Chapter 11

Coastal Structures Along Lake Erie

Many natural factors have affected the development of Lake Erie's coast during the last 10,000 years—glaciers, waves, ice, geologic conditions and sand resources to name a few. But during the last 200 years, the major influence shaping Ohio's Lake Erie coast has been the installation of man-made coastal structures intended to promote safe navigation, commerce and recreation. These structures, along with measures to control erosion and prevent the loss of property have forever changed Ohio's north shore.

Upon statehood in 1803, there were few coastal structures along Ohio's Lake Erie shore. In the 1870s, 68 percent of the mainland shore had beaches, a significant percentage of which were wide sand beaches used for travel along northern Ohio. Over time, however, commerce on Lake Erie brought about the need to develop ports and harbors to meet the growing trade in commercial goods.

Navigation Structures

Throughout the 1800s, Ohio developed ports and harbors at most of its major Lake Erie tributaries to support the growing commercial needs of the nation. Coastal structures such as jetties and breakwaters were built at or near the mouths of most of Ohio's rivers. These structures served to provide protection from wave forces for vessels entering and using ports along Lake Erie, a safe harbor for vessels seeking protection from storms, and protection for the port facilities themselves. Depending on their location, jetties and breakwaters were also used to trap sand moving along the shore to prevent shoaling which could prove to be a navigational hazard. Other structures, such as bulkheads and wharfs, were installed within harbors and ports so commercial and recreational vessels could make better use of the lake.

Shore Structures

Coastal structures were also used to address the needs of a growing population that wanted to live along the Lake Erie coast. The lake and beaches attracted people to the shore, and ever increasing areas of the shore were developed with homes and businesses. In many places the dynamics of the coastal area were not well understood, and erosion and flooding caused extensive damage and loss of property. To prevent or slow erosion of the shore, groins were installed to trap sand and maintain beaches. Seawalls and revetments were placed in many locations to reinforce bluffs and protect against wave and ice forces, and dikes were used to prevent flooding in lower lying areas.

Effects of Coastal Structures

While homes and businesses constructed near Lake Erie created economic opportunities, their accompanying coastal structures created changes to the composition of the shore—not all of which were positive. Jetties and breakwaters designed to protect harbors trapped substantial amounts of sand that formerly moved along the shore. This resulted in the creation of wide beaches updrift of the harbors, but downdrift areas were left with a deficiency of sand.

Sand and sediment from rivers that previously replenished beaches has been dredged to maintain navigable channels. Groins and detached breakwaters have been built to capture sand and maintain beaches, but in areas where they have been improperly designed, they have caused erosion to nearby downdrift areas. Compounding the problem is that some sand which makes up beaches comes from the natural erosion of the shore and nearshore areas. Coastal structures, such as seawalls and revetments meant to provide erosion protection to these areas, have greatly reduced or eliminated sources of material that would have otherwise naturally replenished beaches. Because of these and other changes, land, homes, businesses and infrastructure such as roads and utilities along the lake shore have been lost.

The change from a natural coast to a developed coast has led to and exemplified today's need for properly designed and installed coastal structures. The need to evaluate the impacts of past decisions and correct problems where possible is key to restoring some of the natural functions of the Lake Erie shore. This is now done by ensuring the proper design and installation of new projects, whether they are for commerce, navigation, recreation or erosion protection,

Most coastal projects today are designed to consider not only the primary and secondary functions and structural integrity of the coastal structure, but also whether the structures will have impacts to sand resources or cause adverse effects to other shore areas. An improperly designed coastal structure may fail during storms, leading to loss of property and lives. A coastal structure that captures sand may create a deficiency of sand along the downdrift shore, causing a loss of a protective beach along the downdrift shore. A coastal structure that reflects wave energy onto the adjacent shore may cause or accelerate increased erosion on that shore, or may create wave conditions that exceed those used to design erosion or flood protection on the adjacent shore.

Designing Coastal Structures

Designing coastal structures begins with gathering information specific to a site and evaluating design conditions that a coastal structure will face. Design conditions are individual elements that reflect the physical environment in which the structure will be built. These elements include water levels, wave heights, sand resources, sand transport rates, and water depths.

Historical information on erosion rates and flooding levels, as well as information on the geology of the nearshore, shore and in some

Concrete module breakwater in Geneva-on-the-Lake, Ashtabula County

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cases bluff or bank, are important in predicting the design conditions at a particular site. Information on the performance and effects of similar structures in the area is also used to create an understanding of the design conditions at the site. It is critical that accurate information be obtained on all of these site-specific design conditions to properly design and evaluate the impact that a new coastal structure will have. Because design conditions may differ at every location along the coast, the design of structures intended to serve a particular purpose, such as erosion control, may also differ in order for the structures to properly function at each specific site *(i.e. A one-size-fits-all approach to designing coastal structures generally does not work.)*.

Once the site conditions and history are known, the structural integrity of a proposed structure and the intended function must be considered. Many remnants of coastal structures exist along Lake Erie's shore— a testament to the need for good structural integrity, the use of strong durable materials, and proper maintenance. Wave and ice forces along Lake Erie are considerable and under-designed structures have a limited life-span. Structural debris from failed structures will wash up on beaches and may cause navigational hazards.

The function of a coastal structure, and whether it will work in that location, must be evaluated to determine if it will meet the intended need. For example, a dock that traps sand and causes shoaling will not be useful because the captured sand will decrease water depths at the dock. A seawall that is intended to work in combination with a beach to provide erosion protection will not function properly if reflection of waves off the seawall erodes the beach.

The design of coastal structures involves a diversified process which is specific to a structure's intended purpose and location. Planners and engineers must examine the impacts the structure(s) will have locally, and at the same time consider both short-term and long-term effects the structure(s) may have on the entire Lake Erie system.

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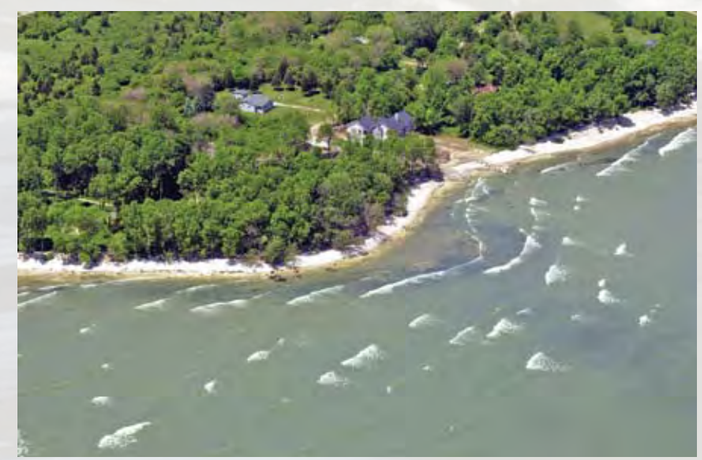
Construction vessel near Geneva-on-the-Lake, Ashtabula County



Waves along the Ohio shore

Background photo – Headlands Dunes State Nature Preserve and Fairport Harbor West Breakwater Lighthouse, Lake County

Breakwaters

Breakwaters are built to reduce wave action in the lee (landward side) of a structure. Wave action is reduced through a combination of reflection and dissipation of incoming wave energy. When used for harbors, breakwaters are constructed to create sufficiently calm waters for safe mooring and loading operations, handling of ships, and protection of harbor facilities. Breakwaters are also built to improve maneuvering conditions at harbor entrances and to help regulate sedimentation by directing currents and by creating areas with differing levels of wave disturbance. Protection of water intakes for power stations and protection of coasts against waves are other breakwater applications.

When used for shore protection, breakwaters are built in nearshore water and usually oriented parallel to the shore like detached breakwaters. The layout of breakwaters used to protect harbors is determined by the size and shape of the area to be protected as well as by the prevailing directions of storm waves, net direction of currents and littoral transport, and the maneuverability of vessels using the harbor. Breakwaters protecting harbors and channel entrances can be either detached or shore-connected.

End of Lorain Harbor's West Breakwater with lighthouse

Breakwaters at Lorain Harbor, Lorain County

Detached Breakwaters

Detached breakwaters are small, relatively short nearshore structures that are not connected to the shore. Built parallel to the shore just lakeward of the shore in shallow water depths, detached breakwaters' principal function is to reduce beach erosion. Multiple detached breakwaters spaced along the shore can provide protection to substantial areas along the shore.

Each breakwater reflects and dissipates some of the incoming wave energy, thus reducing wave heights in the lee (landward side) of the structure and reducing shore erosion. Beach material transported along the beach moves into the sheltered area behind the breakwater where it is deposited in the lower wave energy region.

Properly designed detached breakwaters are very effective in reducing erosion and in building up beaches using natural littoral drift. Moreover, they are effective in holding artificially nourished beach material. Optimizing detached breakwater designs is difficult when large water level variations are present, as is the case on Lake Erie.

View of detached breakwater, Euclid Beach, Cuyahoga County

Overhead view of Sims Park detached breakwater in Euclid, Cuyahoga County. Photo by U.S. Army Corp of Engineers

Revetments

Revetments are onshore structures with the principal function of protecting the shore from erosion. Revetment structures typically consist of a cover of stone or concrete block to armor sloping shore profiles. In the Corps of Engineers, the functional distinction is made between seawalls and revetments for the purpose of assigning project benefits; however, in the technical literature there is often no distinction between seawalls and revetments.

Revetment (onshore) and detached breakwater (offshore) in Geneva-on-the-Lake, Ashtabula County

Bulkhead in Sandusky, Erie County

Bulkheads

Bulkhead is the term for structures primarily intended to retain or prevent sliding of the land, whereas protecting the surroundings against flooding and wave action is of secondary importance. Bulkheads are built as soil retaining structures, and in most cases as a vertical wall anchored with tie rods. The most common application of bulkheads is in the construction of mooring facilities in harbors and marinas to minimize exposure to wave action. Some reference literature may not make a distinction between bulkheads and seawalls.

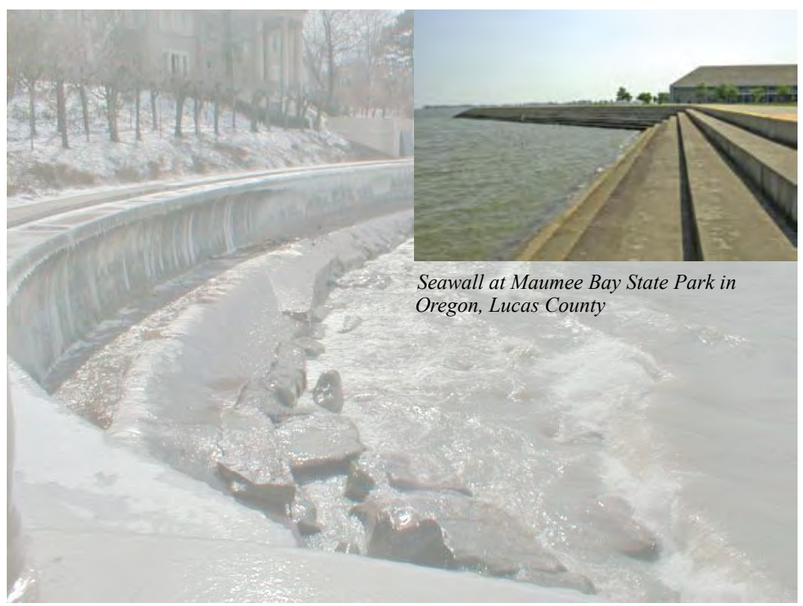
Bulkhead at Oak Point State Park on South Bass Island, Ottawa County

Coastal Structures

Seawalls

Seawalls are onshore structures with the principal function of preventing or alleviating overtopping and flooding of the land behind the structures due to storm surges and waves. Seawalls are built parallel to the shore as a reinforcement of the upland property profile. Quite often seawalls are used to protect promenades, roads and houses. Seawalls may be vertical-, stepped- or curved- face structures such as massive gravity concrete walls, tied walls using steel or concrete piling, or stone-filled cribwork.

Stopping or reducing erosion of the area landward of a seawall is usually a primary goal of installing a seawall. However, erosion of the lakebed immediately in front of the structure (undercutting) may increase due to wave reflection off of the seawall. Erosion can result in a steeper lakebed profile which subsequently allows larger waves to reach the structure. As a consequence, seawalls can be in danger of instability caused by erosion of the lakebed at the toe of the structure. Because of their potential vulnerability to toe scour, seawalls are often used in conjunction with a system of beach control measures such as groins and beach nourishment. Exceptions include cases of stable rock foreshores and situations where the potential for future erosion is limited and can be accommodated in the design of the seawall.



Seawall at Maumee Bay State Park in Oregon, Lucas County

Seawall in Bratenahl, Cuyahoga County

Groins

Groins are built to stabilize a stretch of natural or artificially nourished beach against erosion that is due primarily to a net longshore loss of beach material. Groins function well when longshore transport occurs. Longshore transport is when the water and sediment move parallel to the beach front.

Groins are narrow structures, usually straight and perpendicular to the pre-project shore. The effect of a single groin can be accretion of beach material on the updrift side and erosion on the downdrift side; both effects may extend some distance from the structure. Consequently, a groin field (series of groins) creates a saw-tooth-shaped shoreline within the groin field and a difference in beach level on either side of the groins.

Groins create very complex wave and current patterns. However, a well-designed groin field can stop or slow down the rate of longshore transport and, by accumulating material in the groin compartments, provide some protection to the coast against erosion. Groins are also used to hold artificially nourished beach material and to prevent sedimentation or accretion in a downdrift area such as an inlet by acting as a barrier to longshore transport.

Groins at Huntington Beach in Bay Village, Cuyahoga County

Jetties

Jetties are used for stabilization of navigation channels at river mouths and tidal inlets. Jetties are shore-connected structures generally built on either one or both sides of the navigation channel perpendicular to the shore and extending into the lake. By confining the stream or tidal flow, it is possible to reduce channel shoaling and decrease dredging requirements. Moreover, on coasts with longshore currents and littoral drift, another function of the jetties is to arrest the crosscurrent and direct it across the entrance into deeper water where it presents fewer hazards to navigation. When extended offshore of the breaker zone, jetties improve the maneuvering of ships by providing shelter against storm waves. Jetties are constructed similar to breakwaters.

Overhead view of Rocky River jetty
Photo by U.S. Army Corp of Engineers

View of jetty at mouth of the Rocky River in Lakewood, Cuyahoga County

Beach Nourishment and Dune Construction

Beach nourishment is a soft structure solution used to reinforce the shore against erosion. Material of preferably the same or larger grain size and density as the natural beach material is placed on the eroded part of a beach to compensate for the lack of natural supply of beach material. The beachfill might protect not only the beach where it is placed, but also downdrift stretches by providing an updrift point source of sand.

Dune construction consists of the piling up of beach-quality sand to form protective dune fields to replace those washed away during severe storms. An essential component of dune reconstruction is planting dune vegetation and placement of netting or snow fencing to help retain wind-blown sand normally trapped by mature dune vegetation. Storm overwash fans may be a viable source of material for dune construction. This type of beachfill is preferred because native material helps maintain beach stability.

Debris & Rubble

Concrete rubble and debris have been used along many portions of Lake Erie in an attempt to stabilize bluffs, prevent erosion and reclaim land lost to erosion. Such material is generally dumped from the top of the bluff onto the side of the bluff and bankface.

Concrete rubble and the associated debris are generally not recommended for use as erosion protection. The concrete is usually too lightweight to remain stable in the energy wave environments along Lake Erie's coast. Instead the rubble tends to be easily transported into the nearshore areas. The concrete may contain steel reinforcement (i.e. re-bar) which becomes exposed as the concrete pieces break apart.

Concrete rubble that has been transported into the nearshore becomes a hazard to navigation, and the exposed steel creates hazards for swimmers, waders and recreational boaters.

Reclaiming land lost to erosion

Sand Resources

Headlands Dunes State Nature Preserve, Lake County

Sheldon Marsh State Nature Preserve, Erie County

Sims Park, Cuyahoga County

Bradstreet's Landing, Cuyahoga County

Sand and gravel occur along the Ohio lakeshore as beaches and nearshore deposits. Beaches are typically less than 25-feet wide, except where sand and gravel are trapped by shore-protection structures, harbor structures and natural promontories. In these areas, beach deposits may be 1,500-feet wide. Nearshore deposits of sand and gravel typically extend less than 1,000-feet offshore. However, updrift of large harbor structures, sand may extend several thousand feet offshore. At the lakeward boundary of the deposits, the sand and gravel thin to expose the underlying clay or rock, or the sands are mixed with fine grained, open lake sediments.

Nearshore bars may be present along some reaches of the lake. Typically there are one or two poorly to moderately defined nearshore bars (1 to 2 and 3 to 4 feet of relief between trough and crest of the bar). However, in areas with larger volumes of sand and gravel, three or more moderately to well-defined bars (relief greater than 5 feet) may be present. In places, clay or rock may be exposed in the trough of nearshore bars.

On wide beaches, sand dunes may develop at the back of the beach. Dunes develop where wind blown sand accumulates beyond the reach of normal wave activity. For much of the lakeshore, this occurs only where the beach is more than 45-feet wide. Sediment in the dunes typically is fine or very fine sand. Sand dunes serve as a reservoir of sand, and during periods of erosion, sand eroded from the dune nourishes the beach.

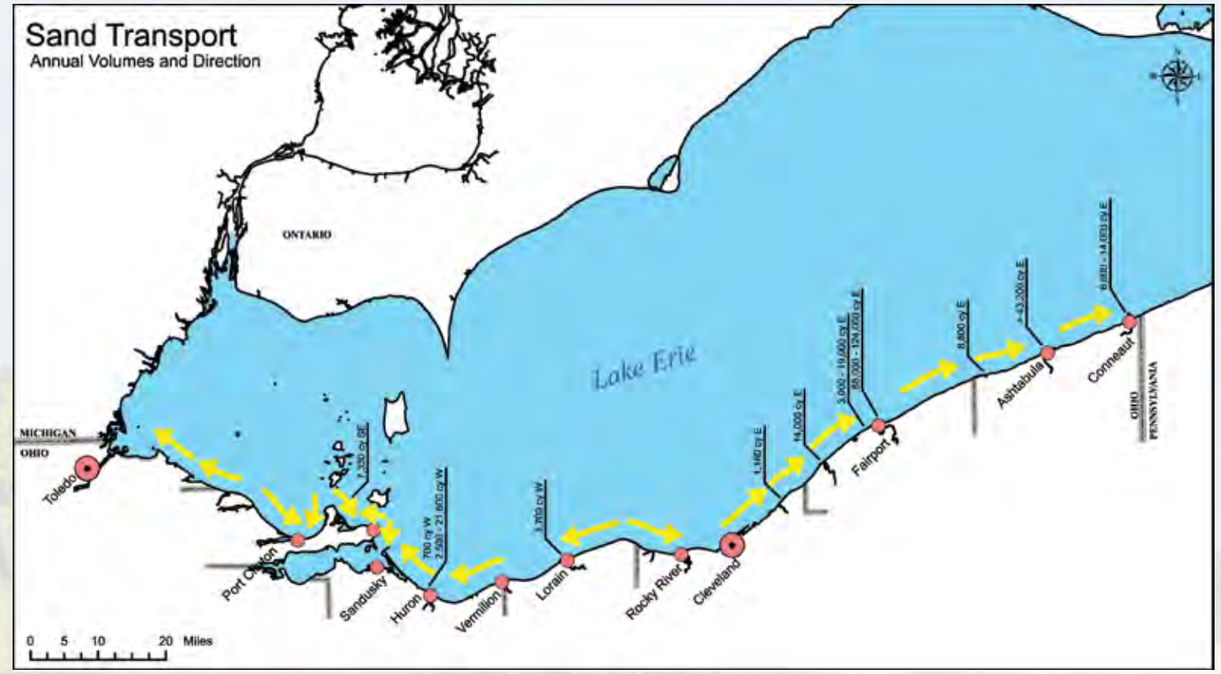
Changes in beaches since the 1870s

When settlers first came along the Ohio shore in 1796, Lake Erie's beach east of Cleveland had been used as a road for many years (Whittlesey, 1838). Since then, Ohio's beaches have changed dramatically. Many reaches of the lakeshore east of Cleveland lack beaches. Much of this change is linked to manmade alterations along the shore.

By the 1820s, construction of jetties and breakwaters built to create harbors at stream mouths, impounded beach sediment on the structures' updrift side, disrupting the longshore transport of sand and causing beach erosion downdrift of the harbors. Even during the low-water years of the mid-1930s, beaches along many reaches of shore were narrower and more segmented than the beaches of the 1870s. As erosion of sand from beaches reduced the width of beaches, shore erosion also increased. However, in many areas, the volume of sand contributed by erosion of bluff materials did not compensate for the volume of materials impounded by structures or eroded from the beach. This trend continues today, aggravated by armoring of the lakeshore to prevent erosion.

Littoral transport of sand and gravel

Waves are the principal agent eroding sand and gravel from beaches. During a storm, several feet of sand may be eroded from a beach, creating a wave-cut scarp several feet high. Under calmer conditions, waves deposit sand and gravel on the beach to restore the beach profile.



Sand Transport Map redrawn from:
Guy, D. E., Jr., 1994, Estimated rates of sand transport for the Ohio shore of Lake Erie: Ohio Geological Survey file data, 2 sheets.

Erosion of sand and gravel from beaches is cyclical. During periods of low wave energy, sand and gravel are deposited on the beach, and winds may blow sand into the back beach. During periods of high wave energy, the beach and dune may be eroded. Erosion of the dune supplies sand to the beach during periods of erosion. Sand and gravel are carried alongshore to downdrift beaches and offshore, where they are deposited in nearshore bars.

Sand and gravel move along the shore in response to waves and currents. This movement is called littoral transport. As waves break along the shore, sand and gravel are moved up and down the beach face in a zigzag pattern. The more obliquely waves approach shore, the more rapidly sediment is transported.

Direction of littoral transport varies over seasons, years and decades in response to changes in the frequency and direction of winds blowing across the lake. Changes in lake level and ice cover may also be significant factors in determining direction of net transport over time.

The net direction of sediment transport can be inferred from the accumulation of sand and gravel next to groins, docks, channel jetties and harbor breakwaters. A map of net sediment transport based upon these accumulations of sand and gravel shows that net littoral transport is generally eastward along the shore east of Avon Point and westward along the shore west of Avon Point (see figure). East of Avon Point, eastward transport by waves generated by prevailing westerly winds exceeds

Sand Resources

westward transport by waves generated by northeast storm winds. West of Avon Point, westward transport by waves generated by northeast storm winds exceeds easterly transport by waves generated by prevailing westerly winds.

Littoral transport along the shore west of Avon Point is further subdivided by several areas of converging and diverging littoral transport. A zone of convergence occurs at the mouth of Sandusky Bay where sand is carried northwestward along Cedar Point and southward along Bay Point. Another convergence occurs at Port Clinton and a zone of divergence occurs at Locust Point.

Sources of sand and gravel

Sand and gravel found along the lakeshore represent the coarse fraction of sediment eroded from rock and clay deposits found in inland areas, in bluffs along the lakeshore, and in the nearshore. Sand and gravel (the coarse-fraction) from inland areas are transported primarily as bedload along the bottom of the stream or river, while silt and clay (the fine fraction) are carried in suspension. At the stream mouth, stream currents slow, depositing sand and gravel near the stream mouth. From there, the sand and gravel are redistributed by waves to form beaches and nearshore deposits. The fine fraction remains in suspension and is carried into the lake where much of the silt and some of the clay settle out.

Erosion of the lake shore contributes sand and gravel directly to the littoral system. Where the shore is composed of sand or rock, all of the eroded material may be retained in the littoral system. Where the bluff is composed of glacial lake sediments or till, only part of the sediment is coarse enough to remain in the littoral system. Glacial lake sediments typically contain 2 to 5 percent sand-sized sediment and are not significant sources of sand and gravel. Glacial till typically contains up to 20 percent sand and gravel. Where the bluff is composed of glacial lake sediments or till, only part of the sediment is coarse enough to remain in the littoral system. Along the lakeshore east of Avon Point, there are numerous stretches where sand and gravel occur in the upper bluff. Nearly all of the sand and gravel eroded from these deposits is retained in the littoral system.

Bedrock found along the lakeshore from Huron eastward is shale, with the exception of one short outcrop of sandstone on the east side of Vermilion. Shale is composed of consolidated silt and clay, and as the shale erodes, it typically breaks down into particles of many sizes. In some cases, the particles are large slabs up to a foot thick and several feet across. In other cases, the particles are gravel or sand size. The shale may also disaggregate into the original silt- and clay-size particles. Thus, only a portion of the eroded shale particles are coarse enough to remain in the littoral system, and eventually these are worn away by harder particles.

Bedrock found in the island area of Lake Erie is limestone and dolostone. As these rocks erode, they typically break up into sand- to boulder-size pieces. Limestone and dolostone are more resistant to abrasion than shale and last considerably longer on a beach.

The volume of sand and gravel supplied to the lake by rivers and by erosion of the shore and nearshore has changed dramatically since Ohio was settled. Damming of streams, mining of sand and gravel from streams, and dredging of navigation channels at the mouths of streams, impounds or captures sand and gravel before they reach the littoral system. Except perhaps at the Chagrin River, probably little of the bedload carried by streams now reaches Lake Erie.

Shore protection has also reduced erosion rates and the volume of sand supplied to the littoral system. For the shore between Sandusky and Conneaut, estimates of sand and gravel annually supplied to the littoral system by shore erosion range from 138,200 cubic yards between 1876-1973 (Carter, 1977) to 205,000 cubic yards between 1876-1990 (Mackey, 1995). These volumes are based on recession of the shore over the respective time periods. However, with ever-longer reaches of the lakeshore being armored, recession is decreasing. From the 1870s to the 1970s, shore protection increased gradually. During and following the record-high lake levels of the 1970s to the 1990s, the rate of armoring accelerated. Now, seawalls and revetments alone protect about 50 percent of the shore east of Sandusky (Gerke and Fuller, 2004), reducing the potential source area of sand and gravel by about 50 percent.

The nearshore remains a source of sand and gravel. However, the volume of sand and gravel eroded in the nearshore is relatively small compared to the volumes contributed by streams or eroded from lake bluffs. Between 1876 and 1973, the volume of sand and gravel supplied to the littoral system along the mainland counties by erosion of the nearshore was approximately 26,587 cubic yards per year (Carter, 1977). This volume of sand and gravel is inadequate to maintain beaches along the lakeshore. Furthermore, erosion of cohesive nearshore materials (glaciolacustrine sediments and till), a process called downcutting, steepens the nearshore profile and allows larger waves to come closer to shore. This exposes shore protection structures to greater wave energy.

Human impact on sand and gravel resources

Urbanization of Ohio's lakeshore has had significant impacts on sand and gravel resources. The first major impact was the development of harbors at the mouths of major rivers. By the 1820s, short jetties had been constructed at most harbors to keep sand and gravel out of the channels. Over time, these jetties were extended to deeper water as sand built up on the updrift side of the harbor. At some harbors, construction of jetties was followed by construction of large breakwater complexes extending up to a mile offshore. These structures form major barriers to littoral transport of sand and gravel. For example, at Fairport Harbor, about 7 million cubic yards of sand have been impounded (U.S. Army Corps of Engineers, 1976). This volume of sand is equivalent to what would be found in a beach 14 miles long and 50 feet wide.

An additional impact of harbors has been open-lake disposal of sand and gravel dredged from navigation channels in the harbors. As most of the sand and gravel found in the outer (lakeward) part of harbors is littoral sediment, open-lake deep-water disposal of the sediment permanently removes it from the littoral system. Sand and gravel found at the upstream ends of some navigation channels is bedload sediment that would eventually have reached the littoral system, were it not for dredging of the navigation channel.

Mining sand and gravel from beaches has adverse impacts on the beach. Once a common practice, it is now discouraged. Likewise, grooming a beach to remove large stones removes coarser sediment that provides natural protection for the beach during storms. If stones are collected as the beach is groomed, they should be buried in the beach where they will be reworked by storm waves. Removing sand dunes to provide an unobstructed view of the lake also has adverse impacts on the beach because removing the dune removes the reservoir of sand that maintains the beach during periods of erosion.

Shore protection structures have significant impacts on beaches. As noted above, one impact is to cut off a potential source of beach building sediment. Nourishing the littoral system with a volume of sand and gravel comparable to what will be

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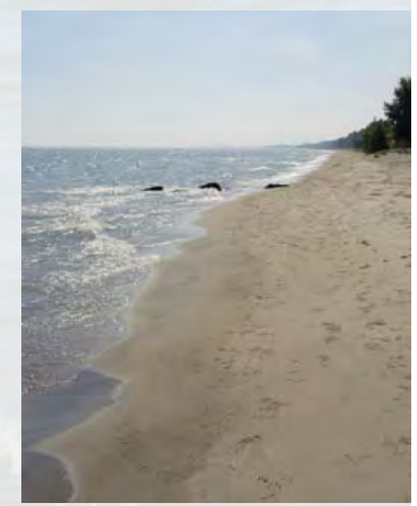

Cedar Point Chaussee, Erie County

Background photo – Cedar Point Chaussee, Erie County

Old Woman Creek Beach, Erie County

Huron Beach, Erie County

Sheldon Marsh State Nature Preserve, Erie County

Lakeview Park, Lorain County

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impounded by the structure and/or what would be introduced by erosion of shore materials over the life of the structure would help mitigate some of the structure's impacts on littoral sand resources.

Shore protection structures, such as groins and breakwaters, provide protection by trapping sand to form a beach. However, these structures typically trap more sand along a given stretch of shore than would normally occur along that stretch. As a result, the beach and shore downdrift of the structure experience an incremental increase in erosion.

Beach and shore erosion have been documented by numerous studies and observed by numerous property owners. Less obvious is loss of sand and gravel from Ohio's nearshore. Comparing sediment surveys made in the 1870s, 1950s and the 1990s documents the loss of sand and gravel from nearshore areas (see substrate change maps).

Mitigating human impacts on sand resources

Sand and gravel dredged from numerous small marinas' channels is bypassed annually or semiannually. The volumes involved are typically less than 2,000 cubic yards per marina, although at Mentor Harbor up to 20,000 cubic yards may be bypassed. Sand and gravel dredged from federally maintained harbors has not been regularly bypassed for several reasons: pollution, economics and equipment. Unfortunately, the volume of sediment tends to be much larger (25,000 to 40,000 cubic yards) and the impacts much greater.

Failure to bypass sand and gravel has a significant long-lasting impact on the beach and nearshore. If 40,000 cubic yards of sand and gravel dredged from a channel are placed in deep water, it may take years to decades for natural erosion to replenish this littoral sediment. Along the Central Basin shore, replenishment may take several years, but in the Western Basin, replenishment may take 30 to 40 years. If open-lake disposal of sand occurs several years in a row, replenishing the sand may take a decade to more than a century.

Since 2001, sand has been bypassed at two federal harbors. In 2001 and 2002, 40,000 and 60,000 cubic yards of sand, respectively, dredged from the lake approach channel at Fairport Harbor were placed nearshore at Painesville on the Lake (Guy and Liebenthal, 2003). In 2004, about 75,000 cubic yards of sand dredged from Conneaut Harbor were placed along the shore east of Conneaut.

Mitigating part of the impact of shore protection structures on sand resources can be accomplished by nourishing the littoral system with sand from upland or open-lake sites. Where the shore is armored to prevent erosion, the impacts of reduced erosion on sediment supply can be mitigated by nourishing the littoral system with a volume of sand comparable to what would have been supplied to the littoral system had shore protection not been constructed. These volumes can be calculated using bluff height, bluff composition, and historical recession rates. Where shore protection structures will trap sand, the beach can be prefilled with sand obtained offsite. These volumes can be calculated using nearshore water depths, morphology of the existing beach, and historical changes in beaches at the site. Prefilling the beach reduces the volume of littoral sediment trapped by the structure helping maintain littoral transport of sediment to downdrift beaches.

Sources of sand to restore Ohio beaches

Potential sources of sand and gravel to nourish and restore Ohio's beach and nearshore areas include sand and gravel dredged from deep water deposits, sand mined from upland deposits, and sand dredged from channels. A new source of beach sediment is shell fragments of zebra and quagga mussels.

Sand and gravel deposits found offshore of the Lorain-Vermilion area and offshore of Fairport Harbor have been dredged commercially for many years. Commercial dredging areas occupy just part of these large deposits. Approximately 41.8 million cubic yards of fine to coarse sand occur offshore of the Lorain-Vermilion area, and 191 million cubic yards of fine to medium sand occur offshore of Fairport Harbor (Williams and others, 1980). These deposits are far enough from shore and in deep enough water that there is likely no exchange of sand with the littoral system.

Sand mined from upland deposits could be used in some locations. However, upland deposits, particularly sand dunes, may be too fine for beach nourishment. In addition, upland deposits are being depleted and/or covered by urban development.

Recovering sand dredged from outer harbor areas is a ready source of beach nourishment material. However, sand dredged from the upper reaches of harbor channels may or may not be suitable for beach nourishment. At Fairport Harbor, sand and gravel dredged from the upper reach of the harbor was suitable for nearshore disposal and was placed in the nearshore at Painesville. At Cleveland, contaminants in sand and gravel from the upper channel make it unsuited for direct placement in the littoral system. However, when the sediment is transferred into the confined disposal facility, the hydraulic transfer process segregates the sand from the finer grained sediment. Segregation and cleaning of the sand and gravel by this process may provide an opportunity to recover the materials for beach nourishment.

In recent years, the shells of the invasive zebra mussels and quagga mussels have become a significant constituent of beach sand along the lakeshore. Along portions of rock-bound shore around the island area and near Huron, shell material may make up the entire sand fraction. Along the western basin, shell material may comprise 50 percent of the sand. Along the central basin, shell material is present in smaller concentrations, but still represents a significant constituent of the beach sand. If these invasive mussels have one benefit to the Ohio lakeshore, it may be providing beach building material to replace that lost by human activities.

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Crane Creek State Park, Lucas County

Sheldon Marsh vs. Headlands Dunes

Coastal process potential cumulative effects on the shore can be demonstrated by profiling two State Nature Preserves adjacent to Lake Erie. Both preserves have a beach area comprised of sand; however, at one preserve rapid erosion has taken place, while at the other substantial accretion has occurred due to the placement of a man-made structure. More than 85 road miles separate Sheldon Marsh in Erie County from Headlands Dunes in Lake County, yet the two are connected through Lake Erie's littoral system.

Note: These preserves are in two different littoral transport cells, one transporting sand west to Sheldon Marsh and one transporting sand east to Headlands.

Sheldon Marsh State Nature Preserve

The 461-acre Sheldon Marsh State Nature Preserve is located on the southwestern shore of Lake Erie at the southeast end of the 6.5-mile Cedar Point sand spit. Sheldon Marsh contains a 1.13-mile barrier beach which provides protection and habitat for a variety of plants and animals living in the cattail marsh, swamp forest, upland hardwood forest, and old-field communities there.

The preserve and contiguous wetlands comprise some of the last remaining undeveloped stretches of coastal area along Lake Erie's southern shore, and one of three remaining Ohio coastal wetlands not restricted by a system of dikes for water level management. However, over the years, Sheldon Marsh's barrier beach has experienced a great deal of erosion, which has shifted the beach southwest. When water levels are high, the barrier beach is subject to washover or breaching during storms; sand is carried across the barrier and deposited into the lagoon on the landward side. According to the U.S. Army Corps of Engineers' April 2005 draft Reconnaissance Report on Sheldon Marsh, restoration of the barrier beach is essential to the survival of existing and future plant and animal communities.

Sheldon Marsh State Nature Preserve, Erie County

According to the Corps' report, the Cedar Point Peninsula sand spit was probably a stable or growing geomorphic feature before the mid-1800s when settlement and industrialization caused "profound" changes to the coastal sediment regime reduced littoral sediment. These reductions were, and continue to be, caused by armoring bluffs, interrupting littoral sediment transport patterns by harbor construction, and depositing dredged material in deep water or on land.

In the early 1900s, Sheldon Marsh's barrier beach extended westward from what is now the NASA Plum Brook water intake pump station to Cedar Point. According to the Corps, the barrier beach remained semi-anchored by an asphalt roadway that formally traversed the barrier beach. In 1968 the barrier beach fronting the marsh was narrow but still continuous, as evidenced by aerial photography.

Then, in 1972, the west-end of the barrier beach was separated from the rest of the Cedar Point spit by a rise in lake level coupled with a major northeast storm. Over the next 30 years, the remaining barrier beach has migrated westward and shoreward approximately 1,200 feet in places, forming a broad U-shaped bay.

Outside the nature preserve, most of the Cedar Point spit was and still is privately or commercially owned and fronted by rock shore protection structures which anchor the position of the shore.

But today at Sheldon Marsh, purchased by ODNR in 1979, the barrier beach is composed of a thin patchy sand layer resting on a clay and peat base. There are no shore protection structures located on or near the beach; only minor protection is afforded from the deteriorating timber pilings and roadbed that are 1,000-feet offshore and typically submerged. The Corps and various state agencies are currently studying ways to prevent additional erosion of the barrier beach system.

The preserve is known to attract nearly 300 species of birds and provides habitat for many kinds of wildflowers. During spring and autumn, many birds, including Neotropical migrants, shorebirds and waterfowl, pass through the marsh on their way to and from their breeding grounds in the north. Before crossing Lake Erie, these long-distance travelers stop briefly to rest and feed in the lush vegetation of the forest and marsh.

Headlands Dunes State Nature Preserve

Extensive development along the Lake Erie shore has all but eliminated the presence of extensive sandy beaches and dunes at the mouths of rivers and inlets along Lake Erie. Ironically, the largeset dune system adjacent to Ohio's portion of Lake Erie, Headlands Dunes, only exists because of the construction of harbor breakwaters.

Located just west of the Grand River mouth, Headlands is a living assemblage of fascinating and highly specialized plants and animals occurring in an environment too hostile for most organisms to survive.

When Headlands was acquired by ODNR in 1976, the preserve was approximately 16 acres. Due to accretion, the upland surface area of the preserve has increased to approximately 23.9 acres as of 2004. The acreage increase does not take into account the amount of sand that has accumulated in the ever-growing dunes, some of which are now 20 feet higher than the beach.

By definition, sand dunes are natural or artificial ridges or mounds of sand landward of the beach. Sand dunes are usually classified as incipient dunes, foredunes or hinddunes. During storm conditions, incipient and foredunes may be severely eroded by waves. During intervals between storms, dunes are rebuilt by wind effects. Dune vegetation is essential to prevent sand drift, and the presence of dunes can also help prevent erosion of upland areas.

The most important vegetation for developing dunes along this stretch of Lake County are switchgrass and/or beach grass (Hicks, 1934). Switchgrass or beach grass becomes established on the upper beach along with annuals such as cocklebur and sea rocket. These lone grass plants quickly spread into huge root-like mats. Sand rapidly accumulates in the relatively quiet vicinity of the switchgrass crown. As this deposition occurs, switchgrass or beach grass continues to grow upward through the sand. Eventually it will grow several feet above the original locality of germination or initial rhizome establishment. As the dune becomes more or less stabilized by the switchgrass or beach grass, grape vines and poison ivy become established on the dunes; eventually cottonwood and willow appear, and finally oak (usually black oak).

Preserve managers have witnessed Headlands' dunes increase in size. One area of sand accumulation is the large dune that separates the nature preserve from the adjoining 120-acre Headland Dunes State Park's mile-long, 100-yard wide beach. Different levels of cover and sand are visible here. The other noticeable area of dune growth has been at the east end of the preserve along the Grand River's west breakwater where small dunes continue to form.

In addition to the vegetation, this 3,878-foot long breakwater has, in-part, caused the dunes at Headlands to grow to a size otherwise unseen along Ohio's coast. The U.S. Army Corps of Engineers estimate that since the 1800s, more than 7 million cubic yards of sand have been impounded west of the breakwater.

While a handful of trails guide visitors through the dunes, some areas are fenced off to restrict access on the fragile dune environment. The preserve provides visitors with a scenic natural beach on Lake Erie with many rare and unusual Atlantic coastal plain plants; and a good site to view migrating birds and monarch butterflies.

Sources:

ODNR Division of Natural Areas and Preserves
2045 Morse Road, Building F-1
Columbus, OH 43229-6693
Tel: 614-265-6453
Web: www.ohiodnr.com/dnap

U.S. Army Corps of Engineers' Draft Reconnaissance report for Sheldon Marsh Nature Preserve – Section 227, Huron, Ohio, April 2005.

Sheldon Marsh State Nature Preserve, Erie County

Headlands Dunes State Nature Preserve, Lake County

Headlands Dunes State Nature Preserve, Lake County

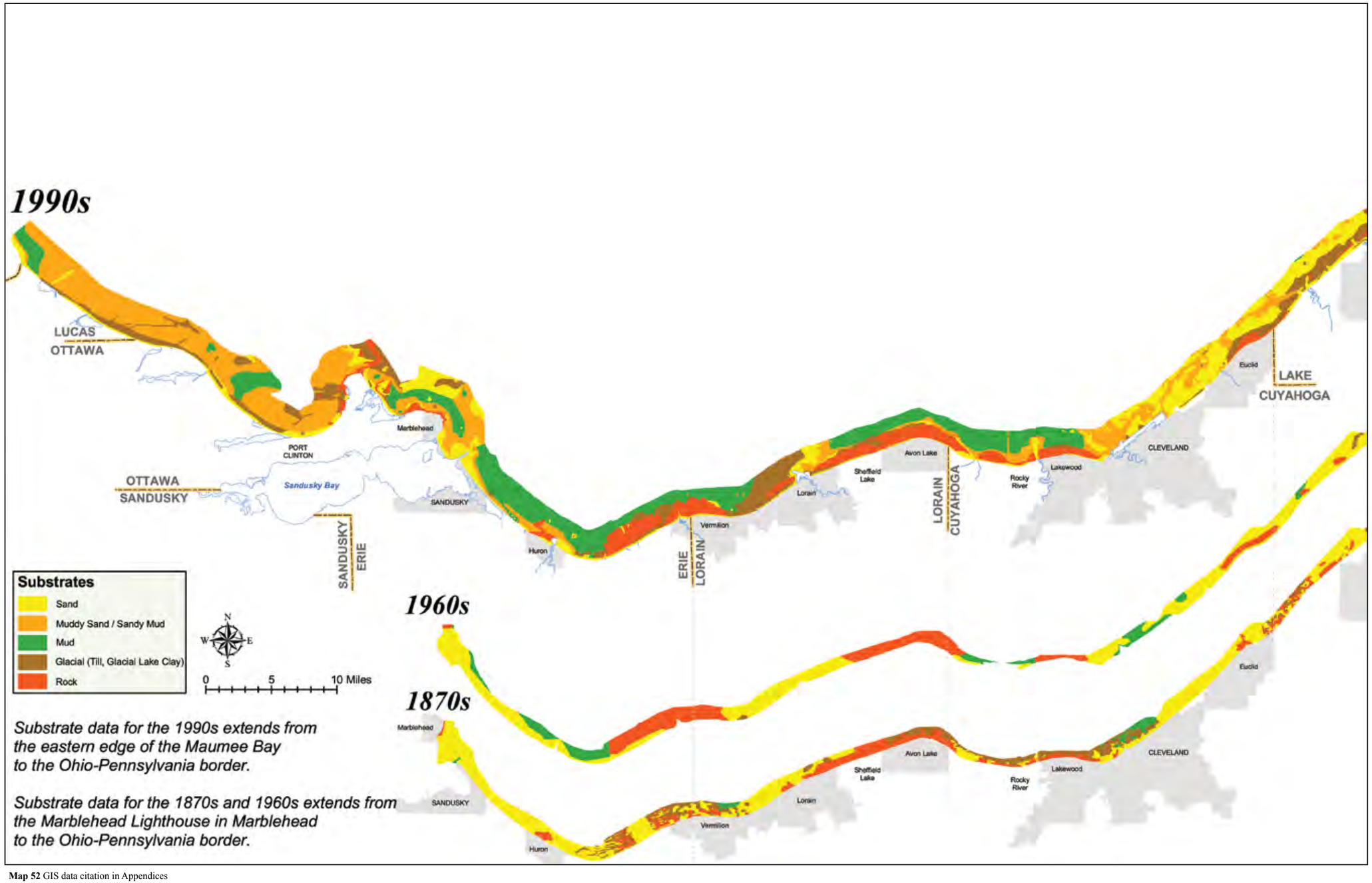
Historic Substrates in the Nearshore

Beach sediment: Sand

Beach sediment: Gravel

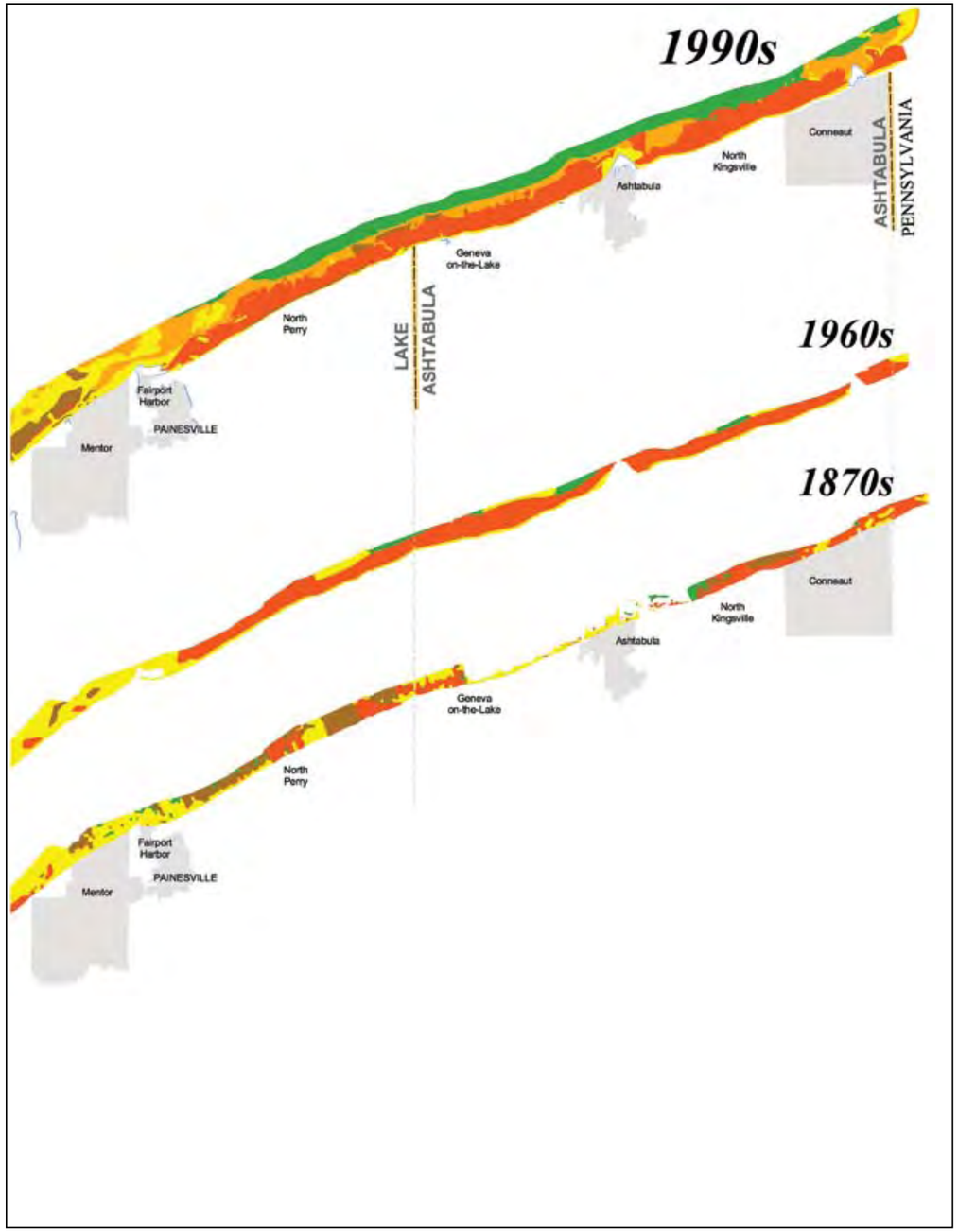
Gravel Beach, Ottawa County

Needles Eye on Gibraltar Island, Ottawa County



Map 52 GIS data citation in Appendices

Historic Substrates



Map 52 GIS data citation in Appendices

Historic Nearshore Substrate Changes

The accompanying maps show historic changes in nearshore substrates. The American Geological Institute (AGI) defines the nearshore as the area extending lakeward an indefinite but generally short distance from the shoreline.

To simplify data presentation, substrates are grouped into five categories: sand, sandy mud/muddy sand, glacial sediments, mud and rock. Definitions for these substrates are provided in the glossary.

These maps were compiled from data collected in the 1870s, the 1950s and the 1990s. In 1876-1877, samples were collected 500-1,650 feet apart along shore-perpendicular lines extending about 1-mile offshore. These survey lines were spaced 500-1,000 feet apart.

In 1957-1958, samples were collected on a 1-mile grid extending out to the middle of Lake Erie. Echo-sounder data, collected between some of the grid points, were also used to map substrates. Although the 1957-1958 data extend to the middle of the lake, only data overlapping the 1876-1877 data are shown.

In the 1990s, substrates were mapped with side-scan sonar surveys. These shore- parallel surveys extend 0.3- to 2.5-miles offshore, covering the nearshore and some offshore areas. To map substrates shoreward of the surveyed area, data were supplemented with echo-sounder data and bottom samples collected in the mid 1970s. Echo-sounder data show differences in bottom penetration and bottom irregularity that can be used to map substrates.

Although different sampling methods were used to collect the data from which these substrate maps were compiled, the maps suggest two major trends in substrate changes. First, sand has been eroded to expose the underlying glacial sediment or rock. Second, glacial sediment has been eroded to expose the underlying bedrock.

Examples of the first trend (sand erosion) appear in the 1870s and 1950s data for the nearshore between Fairport and Ashtabula and between Huron and Vermilion. The same trend also appears in the 1950s and 1990s data for the nearshore between Vermilion and Lorain and between Euclid and Mentor. Examples of the second trend (glacial sediment erosion) appear in the 1870s and 1950s data for the nearshore between Huron and Vermilion and between Fairport Harbor and Geneva.

These trends suggest the distribution of sand is changing over time owing to impoundment of sand at large harbor and shore protection structures, open-lake disposal of sand dredged from channels, and loss of source areas of sand. A link between impoundment of sand and change in sand substrates is supported by the marked change in substrates downdrift (east) of Fairport Harbor, where more than 7 million cubic yards of sand have been impounded west of the harbor breakwater since the 1800s (U.S. Army Corps of Engineers, 1986). In addition, sand dredged from the lake-approach channel was dumped offshore until the 1980s.

A link between loss of source area and change in sand substrate is suggested by the decrease in sand lakeward of the heavily armored shore between Cleveland and Mentor. Between 1876 and 1973, shore erosion contributed approximately 2,000 cubic yards of sand per mile of shore each year (Carter, 1977). Shore-protection structures now armor most of this reach cutting off the supply of sand.

Change from sand substrate to glacial or rock substrates may influence "community composition with respect to native fish and benthic invertebrates" and may increase the "likelihood of invasions by non-native species such as zebra mussels and round gobies,"(Goforth, 2002). More than 75 percent of Great Lakes fish species' young-of-the-year and about 65 percent of fish species adults use gravel, sand or silt substrates in nearshore areas as habitat (Lane and others, 1996a, 1996b). Change from sand substrate to glacial or rock substrates and change from glacial to rock substrate indicate that the lakebed has been lowered by erosion. Lowering of the lakebed increases water depth enabling larger waves to reach shore, aggravating erosion problems and subjecting shore protection structures to more wave energy.

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Fuller, J. A., and Foster, D.S., 1998, Sidescan sonar Differentiation of Ohio's Nearshore (Lake Erie) Surficial Sediments, Ohio Division of Geological Survey Map LE-1, scale 1:633,600, 1 map and GIS files.

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Jackson, J.A., ed., 1997, Glossary of Geology: Alexandria, Virginia, American Geological Institute, 769 p.

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U.S. Army Corps of Engineers, 1986, Section 111 initial appraisal report at Fairport Harbor, Ohio: Buffalo, New York, U.S. Army Corps of Engineers, 76 p.

American Geological Institute, Julia A. Jackson, ed., 1997, Glossary of Geology: Alexandria, Virginia, 769 p.

Historic Substrates in the Nearshore:

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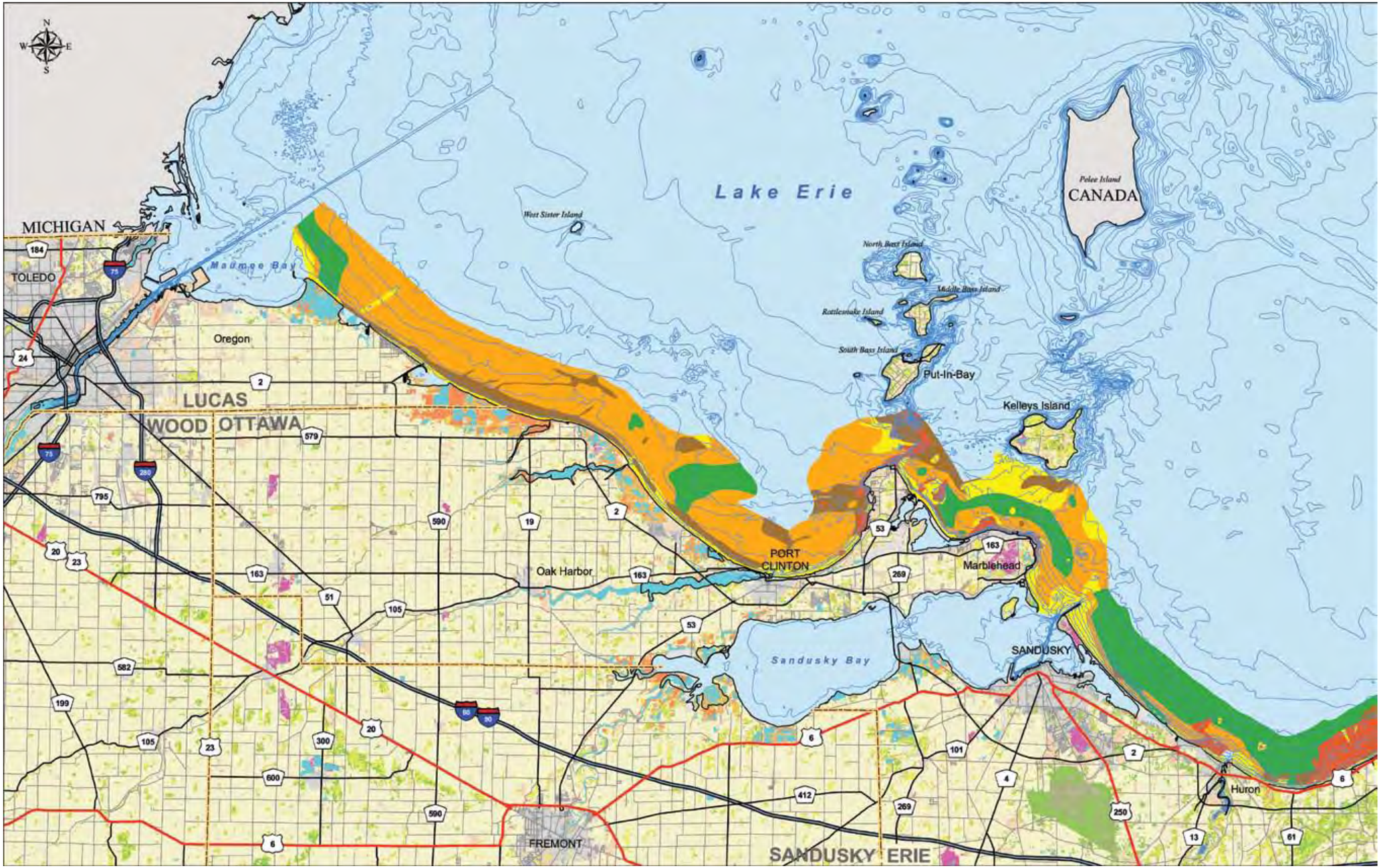
Nearshore Substrates (1990s) – Western Lakeshore

Cedar Point Chaussee, Erie County

Northeastern tip of Middle Bass Island, Ottawa County

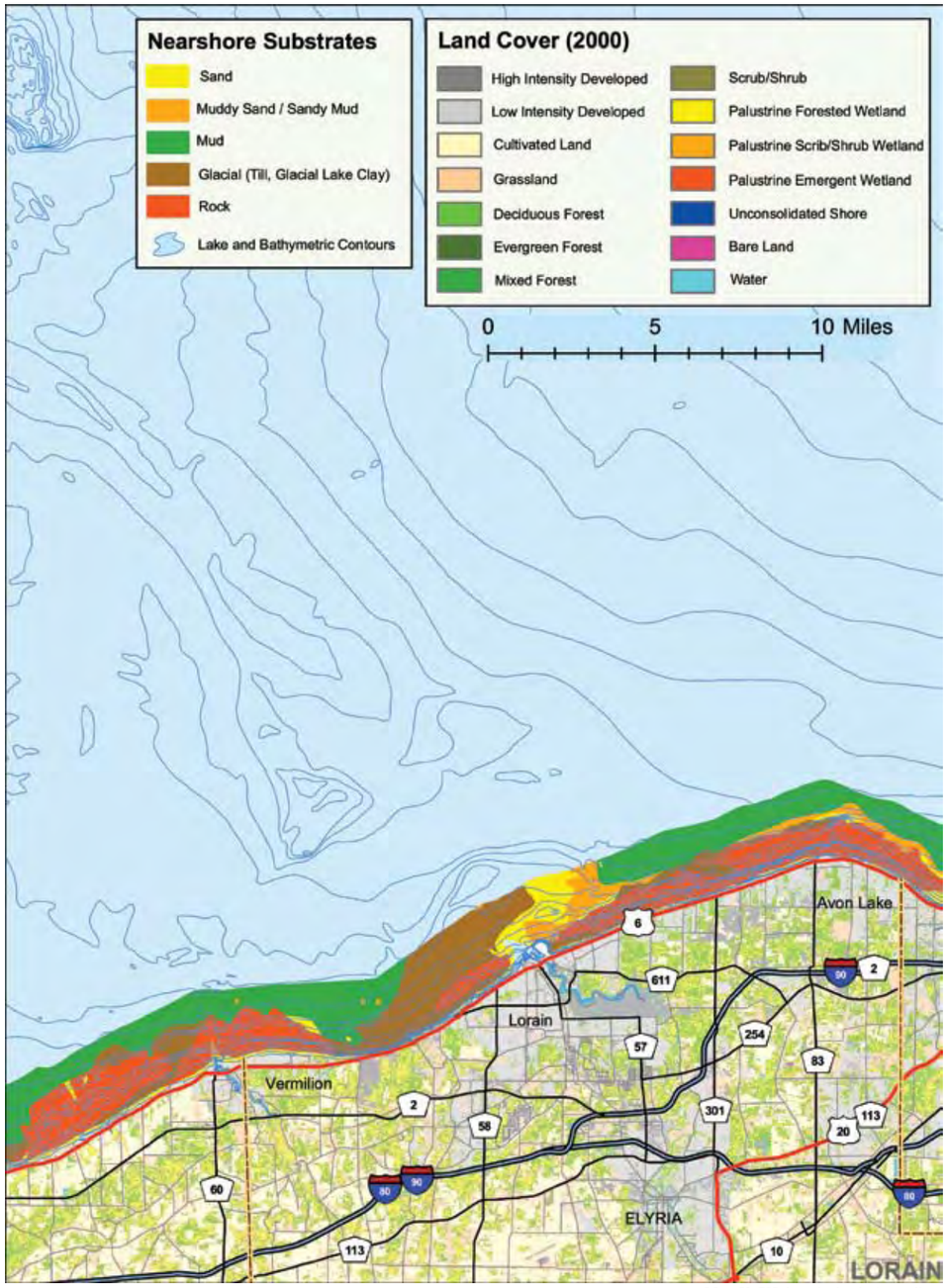
Sheldon Marsh State Nature Preserve, Erie County

Lakeview Park, Lorain County



Map 53 GIS data citation in Appendices

Nearshore Substrates (1990s) – Western Lakeshore



Map 53 GIS data citation in Appendices

Nearshore substrates in Lake Erie west of the islands differ from those east of the islands. West of the islands the principal substrate is sandy mud/muddy sand. East of the islands, mud and rock are the principal substrates.

In the Western Basin, the low relief land surface composed of till and glacial lake sediment extends well lakeward of the modern shore. This gently sloping surface can be seen in the widely spaced bathymetric contours that extend lakeward from the shore; water depths 2.5 miles offshore are only 19 to 23 feet. This is most pronounced near Locust Point, located just east of Magee Marsh Wildlife Area in Ottawa County.

As waves erode the till and glacial lake sediments, the sandy fraction remains as a lag deposit on the glacial substrate while the finer grained sediment goes into suspension. During periods of calm water, some fine-grained sediment settles out on the eroded till surface and is mixed with the sand to create a sandy mud/muddy sand substrate. Side-scan sonar data suggest that the sandy mud/muddy sand substrate is a thin lag deposit over a glacial substrate (Fuller, 1996).

Shoreward of the sandy mud/muddy sand substrate is a band of glacial substrate. This is formed in the surf zone where sediment eroded from the glacial substrate is swept away by waves and currents.

Two sand deposits occur along the Western Basin. One deposit is at the Little Cedar Point sand spit at Maumee Bay, and the other is in the embayment at Port Clinton. Both deposits occur at the downdrift end of littoral transport cells. Sand substrate also occurs as a very narrow band along the shore. Lack of other extensive sand deposits reflects the lack of an upland source area— there are no high, eroding bluffs along western Lake Erie. In addition, tributaries entering the Western Basin carry primarily fine-grained sediment due to gentle stream gradients and because the clayey soils contain little sand. The exception is the Maumee River, but much of its sandy sediment is deposited in the lower reach of the river.

Around Catawba Island and the Marblehead Peninsula, substrate distribution is complex. On the flanks of Catawba Island, the Marblehead Peninsula and the Lake Erie islands, water depths vary greatly over short distances. Here waves erode sediment from shallow areas and currents scour sediment from deeper areas. In this region, like the rest of the lakeshore, rock and glacial substrate typically occur in areas of erosion or non-deposition, and sand and mud substrates typically occur in areas of deposition.

Key features of substrate distribution between Cedar Point and Avon Point are the sand deposits associated with sand spits at the mouth of Sandusky Bay; outcrops of bedrock (shale) just west of Huron, around the greater Vermilion area and from Lorain to Avon Lake; and mud in deeper water areas.

Mouth of the Sandusky Bay Image courtesy of the Image Science & Analysis Laboratory, NASA Johnson Space Center, http://eol.jsc.nasa.gov; Image ISS012-E-15050

Sand deposits at the mouth of Sandusky Bay occur at the downdrift end of the littoral cell extending from Avon Point to Sandusky. Sand found in these deposits came from eroding bluffs to the east. Rock substrate occurs in areas where the elevation on the bedrock surface is high enough that rock is exposed on the lake floor. Along many reaches where shale crops out on the lake floor, shale also crops out above lake level, forming broad, cliffed headlands.

Mud occurs between Sandusky and Avon Point because nearshore slopes are steep enough that water depths 0.3 miles offshore exceed 23 feet (compare this to the Western Basin where these water depths occur 2.5 miles offshore). As a result, fine-grained suspended sediment settles out closer to shore. This mud is the landward edge of mud that covers much of the Central Basin.

Nearshore Substrates (1990s):

Fuller, J. A., and Foster, D.S., 1998, Sidescan sonar Differentiation of Ohio's Nearshore (Lake Erie) Surficial Sediments, Ohio Division of Geological Survey Map LE-1, scale 1:633,600, 1 map and GIS files.

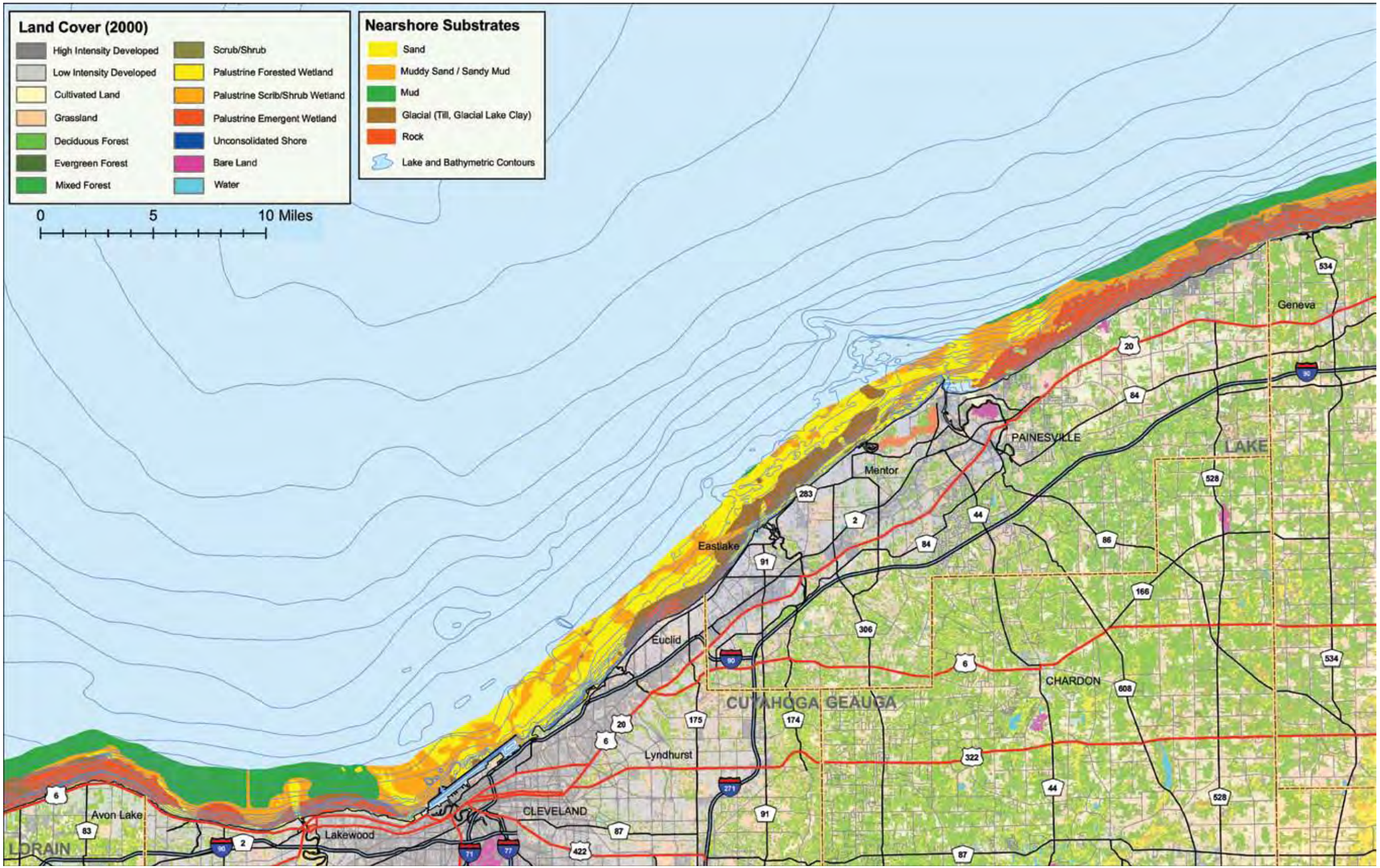
Nearshore Substrates (1990s) – Eastern Lakeshore

Huntington Reservation in Bay Village, Cuyahoga County

Headlands Dunes State Nature Preserve, Lake County

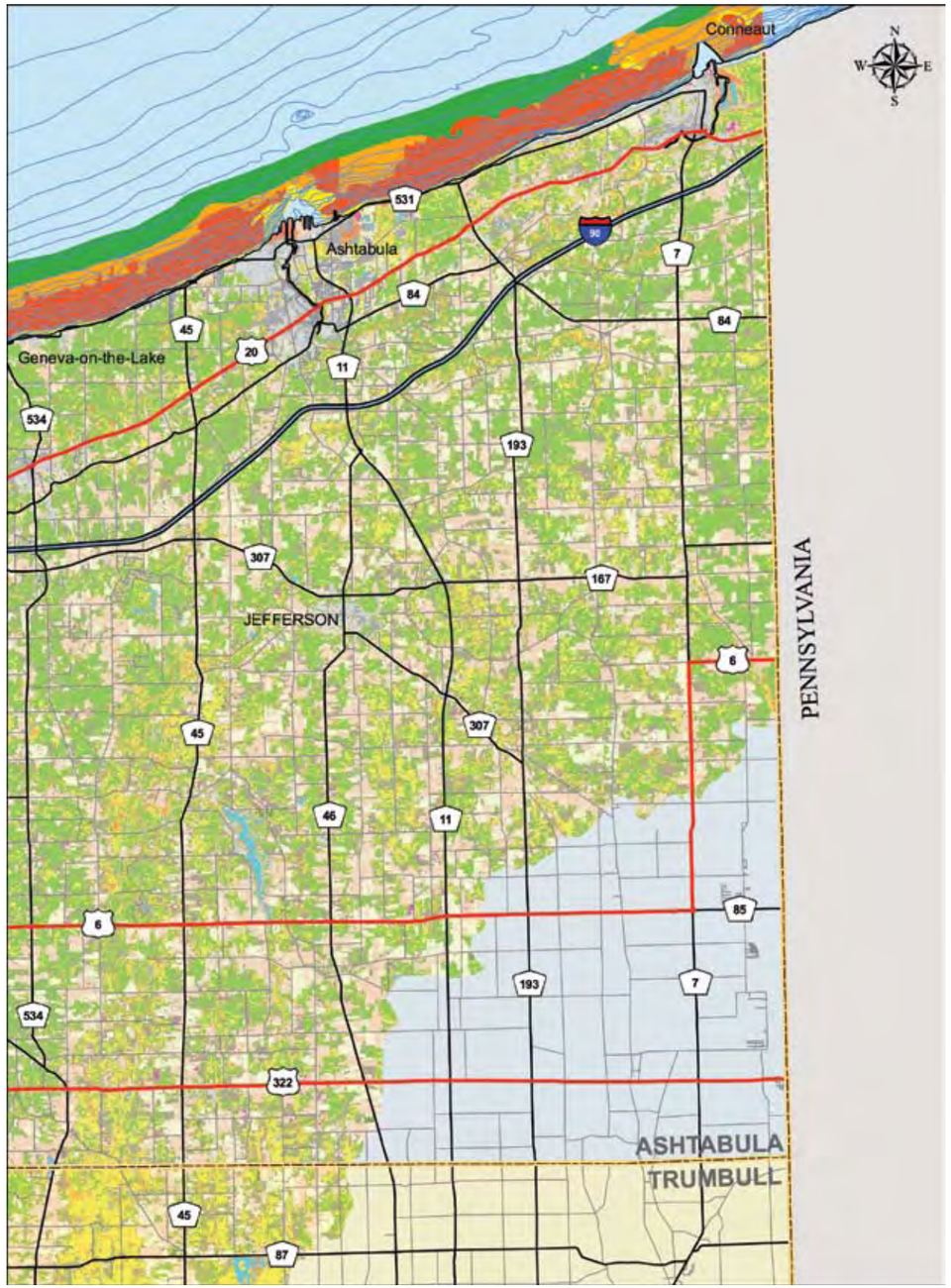
Nearshore substrates in Lake County

Geneva State Park, Ashtabula County



Map 53 GIS data citation in Appendices

Nearshore Substrates (1990s) – Eastern Lakeshore



Map 53 GIS data citation in Appendices

Key features of nearshore substrates along the eastern lakeshore are the outcrops of rock from Avon Point to Cleveland and from Fairport Harbor to the Ohio-Pennsylvania state line, and the extensive sand deposits from Cleveland to Fairport Harbor.

Shale occurs in the nearshore where bedrock elevations are higher. From Avon Point to Cleveland and along a short stretch of Euclid, bedrock rises above lake level to form broad headlands. From Fairport Harbor to the Ohio-Pennsylvania state line, shale rises just above lake level in only a few places. In areas where rock substrate occurs in the nearshore, the nearshore slope tends to be gentler. As a result, water depths are shallower and waves typically keep the bedrock scoured clean of all but a very thin (less than 1 mm) veneer of mud that accumulates during periods of calm wave conditions.

Lack of sand along the lakeshore east of Fairport Harbor is due to entrapment of sand updrift of the harbor structures and to open-lake disposal of sand dredged from the entrance to Fairport Harbor. As sand eroded from the nearshore downdrift (east) of Fairport Harbor, the underlying glacial substrate was eroded to expose the rock substrate.

The broad expanse of sand between Cleveland and Fairport is derived in part from sand and gravel contributed by the Grand River (Carter, 1984) and possibly the Cuyahoga and Chagrin Rivers and in part from relict sand deposits associated with a glacial moraine that extends across Lake Erie to Erieau, Ontario (Fuller and others, 1994).

The broad (0.7-mile wide) band of glacial material exposed on the lake floor from Euclid to Mentor has formed since 1950. Loss of sand from the area is probably a cumulative and secondary impact of shore protection structures built along the lakeshore east of Cleveland, deep-water or confined disposal of sand and gravel dredged from navigation channels in Cleveland, and entrapment of sand updrift (west) of Cleveland Harbor and shoreward of Cleveland's east breakwater. As a result, there is an insufficient supply of sand to replace what waves and currents transport eastward.

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Nearshore Substrates (1990s):

Fuller, J. A., and Foster, D.S., 1998, Sidescan sonar Differentiation of Ohio's Nearshore (Lake Erie) Surficial Sediments, Ohio Division of Geological Survey Map LE-1, scale 1:633,600, 1 map and GIS files.

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View of Avon Lake (in upper left corner) to Cuyahoga and Lake county line (in upper right) - Image courtesy of the Image Science & Analysis Laboratory, NASA Johnson Space Center, http://eol.jsc.nasa.gov; Image STS059-234-37