Lake Michigan Shore in Illinois.** Illinois Geological Survey, Environmental Geology Notes. Number 16. Study of erosion, recession rates and volume losses on bluffs of Illinois Lake Michigan Shore; specific data. General conclusions about contributing factors.
- Conservation Foundation. 1980. **Coastal Environmental Management: Guidelines for Conservation of Resources and Protection Against Storm Hazards.** John Clark, Project Director. Washington, D.C. Chapter 4 includes a brief discussion of slumping phenomena and three management policy recommendations: 1) alteration of bluff-top danger zones, 2) alteration of the slope, and 3) protection for the toes of bluffs. The report is available through the Government Printing Office.
- DeYoung, Bruce and Brown, Larry 1979. **Controlling Bluff Groundwater Along the Great Lakes.** Six page fact sheet which explains the role of groundwater in bluff instability and gives examples of drainage systems to correct this problem. Available from New York Sea Grant Extension Program, Fernow Hall, Cornell University, Ithaca, New York 14853. 15¢ each.

- Edil, Tuncer B. and Vallejo, Luis E. 1976. **Shoreline Erosion and Landslides in the Great Lakes.** University of Wisconsin Sea Grant Program. Advisory Report No. 15. A study using field and laboratory investigations of six active bluffs to perform a stability analysis and establish models of slope evolution.
- Edil, Tuncer B. 1980. **Control of Coastal Landslides.** In **Proceedings of the International Symposium on Landslides**, Vol. 3, New Delhi, India. Describes the natural coastal landslides and possible methods of control, primarily engineering solutions with only a brief mention of non-structural alternatives.
- Gray, Donald and Tainter, Suzanne, eds. 1982. **Bluff Slumping: Proceedings of a State-of-the-Art Assessment Workshop.** Michigan Sea Grant report, MICHU-SG-82-901. Collection of papers, and recapitulation of discussion at a state-of-the-art workshop held February, 1982.
- Hadley, David W. 1976. **Shoreline Erosion in Southeastern Wisconsin.** Wisconsin Geological and Natural History Survey. Special Report Number 5. Includes a description of the geology of Wisconsin's Lake Michigan shore, mechanisms of bluff slumping, and briefly discusses possible solutions; indicates areas for research and the importance of a good data base.
- Illinois Coastal Zone Management Program 1979. **Harmony With the Lake: A Guide to Bluff Stabilization.** Division of Water Resources, Illinois Department of Transportation, Room 1010, Marina City Office Building, 300 North State Street, Chicago, IL 60610. A pamphlet which describes processes of erosion, identifies shore types on the Lake Michigan shoreline of Illinois, and explains in practical detail a variety of mitigation techniques.

CITIZEN ACTION

- Burke-Griffin, Barbara 1979. **Racine County Coastwatch Program: Final Report.** County Planning and Zoning Department and Wisconsin Coastal Management Program. A report on a volunteer/public involvement program set up to monitor shore erosion. Primarily evaluates the program's effectiveness and specific problems. For further help on setting up a similar program, see Gabriel.
- Gabriel, Stephen R. 1980. **Implementing A Beachwatch and Sand Dune Development Program: A Community Handbook.** City of Ocean City, N.J. Excellent handbook of "how-to" for community involvement in monitoring and improving coastal hazard areas in New Jersey dunes/beach environment.

PERMITS, REGULATIONS AND PLANNING GUIDES

- Butler, Kent; DeGroot, Robert; Greenwood, Mark; and Thomas, David 1978. **Feasibility of Compensation for Man-Induced Shore Erosion.** Wisconsin Coastal Management Program. Part I - Summary report, including brief analysis of legal and administrative options for gaining erosion compensation (insurance, tax relief, legal actions), feasibility of relating human activities to erosion, and options for the individual and the state. Part II - Legal options including theory, standing and evidence requirements. Part III - Relation of human actions, such as lake level regulation, shore protection structures, upland land management, and navigation, to erosion.
- Fisheries and Oceans Canada/Ontario Ministry of Natural Resources 1978. **Canada/Ontario Great Lakes 100-year Flood and Erosion Prone Area Maps.** Public Information Center, Whitney Block, Queens Park, Toronto.
- Fisheries and Oceans Canada/Ontario Ministry of Natural Resources 1978. **A Guide for the Use of Canada/Ontario Great Lakes Flood and Erosion Prone Area Mapping.** A discussion of Canada's hazard mapping project -- includes its uses, development, definitions, and criteria for determining areas of risk.
- Illinois Department of Transportation 1979. **Lake Michigan Shoreline Erosion: A Report To State Officials.** Briefly discusses the erosion problem in Illinois, and the development of the Lake Michigan Shore Erosion Protection Plan, and makes recommendations regarding planning principles, several specific sites, and future actions.
- Michigan Department of Natural Resources 1979. **Great Lakes Shoreland Erosion.** Division of Land Resource Programs. A brochure which discusses Michigan's Shorelands Protection and Management Act as it applies to high risk erosion areas; includes discussion of some of the costs associated with erosion, methods for determining rate and extent of process, and restrictions and standards for new development on shore.
- Pennsylvania Coastal Zone Management Program 1975. **Shoreline Erosion and Flooding: Erie County, Pennsylvania.** Department of Environmental Resources. Extensive field study of erosion and flooding in Erie County, PA, which includes a very good discussion of contributory mechanisms.
- Roden, Robert W. 1977. **Some Non-structural Alternatives for the Reduction of Shore Damages.** Wisconsin Coastal Zone Management Program, Wisconsin Department of Natural Resources. A fairly detailed description of non-structural responses to coastal hazards including warning/disclosure mechanisms, land use controls/zoning, delineation of a hazard zoning district, zoning administration, insurance, relocation of buildings, and public acquisition of hazard areas.

- Schultz, Carol J. 1979. **Erosion Hazard Areas: An Option for Shore Management.** Wisconsin Geological and Natural History Survey, University of Wisconsin Sea Grant Institute. A further development of Wisconsin's Shore Erosion Plan which focuses on non-structural approaches; includes good assessment of discussions of delineating hazard areas and potential management strategies.
- Springman, Roger and Born, Steve 1979. **Wisconsin's Shore Erosion Plan: An Appraisal of Options and Strategies.** Wisconsin's Coastal Zone Management Plan. A policy plan which assesses structural and non-structural options for reducing shore erosion damage in Wisconsin, including discussion of present framework, possible policy responses (regulation, financial, and technical assistance), and several valuable appendices.
- U.S. Army Corps of Engineers. **Permit Program: A Guide for Applicants.** EP 1145-2-1
- Yanggen, Douglas A. 1981. **Regulations to Reduce Coastal Erosion Losses.** Wisconsin Coastal Zone Management Program, State Office of Planning and Energy, GEF II, 101 South Webster Street, Madison, WI 53702. This report discusses the use of zoning and subdivision regulations to adjust land use to erosion hazard, and legal factors that should be considered in regulatory policies. Part II includes some erosion provisions that can be included in zoning ordinances.

VEGETATION

- Gray, Donald H. and Leiser, Andrew T. 1981. **Biotechnical Slope Protection and Erosion.** Van Nostrand Reinhold Co. 1981. A book describing the combined use of vegetation and structures to deal with slope and erosion problems.
- Gray, Donald H.; Leiser, Andrew T.; and White, Charles A. January 1980. **Combined Vegetative-structural Slope Stabilization. Civil Engineering.** Brief descriptions of techniques for erosion control using both vegetative and structural components. Includes contour wattling, staking of willow cuttings, and conventional plantings used in conjunction with retaining structures.
- Great Lakes Basin Commission* **The Role of Vegetation in Shoreline Management: A Guide for Great Lakes Shoreline Property Owners.** Ann Arbor, Michigan. Following a general discussion of coastal problems and the role of vegetation, this brochure includes a checklist for identifying particular shoreland problems, guidelines for shoreland planning and design with vegetation, and a plant list.
- Great Lakes Basin Commission joint with U.S. Department of Agriculture, Soil Conservation Service* 1977. **Proceedings of the Workshop on the Role of Vegetation in the Stabilization of the Great Lakes Shoreline.** Ann Arbor, Michigan. A look at the roles vegetation plays in shoreland management.

*Basin Commission no longer in existence. Federal depository libraries may have the reports.

Glossary

Angle of Repose - The angle that the bluff makes with the lake.

Beach - Zone of sand or gravel extending from the low water line to a point landward where either the topography abruptly changes or permanent vegetation first appears.

Bluff - High, steep bank at the water's edge. In common usage, a bank composed primarily of soil. See CLIFF.

Boulders - Large stones with diameters over 10 inches. Larger than COBBLES.

Breakwater - Structure aligned parallel to shore, sometimes shore-connected, that provides protection from waves.

Clay - Extremely fine-grained, cohesive soil with individual particles less than 0.002 millimeters in diameter.

Cliff - High, steep bank at the water's edge. In common usage, a bank composed primarily of rock. See BLUFF.

Cobbles - Rounded stones with diameters ranging from 3 to 10 inches. Cobbles are intermediate between GRAVEL and BOULDERS.

Crest - Upper edge or limit of a bluff or shore protection device.

Cross Section - View of a structure or beach as if it were sliced by a vertical plane. The cross section should display structure, ground surface, and underlying material.

Current - Flow of water in a given direction.

Cut and Fill - Method of reshaping the bluff contour by removing bluff material from higher portion and adding it to lower region to change the angle of repose.

Dune - Hill, bank, bluff, ridge, or mound of loose, wind-blown material, usually sand.

Equilibrium - State of balance or equality of opposing forces.

Erosion - Wearing away of land by action of natural forces.

Face - Front surface of the bluff which faces the lake.

Filter Cloth - Synthetic textile with openings for water to escape, but which prevents passage of soil particles.

Glacial Till - Unstratified glacial drift consisting of unsorted clay, sand, gravel, and boulders, intermingled.

Gravel - Small, granules of rock with individual diameters ranging from 3 down to 0.18 inches. Gravels are intermediate between SAND and COBBLES.

Groin - Shore protection structure built perpendicular to shore to trap sediment and retard shore erosion.

Groundwater - water within the pores between soil particles; usually, a permanent groundwater table is evident; this is the source of water for wells and springs; if water percolating through the soil encounters barriers before reaching the permanent groundwater table, a perched water table may form.

International Great Lakes Datum (IGLD) - Common reference datum for the Great Lakes area based on mean water level in the St. Lawrence River at Father Point, Quebec and established in 1955.

Landslide - any movement of soils down the bluff; major forms are translational slides and SLUMPS; translational slides are generally shallow and have a planar sliding surface.

Lens - a pocket of sand or silt in a less permeable layer of soil.

Littoral Material - Sediments moved in the LITTORAL ZONE by waves and currents. Also called littoral drift.

Littoral Transport - Movement of LITTORAL MATERIAL by waves and currents.

Littoral Zone - Indefinite zone extending from the shoreline to just beyond the breaker zone.

Low Water Datum (LWD) - The elevation of each of the Great Lakes to which are referenced the depths shown on navigation charts and the authorized depths of navigation projects.

Marsh - Area of soft, wet, or periodically inundated land, generally treeless, and usually characterized by grasses and other low growth.

Nearshore - In beach terminology, an indefinite zone extending seaward from the shoreline well beyond the breaker zone.

Perched Water Table - table of groundwater which forms when excess groundwater collects in a soil layer more permeable than the layer below it, but above the usual groundwater layer.

Permeable - Having openings large enough to permit free passage of appreciable quantities of (1) sand, or (2) water.

Polyvinyl Chloride (PVC) - Plastic material (usually black) that forms a resilient coating suitable for protecting metal from corrosion.

Profile, Beach - Intersection of the ground surface with a vertical plane that may extend from the top of the dune line to the seaward limit of sand movement.

PVC - see POLYVINYL CHLORIDE.

Revetment - Facing of stone, concrete, etc., built to protect a scarp, embankment, or shore structure against erosion by waves or currents.

Riprap - Layer, facing, or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also, the stones so used.

Rubble - (1) Loose, angular, waterworn stones along a beach. (2) Rough, irregular fragments of broken rock or concrete.

Runoff - excess water from rain, lawn sprinkling, swimming pool splashes, etc. which rather than soaking into the ground, instead runs off the slope.

Runup - The rush of water up a structure or beach on breaking of a wave. Amount of runup is the vertical height above stillwater level that the rush of water reaches.

Sand - Generally, coarse-grained soils having particle diameters between 2 and 0.075 millimeters. Sands are intermediate between SILT and GRAVEL.

Scour - Removal of underwater material by waves or currents, especially at the base or toe of a shore structure.

Seawall - Structure separating land and water areas primarily to prevent erosion and other damage by wave action. See also BULK-HEAD

Seepage - Water which leaks out the face of the bluff usually from a LENS or PERCHED WATER TABLE

Shallow Water - Commonly, water of such a depth that surface waves are noticeably affected by bottom topography. It is customary to consider water of depths less than one-twentieth the surface wave-length as shallow water.

Shear Strength - Ability of soil to resist forces trying to shear away pieces of the bluff or detach individual particles.

Shore - Narrow strip of land in immediate contact with the sea, including the one between high and low water lines. A shore of unconsolidated material is usually called a beach.

Shoreline - Intersection of a specified plane of water with the shore or beach (e.g., the high water shoreline would be the intersection of the plane of mean high water with the shore or beach). Line delineating the shoreline on National Ocean Survey nautical charts and surveys approximates the mean high water line.

Silt - Generally refers to fine-grained soils having particle diameters between 0.075 and 0.002 millimeters. Intermediate between CLAY and SAND.

Slope - Degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating 1 unit vertical rise in 25 units of horizontal distance; or in degrees from horizontal.

Slump - Usually, a deepseated movement of a whole chunk of a bluff; its soil moves down and rotates, leaving behind a concave depression. The bluff looks like a giant ice cream scoop was used to scoop out a portion of the bluff, and then the scoop was dumped at the foot of the bluff.

Specifications - Detailed description of particulars, such as size of stone, quality of materials, contractor performance, terms, and quality control.

Solifluction - Downslope flowing movement of water-saturated soil in a previously frozen slope.

Stillwater Level - Elevation that the surface of the water would assume if all wave action were absent.

Surface Water - Rain, snow melt, lawn sprinkling, and any other additions of water to the soil surface.

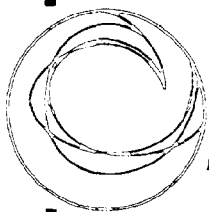
Subsurface Water - Surface water after it has soaked into the ground, or additions made to soil below the surface such as from a septic system drain field.

Table Land - The top surface of the bluff; the sort of bluff land used for building.

Toe - The base of the bluff where it meets the beach, or if there is no beach, the lake.

Topography - Configuration of a surface, including relief, position of streams, roads, buildings, etc.

Wave - Ridge, deformation, or undulation of the surface of a liquid.



MICHIGAN SEA GRANT
MICHU-SG-82-902

