Lake Erie Shore Erosion

The two primary shore erosion processes at work along Ohio's Lake Erie shoreline are **wave erosion** (which removes material from the beach) and **mass wasting** (which removes material from an adjacent bluff). Rates of erosion are highly variable and may range from as low as 1 foot per year to as high as 5 to 15 feet per year (Carter et al. 1987). The lower rates are usually found where hard bedrock meets the water, with higher rates where soft marsh and clay substrate form the lakeshore.

Many factors determine the rates of shoreline erosion. The weather influences the size and frequency of waves striking the shoreline, and therefore the force directed against it. The physical setting – shore orientation, presence or absence of a beach or man-made structures, coastal geology – also contribute to the variability of shore erosion.

**WAVE EROSION**

Wave erosion is the primary coastal erosion process at work on the Ohio shoreline. Wind blowing across Lake Erie transfers energy to the water and generates waves, and much of this energy is released when the waves break on the shoreline.

Although waves come in all sizes, they all have essentially the same characteristics. Every wave has a top (crest) and a bottom (trough). The **height of a wave** is measured vertically from the wave’s crest to its trough. **Wave length** is measured from any point on one wave to that same point on the next wave; for example from the crest of one wave to the crest of the next wave, or from trough to trough. **Wave period** (wave speed) is the time it takes a wave, trough to trough or crest to crest, to travel the distance equal to one wave length. Waves with a short period are moving up and down very quickly, so the transition from trough to crest to trough happens more quickly for a short-period wave than for a long-period wave.
A good rule of thumb is that a wave will break when the depth of the water is four-thirds of the wave height. A one-foot wave will break in 16 inches of water, while a three-foot wave will break in water four feet deep. When waves break against the shore, the amount of released energy is dependent upon the slope of the bottom and the wave height: the steeper and smoother the bottom slope, the more abruptly a wave will slow down and break, thereby releasing more energy and causing greater damage.

The amount of energy in a wave is proportional to the square of the wave height, and the higher the wave, the more energy it contains. This means there is a four-fold increase in energy for a two-fold increase in wave height. For example, a two-foot wave with a period of five seconds between crests contains over 4,000 foot-pounds of energy per foot of wave crest. A four-foot wave (two times the height) with the same period contains over 16,000 foot-pounds (four times the energy) of energy per foot of wave crest.

A series of two-foot waves with a five-second period will break upon the shoreline at a rate of 720 waves and a total of over 2.9 million foot-pounds of energy per hour. In one 24-hour day this adds up to 17,280 waves and more than 70.7 million foot-pounds of energy per foot of shoreline. This uncontrolled energy continuously erodes material away from the shore, transporting material along the shoreline and cutting away at the shore.

However, wave energy arriving at the shoreline is not constant. Wind blows neither continuously nor always from the same direction, so the supply of energy varies from place to place along the coast and with time at each location. Wide beaches, shallow nearshore slopes and nearshore bars cause large waves to break and expend much of their energy offshore. The resulting smaller waves reaching the shore then contain less energy and cause less shoreline erosion.

Weather directly influences coastal erosion rates because it affects the size of wave-related forces. Storm-generated winds can increase erosion rates due to temporary high water levels (storm surges) and large waves. For example, on November 12-13, 2003, westerly storm winds along the 242-mile length of Lake Erie created a 13-14 foot difference in water levels when measured simultaneously at Toledo, Ohio and Buffalo, New York. These are some of the highest water level differences recorded on Lake Erie. More erosion occurs during storms and high water levels than at any other time.

Ice can have a moderating effect on erosion because it protects the nearshore area from late winter storms and waves. Nearshore ice eliminates waves reaching the shore as waves from the open lake break on the off-shore ice, not the beach. A solid sheet of ice covering the lake prevents wind from affecting the surface of the water, thus preventing the formation of waves. However, once the ice sheet has broken, this moderating effect goes away. With a trend towards less ice on the Great Lakes, the loss of the moderating effect of winter ice can lead to increased erosion of the shoreline.

MASS WASTING (BLUFF SLUMPING)
Mass wasting, when large masses of the shoreline drop down toward or into the lake as a single chunk of material, is seen in northeastern Ohio, where erosion-prone bluffs meet the lakeshore. This downward movement has various and sometimes complex causes. Waves may erode the foot (also called the base or toe) of a bluff, reducing the stability of the material above. Surface water can compound the problem by adding weight at the top, and by reducing the bluff’s resistance to shear stress. Groundwater seepage (water within the bluff) acts as a lubricant between sediment layers and further reduces the stability of a bluff. When this occurs, the material in an upper layer may slide downward in one mass. Rain saturating a bluff can increase the rate of erosion in a similar fashion. Rain also produces runoff that causes surface erosion, creates gullies and ravines, and steepens bluffs.
Erosion by mass wasting does not happen every year but it may follow a specific sequence of events. Wave action removes material from the toe (base) of the bluffs, steepening and eroding the bluff face. Winter is a fairly static period because of freezing temperatures and lakeshore ice. In the spring, frequent rains, storm runoff, increased groundwater levels, storm waves and increasing seasonal water levels cause already eroded bluffs to become unstable, and mass wasting or slumping may occur. As long as wave energy carries material away from the base of a bluff and groundwater saturates the bluff material, the bluff will continue to recede. The rate of recession, however, is not constant because of several factors, one of which may be that the amount of wave energy reaching the shoreline is not constant, but varies with the weather, lake levels, and the physical setting of the shoreline. Storms may temporarily raise lake levels and flood beaches, thus allowing large waves to reach the shore and directly erode the toe of a bluff. The nature of the shoreline material being eroded (resistant rock, human-constructed shore protection, movable sand etc.) is also a major influence on how much and how fast the shoreline and/or the bluff erode. 

While wide beaches always serve as protective barriers against erosion, the same cannot be said of man-made structures – even those built for that purpose. Many bulkheads and seawalls do slow wave-based erosion, but others can actually make the problem worse. Poor design and/or construction of a shore protection structure may turn a minor erosion problem into a severe one. A built structure may worsen erosion problems at the site where it has been constructed, or it may increase rates of erosion of a neighbor’s property. Vertical seawalls may deflect erosive wave forces down, removing beach material from in front of the seawall. Other structures may trap sand in one area (protecting that location) but prevent material from moving away, denying this protection to other areas of the lakeshore. 

A discussion of erosion is not complete without considering the nature of the material being eroded. Softer, loose material like clay, silt and sand erode more easily and quickly than more durable materials like shale and limestone rock. Indeed, the makeup of the shoreline is one of the most crucial variables affecting erosion rates. 

There are two key ideas in considering shoreline erosion: 1) along Lake Erie, shore erosion is very site-specific depending on site conditions, and 2) highly variable depending on weather, lake levels, storms and other factors acting together to influence shoreline erosion. These factors include the nature of the material being eroded, the physical setting of the shore, the presence or absence of protective beaches and/or man-made shore protection devices, geographic shore line orientation and its exposure to waves, lake levels, and the weather. Many shoreline property owners are faced with erosion problems and must make decisions concerning this issue. Any effort to slow down and lessen the effects of this natural process requires time, money, and effort, and providing shore protection at one location may just move the problem downdrift to the adjacent property. Thus it is particularly important for coastal property owners to learn and understand as much about shore erosion as possible. A good place to start is the ODNR–Office of Coastal Management web site at: http://www.dnr.state.oh.us/coastal.

Large waves are reaching the shore and breaking against shore erosion devices, while smaller waves break on the sloping beach at Fairport Harbor Beach. Taken looking east towards Painesville Township Park. Lake County, Ohio, during Super Storm Sandy on October 30, 2012.

FOR MORE INFORMATION ON EROSION, CONTACT: 
ODNR Office of Coastal Management 105 West Shoreline Drive Sandusky OH 44870 419-626-7980 1-888-OHIO-CMP (toll free) coastal@dnr.state.oh.us coastal.ohiodnr.gov

References