ERDC/CHL TR-05-11

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*National Shoreline Erosion Control Development and Demonstration Program (Section 227)*

# Geology and Historical Evolution of Sheldon Marsh Nature Preserve, Lake Erie, Ohio

Andrew Morang and Shanon Chader

September 2005

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**ABSTRACT:**

Sheldon Marsh Nature Preserve is located on the southwestern shore of Lake Erie on the southeast end of the 10.5-km-long Cedar Point sand spit. The preserve resembles an inverted “L” with a 1.8-km-long barrier beach that fronts Lake Erie and shields a wetland area. The center of the beach is at 82°36'42"W longitude and 41°25'26"N latitude (NAD83).

Sheldon Marsh only covers 465 acres, but its ecological importance cannot be overemphasized. The marsh is a unique habitat and is a critical stopover for migratory birds. The beach has suffered severe erosion since the 1950s, and protection and partial restoration of the sand barrier is essential to the survival of existing and future plant and animal communities.

Retreat of the shoreline at the preserve has been a continuing problem throughout the 20th century. Between 1937 and 2003, the beach retreated an average of 360 m. This averages to 5.4 m/year, but the retreat was episodic, with years of rapid retreat interspersed with periods of relative stability. The beach has been relatively stable during lower lake levels (post-1998). A water level rise in the future due to climatological factors (e.g., increased rainfall, less evaporation because of cloud cover, unexpected snowmelt), would subject the barrier to significant damage from storm waves.

The main cause of erosion along the Ohio shore is a lack of littoral sediment. The most immediate contributor to the sediment loss in the Sheldon Marsh area is the Huron jetties, only 4,900 m to the southeast. Because of the sheltering effect of the confined disposal facility at the Huron west jetty, significant amounts of sediment have been trapped next to the west jetty, thereby further depriving the littoral system of sediment. A lack of sediment indicates that erosion of the Sheldon Marsh barrier will occur under all Lake Erie water levels. However, higher water level will make the barrier narrower and therefore more vulnerable to breaches or overwash. During low-water periods, downcutting may occur offshore, allowing storm waves to reach the beach with less frictional loss.

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# Preface

This report is one of a series that documents the study setting, engineering design, construction techniques, and project performance of the National Shoreline Erosion Control Development and Demonstration Program (Section 227). This study was authorized under Section 227 of the Water Resources and Development Act of 1996 (Public Law 104-303, 110 Stat. 3658) and funding was appropriated to initiate the program in Fiscal Year 2000. The program's emphasis is on evaluating innovative or nontraditional approaches to help prevent coastal erosion and to improve shoreline sediment retention. A series of study sites were selected around the Unites States on all of the ocean coasts and the Great Lakes. Mr. William R. Curtis, Coastal and Hydraulics Laboratory (CHL), is the Section 227 Program Manager.

This document describes the geographical setting, morphology, geology, and physical processes of the Sheldon Marsh State Nature Preserve, in Huron, Ohio. A Reconnaissance Report prepared by U.S. Army Engineer District, Buffalo, will discuss the physical model tests and engineering design of the innovative, wide-crested submerged breakwaters that have been proposed as the optimal solution to retard further erosion at the preserve. If the project is constructed, future reports will cover the monitoring and performance of the breakwaters.

This report was prepared by Dr. Andrew Morang of the U.S. Army Engineer Research and Development Center, CHL, Vicksburg, MS, and Mr. Shanon Chader, U.S. Army Engineer District, Buffalo, NY.

Work was performed under the general supervision of Dr. Yen-Hsi Chu, former Chief, Coastal Engineering Branch, CHL; Ms. Joan Pope, former Technical Director for Flood and Coastal Storm Damage Reduction, CHL; Mr. Thomas W. Richardson, Director, CHL, and Dr. William D. Martin, Deputy Director, CHL.

The authors wish to thank the following individuals and organizations for data and assistance with this project:

*a.* Mr. Robert Puzak, NASA Glen Research Center, Plum Brook Station, Sandusky, Ohio.

*b.* Mr. Mark A. Wroblewski, Erie County Auditor’s Office, Sandusky, Ohio.

*c.* Messrs. Gary Obermiller and John McFadden, Ohio Department of Natural Resources, Division of Natural Areas and Preserves, Sandusky, Ohio.

*d.* Messrs. Donald Guy and Jonathan Fuller, Lake Erie Geology Group, Ohio Geological Survey, Ohio Department of Natural Resources, Sandusky, Ohio.

*e.* Messrs. Michael Mohr, U.S. Army Engineer District, Buffalo, Patrick Lee, University of Virginia, and Kenneth Connell, CHL, reviewed the manuscript and made many helpful comments.

At the time of publication of this report Dr. James R. Houston was Director of ERDC, and COL James R. Rowan, EN, was Commander and Executive Director.

# 1 Project Setting

Dr. Dean Sheldon, Sr., purchased a quiet expanse of forest and marsh on the Lake Erie shore in 1954 as a family retreat. He built a rustic cabin but otherwise left the land undisturbed. In jest, local residents sometimes called the good doctor's retreat "Sheldon's Folly," but over time, it became a sanctuary for migrating birds. In 1979, the state of Ohio purchased the land from Dr. Sheldon's estate and established a nature preserve. The Ohio Department of Natural Resources (DNR), Division of Natural Areas and Preserves, now manages the site.

Sheldon Marsh Nature Preserve is located on the southwestern shore of Lake Erie on the southeast end of the 10.5-km- (6.5-mile-) long Cedar Point sand spit (Figure 1). The preserve is in Erie County approximately 3 km (1.8 miles) west of the city of Huron on U.S. Route 6. The shape of the preserve resembles an inverted "L" with a 1.8-km- (6,000-ft-) long barrier beach that fronts Lake Erie and shields a wetland area (Figure 2). The center of the beach is at lat 41°25'26"N and long 82°36'42"W, North American Datum of 1983 (NAD83).

Sheldon Marsh only covers 188.2 ha (465 acres), but its ecological importance cannot be overemphasized.

*a.* Sheldon Marsh State Nature Preserve and contiguous wetlands comprise some of the last remaining undeveloped stretches of shoreline in the Sandusky Bay region. As Ohio's once expansive coastal wetland habitat continues to disappear in the face of encroaching development, the importance of Sheldon's Marsh increases immensely.

*b.* Preservation of habitat is seen as the key to survival of wild plant and animal communities, and this preserve contains many types of habitats such as old field, hardwood forest, woodland swamp, cattail marsh, barrier sand beach and open water lake. All are relicts of the lake-marsh-forest ecosystem that originally encompassed thousands of acres along Lake Erie's western basin.

*c.* This preserve is known to attract nearly 300 bird species and provides habitat for many kinds of wildflowers.[1]

[1] From Ohio Department of Natural Resources, http://www.dnr.state.oh.us/dnap/location/sheldon.html (14 April 2005).

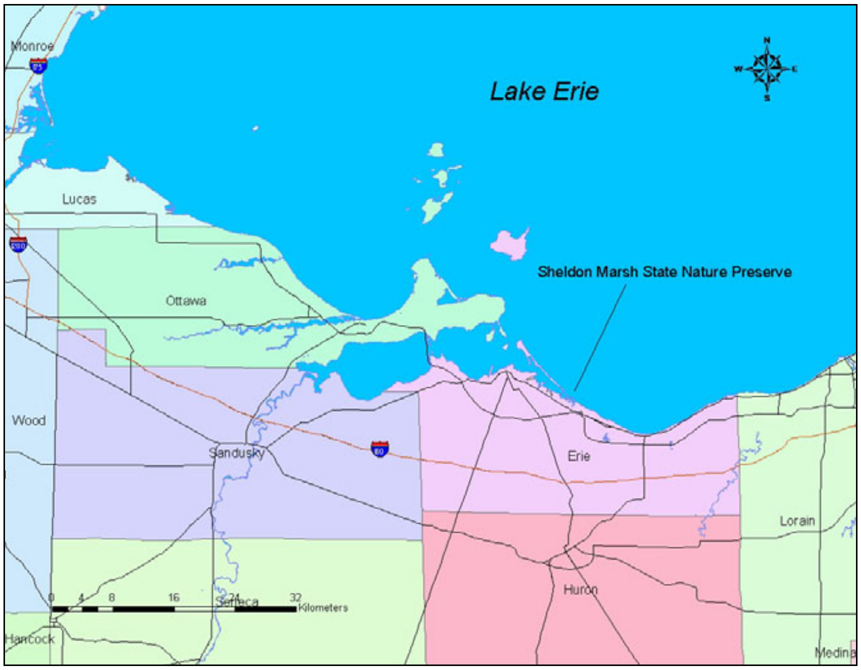


Figure 1.  Sheldon Marsh study site, southwest Lake Erie

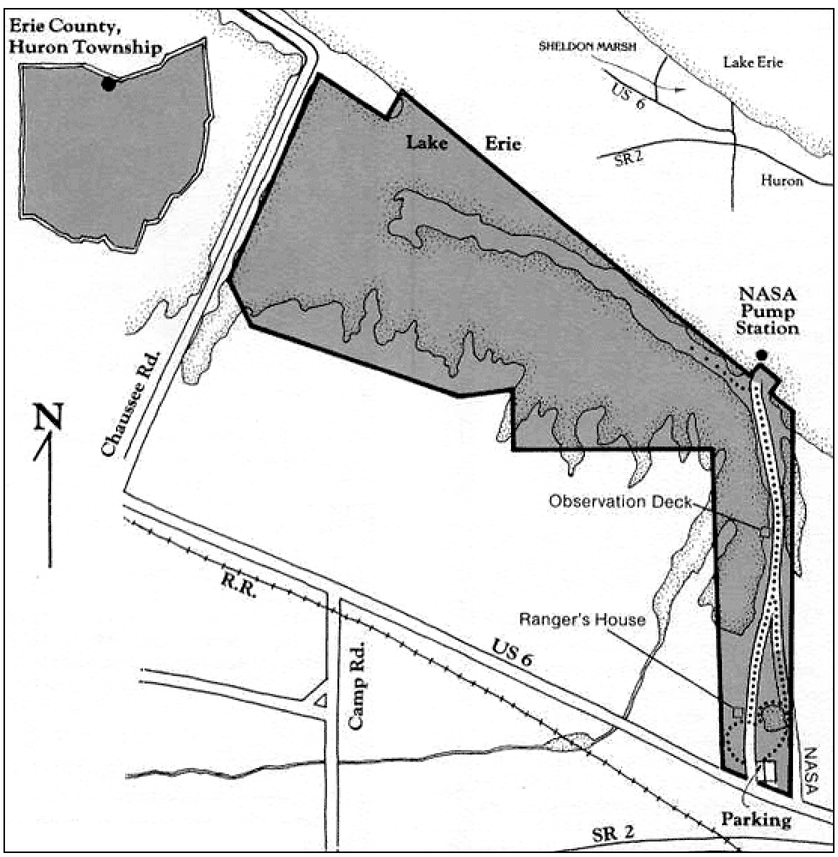


Figure 2.  Sheldon Marsh State Nature Preserve site diagram.  Figure from Ohio DNR (*http://www.dnr.state.oh.us/dnap/location/sheldon.html*)

The marsh is a unique habitat and is a critical stopover for migratory birds. The beach has suffered severe erosion since the 1950s, and protection as well as partial restoration of the sand barrier is essential to the survival of existing and future plant and animal communities.

An elevated paved road marks the east edge of the nature preserve. This follows the alignment of the original Chaussee Road to the Cedar Point amusement park. Built in 1913-1914, it was the first concrete road in Ohio. Until the mid-1990s, the historical iron entrance gate still stood near the ranger station.[1] The road now ends at a pump facility, which projects out into Lake Erie (Figure 3), but during the 1910s, the road turned left and proceeded along the beach to the west. Because of erosion, the road deteriorated and was abandoned around 1917-1920. In the 1960s, concrete blocks could still be seen on the barrier, but they are now underwater. Remnants of the concrete blocks and wood piles can be seen in side-scan sonograms of the lake bed.[2]

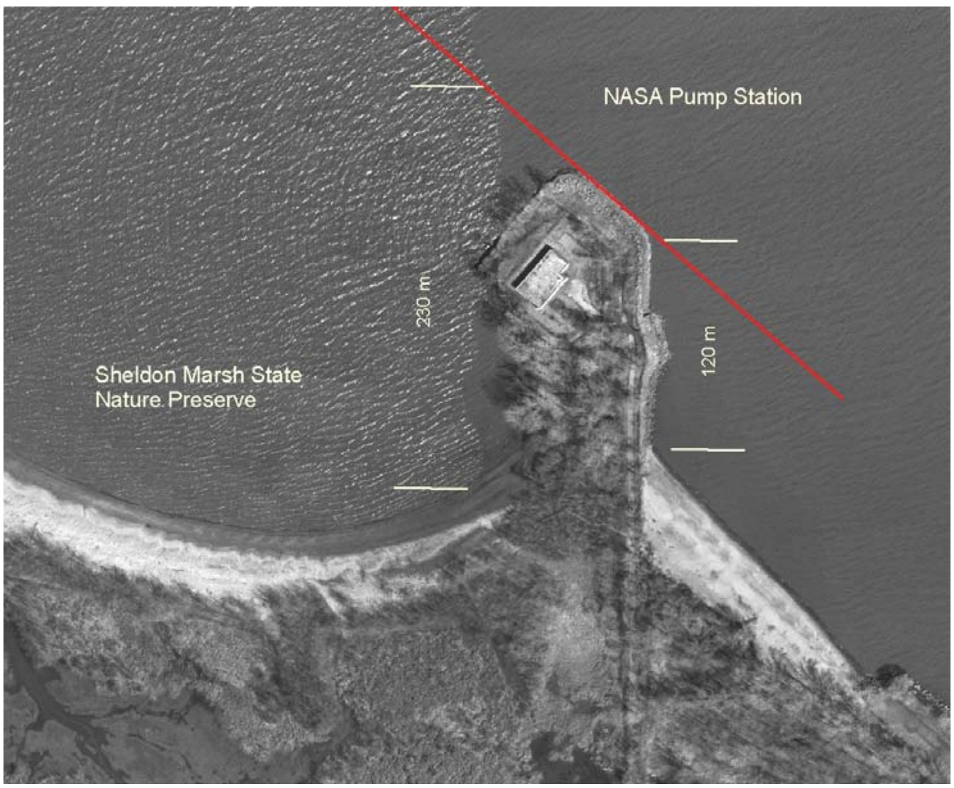


Figure 3. NASA pump station and beach at Sheldon Marsh, 12 April 2003 (north is to the top). The fact that beach has retreated on both east (updrift) and west (downdrift) sides indicate how little sediment is available in this system. Red line marks 1937 shoreline position (photograph courtesy of Erie County Auditor's Office)

[1] Coastal Ohio Web page: http://www.coastalohio.com/site.asp?id=21 (14 April 2005).
[2] Personal Communication, 28 April 2005, J. A. Fuller, Ohio Geological Survey.

The causeway along the west side of the preserve is now labeled as the Chaussee. This was once known as Willow Road but was renamed when the original Chaussee was abandoned. The causeway serves homeowners on the peninsula east of the amusement park. Just lakeward of the west edge of the preserve is an armored spit developed with condominiums (Figure 4). This is now the southeast end of Cedar Point Peninsula, but at one time was attached to the barrier beach that shielded the marsh.

Figure 4. View looking south of west half of Sheldon Marsh, 13 April 1999. Armored spit on right is now easternmost end of Cedar Point Peninsula, but at one time, beach was continuous (photograph courtesy of U.S. Army Engineer District, Buffalo)

Cedar Point peninsula and its famous amusement park have a colorful past. The following quote from *The Ohio Cardinal* outlines some of the history:[1]

> "Actually, a modest beer-garden resort had already existed on a small portion of the Ridge section as early as the 1870s. The Cedar Point Pleasure Resort, situated a mile east of the tip, attracted more free-spenders in the late 1880s. The Grand Pavilion was built in 1888, and although the first semblance of a roller-coaster was installed in 1892, rides and amusement attractions did not become an area attraction until the period from 1905 to 1920. Instead, the resort was best known for its bathing beaches, dining, and various stage productions. With a daily attendance sometimes reaching 10,000 by the

[1] From *The Ohio Cardinal*, a quarterly publication devoted to the study and appreciation of Ohio's bird life, http://www.sheldonsmarsh.org/history.html (11 April 2005).

> early 1900s, expansion was inevitable. The lagoons were dug into the Ridge section west of the Pavilion in 1904, expanding into previously undeveloped natural areas. In 1905, the famous Breakers Hotel opened, hosting celebrities ranging from several U.S. Presidents to John Philip Sousa, John D. Rockefeller, and Annie Oakley. But keep in mind that everyone visiting the resort arrived by water—Henry Ford hadn't introduced his Model-T until 1908. With the advent of the auto, resort owners soon recognized the need for a permanent roadway serving the area. Thus, in 1914 the "Chaussee" was opened, stretching from the mainland to nearly three-fourths the distance of the entire peninsula. This, of course, paved the way for development of the rest of the area, and although substantial development of the Bar section did not occur until the 1950s, the damage had been done."

During the Great Depression, attendance at the amusement park dropped drastically, and the facility survived largely due to the popularity of Big Bands that performed at the dance hall.[1] By the mid-1950s, the park was about to close for good, and developers planned to convert the land into a housing development. But in 1957, new owners redeveloped the park with new rides and equipment and opened a more convenient Cedar Point Causeway between Highway 6 and the peninsula. The improvements were successful, and the park continues to be a thriving and popular tourist destination.

The National Aeronautics and Space Administration (NASA) pump station, located on the end of the original access road, has had a major influence on sediment transport along the shoreline. It has an interesting World War II and Cold War history. The facility, on a 0.55-ha (1.35-acre) site, was built in 1941 to provide water for the manufacture of munitions at the Plum Brook Ordnance Works (PBOW). The 3,600-ha (9,000-acre) site south of Sandusky was originally acquired by the War Department in 1938 as part of a massive effort to develop a munitions industry in the United States capable of supporting the upcoming war. From 1941 to 1944, the Trojan Powder Company produced trinitrotuluene (TNT), dinitrotuluene (DNT) and Pentolite at the PBOW for the war effort. After the war, armaments production ended. The property was transferred to the Ordnance Department in 1946 and then to the General Services Agency (GSA) in 1949.[2]

NASA's Glenn Research Center occupied the site in 1963. NASA built numerous facilities to test space power generation, propulsion systems, and space hardware under simulated conditions. NASA began construction of a research test reactor there in 1958 (Bowles and Arrighi 2004). The original purpose of the reactor was to develop technologies for the nuclear-powered aircraft, one of many ambitious Cold War programs.[3] Just when the reactor was completed in 1961, President John F. Kennedy suspended the nuclear aircraft program for safety, technical, and managerial reasons (and after consuming over $7 billion in

[1] The CedarPoint.com Web page has an interesting and well illustrated history of the amusement park: http://www.cedarpoint.com/public/new/history/a.cfm (11 April 2005). Archives from the *Walkerville Times* are available on the Web: http://www.walkervilletimes.com/36/cedar-point.html (12 April 2005). Another chronological history is at PointBuzz™: http://www.pointbuzz.com/history.htm (12 April 2005).

[2] History condensed from the Huntington District Web page: http://www.lrh.usace.army.mil/projects/current/derp-fuds/pbow/ (12 April 2005).

[3] An interesting on-line history of nuclear flight is at: http://www.megazone.org/ANP/ (15 April 2005).

1950s dollars) (York 1970). However, in its place, he advocated an even bolder plan - a nuclear rocket. The Plum Brook Reactor Facility became one of the primary research centers to test materials for this rocket. The reactors were operated continuously from 1961 to 1973, when the nuclear rocket fell prey to cost-cutting in the face of programs like the Space Shuttle that appeared to have greater payoff. NASA discontinued nuclear research and placed the reactor in a standby condition. It finally marked the facilities for decontamination and dismantling in 1998[1]. The reactors and all contaminated materials are to be removed, allowing the land to revert to farming use, as they were before 1938. Currently, the U.S. Army Engineer District, Huntington, has initiated remediation activities under the Defense Environmental Restoration Program for Formerly Used Defense Sites (DERP-FUDS).

During the 1960s, the pump provided cooling water for the reactors (Figures 5, 6, and 7). The following caption from Bowles and Arrighi (2004) provides more details:

> Image 51: Plum Brook had two pumping stations to obtain raw water from nearby Lake Erie. The reactor required one million gallons of water daily for cooling, shielding, and dilution of radiation. The main one was at Rye Beach (pictured) and the other was at Big Island. They were initially constructed in 1941 for the Ordnance Works and were closed in late 1945. In March 1958, NACA[2] assumed control of both facilities, but it took several years of repairs and cleaning before both would consistently function properly. They were connected to Plum Brook by 9.5 km (5.9 miles) of 61-cm (24-in.) steel piping. Together, they could pump 51 million gallons of lake water per day. (1983) (NASA C–2003–838).

The pump house was armored by the USACE sometime in the early 1940s (Figure 5). As the surrounding shore eroded, the pump house projected out from the shoreline like a peninsula. In Figure 3, the diagonal line indicates the position of the 1937 shoreline. As of 2003, the shoreline on the east side of the pump had receded about 120 m (394 ft), and the west (nature preserve) side about 230 m (754.6 ft). The pumps have not been used since the mid-1990s, but recently NASA and Erie County entered into an agreement to lease the water line, which passes underneath the marsh, for municipal water supply. The line has been pressure tested, and modern electric pumps will replace the diesel units.

[1] From Nuclear Regulatory Commission decommissioning plan, March 2001: http://www.grc.nasa.gov/WWW/pbrf/documents-records/Decom_Plan-public3-01.pdf (12 April 2005).
[2] National Advisory Committee for Aeronautics.

Figure 5. West side of NASA pump facility, 27 April 2005. Barrier beach at nature preserve is in background

*Image 51: Plum Brook had two pumping stations to obtain raw water from nearby Lake Erie. The reactor required one million gallons of water daily for cooling, shielding, and dilution of radiation. The main one was at Rye Beach (pictured) and the other was at Big Island. They were initially constructed in 1941 for the Ordnance Works and were closed in late 1945. In March 1958, NACA assumed control of both facilities, but it took several years of repairs and cleaning before both would consistently function properly. They were connected to Plum Brook by 5.9 miles of 24-inch steel piping. Together, they could pump 51 million gallons of lake water per day. (1983) (NASA C–2003–838)*

Figure 6. Pump station located at Sheldon Marsh. NASA photograph dated 1983 (from Bowles and Arrighi (2004), Image 51)

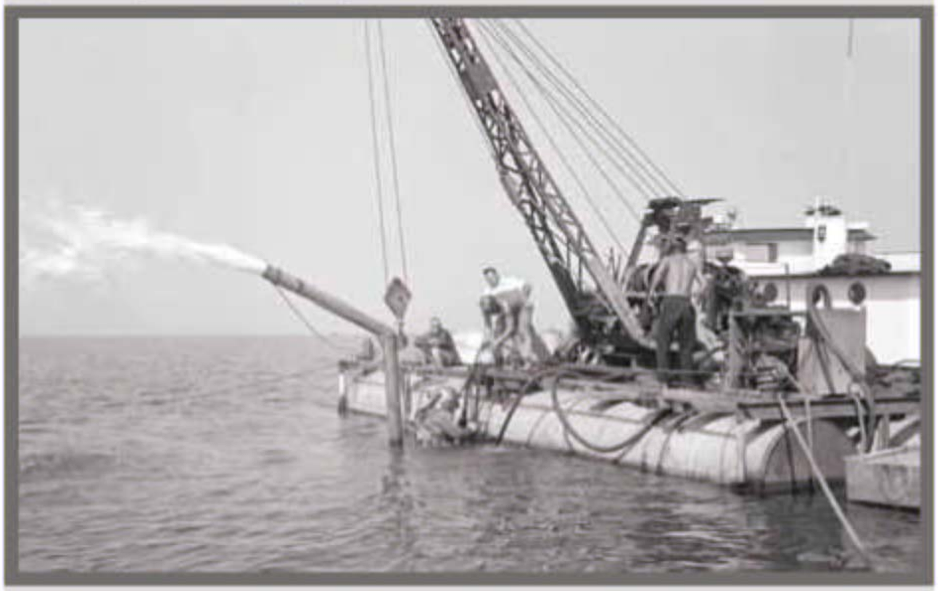

*Image 52: A diver emerges after working on the Plum Brook water pumps in Lake Erie. Divers had to flush the intake line and clear it of mud, silt, and debris regularly. (NASA C–1961–58167)*

Figure 7. Maintenance work to clear silt and debris from water intake. NASA photograph dated 1961 (from Bowles and Arrighi (2004), Image 52)

# 2 Lake Erie Water Levels

The Great Lakes of North America have always been subject to water level changes that occur over irregular cycles of years or decades (Headquarters, U.S. Army Corps of Engineers, 1995). Five main factors are responsible:

*a.* Long-term geologic changes on scales of centuries, such as crustal movements. For example, the earth's crust at the eastern end of Lake Superior is rebounding about 25 cm/ (9.8 in./) century faster than the western end, resulting in a drop of the datums (apparent higher water) at the west end at Duluth.

*b.* Global climate trends over decades to centuries. Long-term changes are caused by regional hydrographic conditions such as precipitation, runoff, temperature and evapo-transpiration, snowmelt, and ice cover (Great Lakes Commission 1986).

*c.* Seasonal changes in rainfall, ice cover, temperature, and evaporation.

*d.* Storms and seiches. On the Great Lakes, astronomic tides have little influence on water levels. Instead, atmospheric pressure changes and winds cause most of the short-term fluctuations.

*e.* Man-made changes to the basins and watersheds due to navigation structures, shore and river modifications, and land use.

Aquatic plant life may also influence the complex cycles of water level changes in the Great Lakes. As a result, the concept of mean water level is not applicable to the Lakes unless it refers to a particular period, such as a specified month or week.

During the last century and a half, Lake Erie's water level has ranged between 173.1 and 175.1 m (567.9 and 574.5 ft) International Great Lakes Datum (IGLD) 1985 (Figure 8). Thompson and Baedke (2000) calculated that these 150 years of recorded lake levels captured most, if not all, possible lake-level extremes not associated with glacial times. Lake level was generally low during the early decades of the 20$^{th}$ century, with the lowest stage of 173.2 m (568.3 ft) occurring in February 1935 during the dust bowl years of the Great Depression (1933-1935). Levels rose during the 1940s and dropped again in the 1950s, culminating in a minimum of about 173.4 m (568.9 ft) during the drought of 1964-1965. Thereafter, lake levels rose steadily for 10 years and then remained high for three decades.

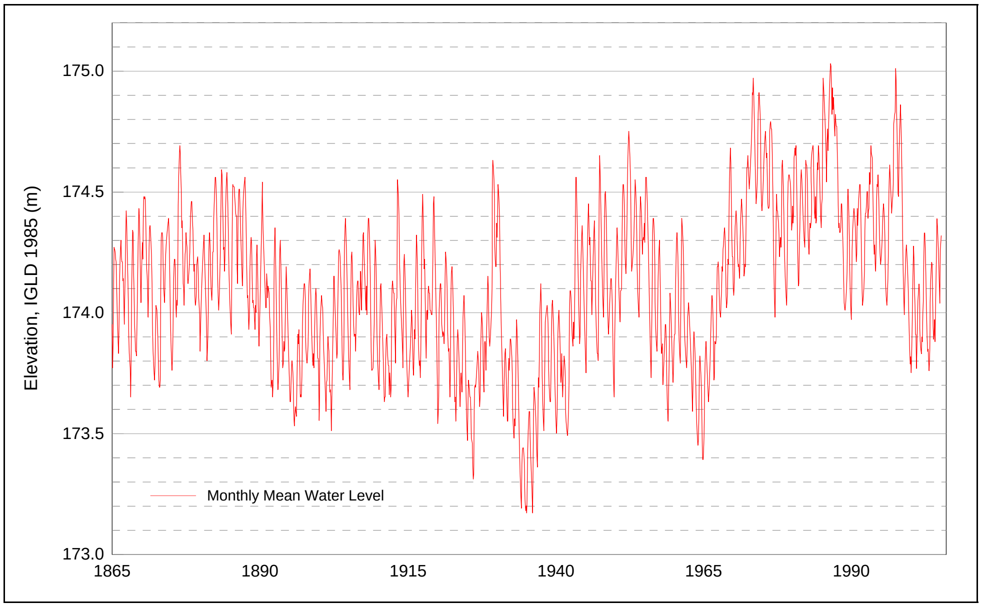


Figure 8. Lake Erie monthly mean water level from 1864 to 2004 (1864 to 1917 are based on a single gauge; 1918 to present are based on a network of gauges). Data from U.S. Army Engineer District, Detroit. Low water datum is defined as 173.5 m IGLD 1985

Low water datum on Lake Erie is defined as 173.3 m (568.6 ft) IGLD 1955 and 173.5 m (569.2 ft) IGLD 1985 (Coordinating Committee 1992).

The period of high water level in the 1980s and 1990s were a time of rapid residential and commercial growth on the lakes, and many homeowners, concerned by the destruction of their property, built shore protection structures of various degrees of engineering and quality. In 1997 and 1998, levels were significantly above average (Figure 9), almost matching the previous highest recorded average monthly water levels of 1985-1987. The high point was in June of 1997, about 0.7 m (2.3 ft) above the long-term (1918-1998) average, but starting in the fall of 1998, water levels began to drop. The winter of 1997-1998 was one of the mildest on record. The following year, 1998-1999, seasonal precipitation was below normal, particularly snowfall. Snowmelt is a key component of the Great Lakes hydrologic cycle. Water from melting snow saturates the ground or becomes overland runoff and flows into waterways and into the Great Lakes. The average monthly water level for Lake Erie in March 1999 was 0.6 m (2.0 ft) below what it was in March 1998, close to the long-term mean. By January of 2000, the water level was at 173.8 m (570.3 ft), the lowest since the spring of 1967. Since then, the level has approximately followed the long-term mean.

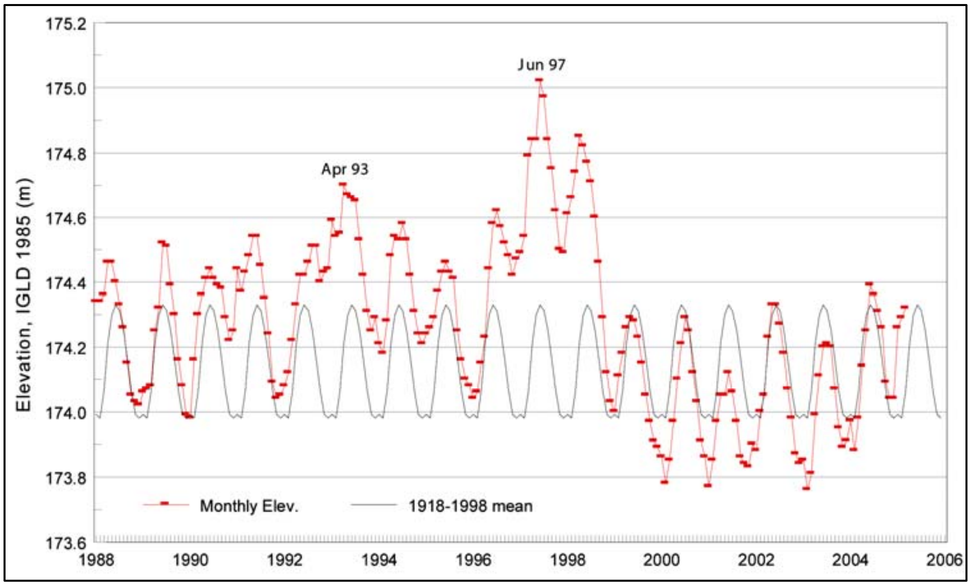


Figure 9. Lake Erie water levels, 1988 to present. Current "low" level is close to 1918-1998 mean

In addition to the multimonth trends previously described, storms can cause abrupt changes in water level that last for only days. These short-term fluctuations can raise or depress the water level as much as 2 m (7 ft). This is an important factor contributing to erosion because bluffs that normally would be well above the lake level can be hit by storm waves. Because of Lake Erie's orientation, during northeasters, northeast winds blow along the axis of the lake and cause seiching. The result can be short-term water level increases of over a meter at the west end of the lake. Fall is a period of maximum atmospheric turbulence as cold air fronts mix with warm, moisture-laden continental air masses, and autumn storms can take a heavy toll on shipping.

One noteworthy storm occurred on 13-14 November 1972, when rising waters forced 15,000 people to flee their homes and flooded unharvested farm fields (Strommen 1973). The highest water level at Toledo at 15:00, 14 November was 575.98 ft IGLD 1955, or 175.55 m IGLD 1985 (Figure 10). Carter (1973) describes the storm:

> The Lake Erie area was hit by a severe storm on the 13th and 14th of November, 1972. A north-northeast wind, which reached a speed of 60 knots, blew for 2 days directly down the long axis of the lake. This wind generated high (12-ft) waves and at the west end of the lake piled up water more than 6 ft above the lake's average November level (or about 4 ft above the record high lake level set in November 1972). The waves and high water caused damage estimated at $22 million to the Ohio shore. Northern Ohio was declared a major disaster area by the President, and the U.S. Small Business Administration declared Lucas, Ottawa, Sandusky, Erie, Lorain, Cuyahoga, and Lake Counties disaster areas.

This is the storm that caused several breaches in the barrier at Sheldon Marsh, after which the west end of the beach retreated rapidly.

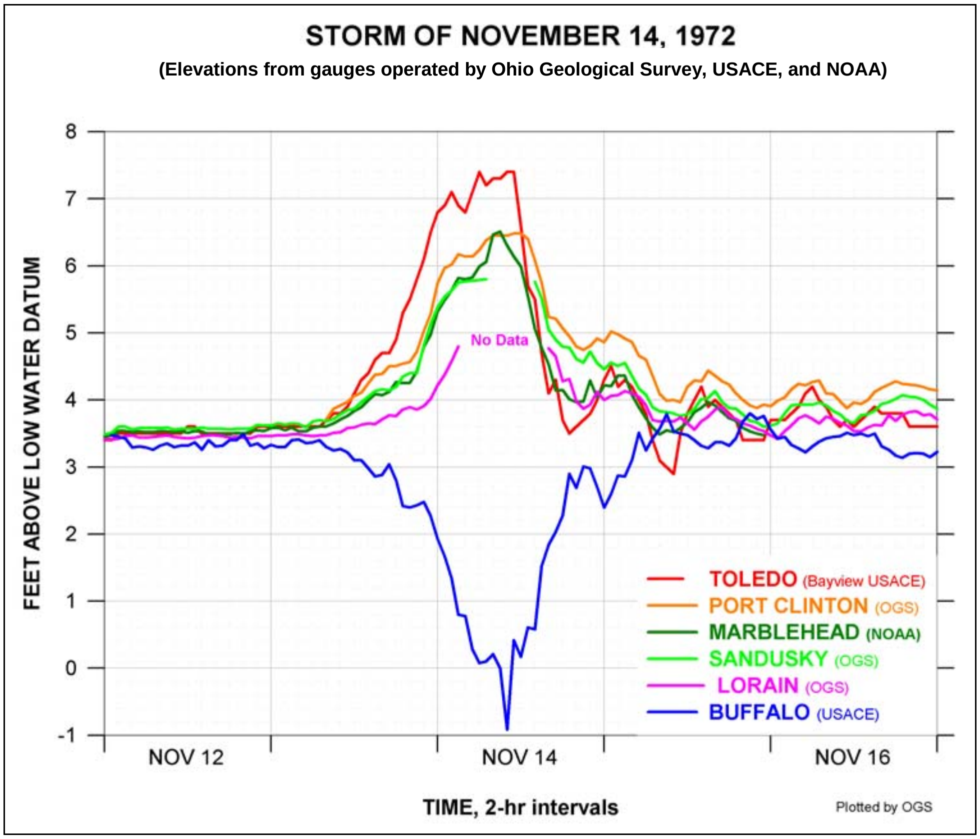


Figure 10. Water levels for 14 November 1972 storm (plot courtesy of Ohio Geological Survey)

# 3 Wave Data

Lake Erie has a wave environment characterized by long periods of calm interrupted by short-lived, high-energy storms. Great Lakes storm waves are typically shorter-period (less than ≈6 sec) and steeper than ocean storm waves. Also in contrast to oceans, there are no long-period swell waves. Lake Erie's wave climate has a seasonal component. The highest energy storms usually occur during October, November, and December, before the lake freezes, and in the spring (March and April), after the ice breaks. During some winters, the lake does not freeze, and the storm season lasts over 6 months. Moderate to low waves normally characterize the summer months.

There is no known shallow-water wave gauge data in the vicinity of Sheldon's Marsh. Therefore, wave statistics have to be developed from hindcast models based on wind fields. As part of the U.S. Army Corps of Engineers' Wave Information Study (WIS), Driver et al. (1991) developed hindcast wave statistics at select locations along the Lake Erie shore based on 32 years (1956-1987) of meteorological data (Table 1). They developed significant wave height-recurrence interval information for three class angles. The three angle classes as viewed by an observer on shore are defined as follows:

*a.* Class angle 1: Mean wave approach angle greater than 30 deg to the right of the normal from shore.

*b.* Class angle 2: Mean wave approach angle within 30 deg to either side of the normal from shore.

*c.* Class angle 3: Mean wave approach angle greater than 30 deg to the left of the normal from shore.

The wave hindcast station closest to the project site was WIS sta 6 at lat 41.43°N and long 82.50°W (Figure 11). The wave angle class bands are based upon a shore normal of 0 deg azimuth, not the orientation of Cedar Point Peninsula. Therefore, class angle 3 statistics are not applicable at this site.

**Table 1**
**Hindcast Wave Statistics, WIS Station 6**

| Return Period Years | Class Angle 1 | | | Class Angle 2 | | |
|---|---|---|---|---|---|---|
| | $H_{m0}$ | | $T_p$ - sec | $H_{m0}$ | | $T_p$ - sec |
| | m | ft | | m | ft | |
| 2 | 3.1 | 10.2 | 7.3 | 2.6 | 8.5 | 6.9 |
| 10 | 3.4 | 11.2 | 7.6 | 3.0 | 9.8 | 7.3 |
| 20 | 3.5 | 11.5 | 7.7 | 3.2 | 10.5 | 7.5 |

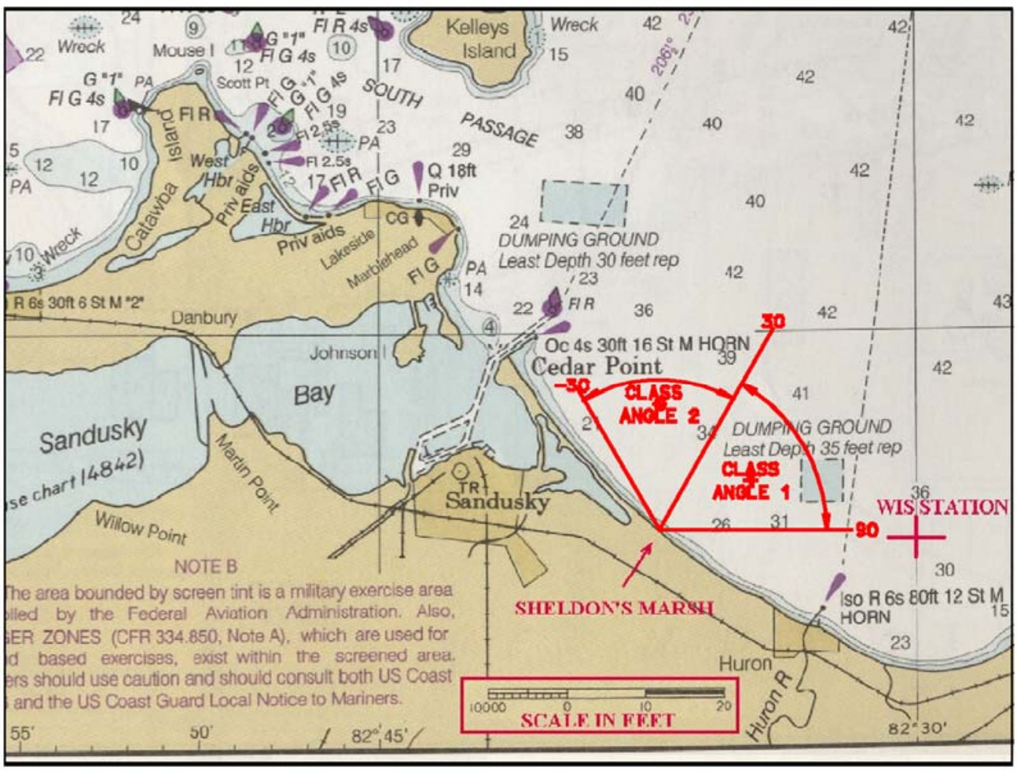


Figure 11. WIS sta 6 and diagram of angle classes at study site

Driver et al. (1991) presented tables of wave heights, periods, and number of waves within 22.5-deg angle bands. A deepwater wave rose for only waves approaching the shore was developed based on a shore orientation of 130-deg azimuth (Figure 12). More detailed information on wave statistics and modeling to project the waves into shallow water are presented in the reconnaissance report (U.S. Army Engineer District, Buffalo, 2005).

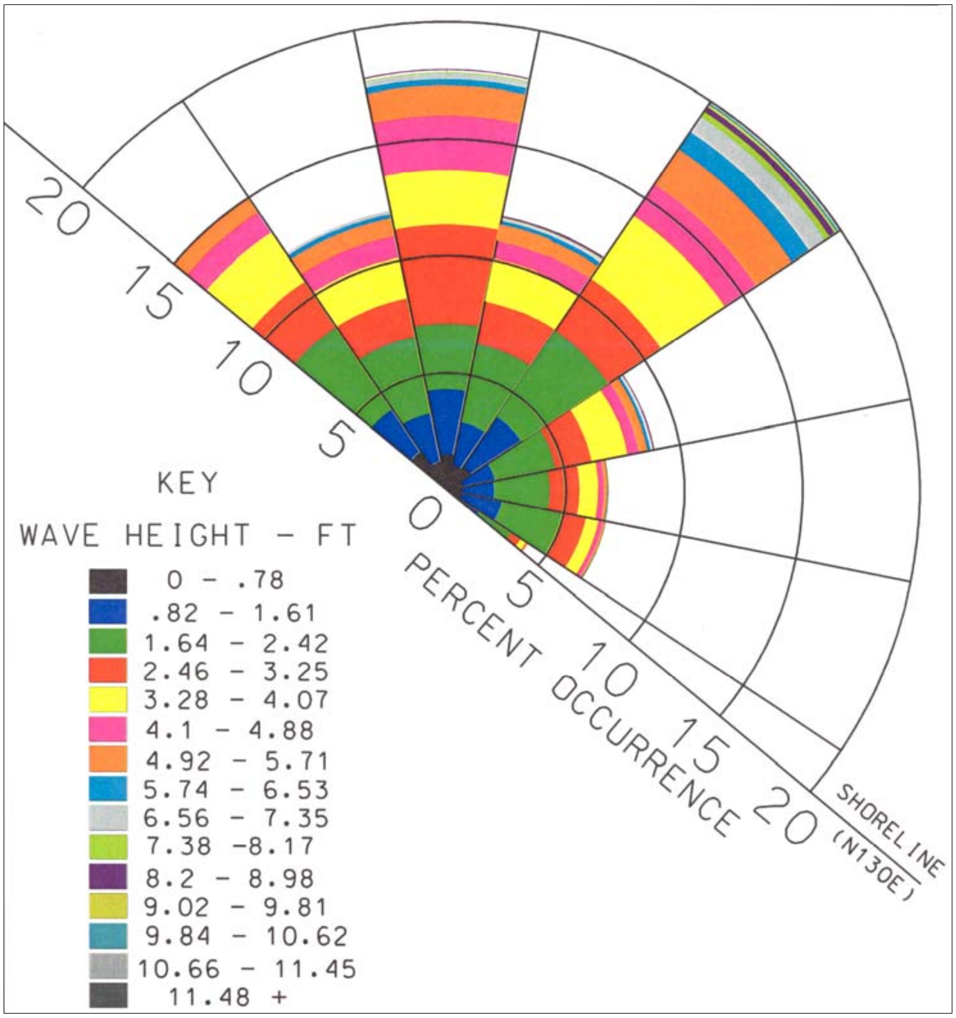


Figure 12. Deepwater wave rose based on WIS sta 6

# 4 Geologic Background and Barrier Retreat

## Background Geology

### Glacial history

Glacial processes and the Holocene adjustment to the retreat of the ice sheets dominate the recent geology of northern Ohio. During the Pleistocene era, glaciers covered northern Ohio and the basin that is now Lake Erie. About 14,000 years ago, as global temperatures began to rise, the last continental ice sheet retreated northward across Ohio. Because the St. Lawrence River Valley was still blocked with ice, glacial meltwater collected in front of the retreating ice. A large lake, called Lake Maumee, formed in the general area of the current Lake Erie but extended over a much greater portion of northwest Ohio. Ancient Lake Maumee, which drained westward into the Wabash River system, had a maximum water elevation of about 70 m (230 ft) above the current lake level (Swinford 2002). When the ice finally retreated beyond the Niagara Escarpment about 12,600 years BP (before present), the waters were free to drain to the northeast into the St. Laurence Valley. Because of isostatic depression, the escarpment was about 40 m (131 ft) below the current lake level, and Lake Maumee emptied to a level of about 130 m (426 ft) above sea level. Isostatic rebound of the escarpment led to the current Lake Erie filling to its present level of about 174 m (570 ft) (Carter et al. 1981).

### Modern sediments

Most of the mainland lakeshore between Huron and Toledo consists of barrier spits and beaches with low relief (< 2 m) or laminated clay banks. The banks are soft and highly subject to wave erosion. The Marblehead-Catawba Island area is unusual for this part of the world because it consists of outcrops of dolostone and limestone. The Marblehead quarry, on the Marblehead Peninsula north of Sandusky Bay, has been mined for limestone for over 150 years, and the historical Marblehead lighthouse, at the very east end of the peninsula, is perched on limestone slabs that project out into the lake.

Layers of modern sediments of variable thickness overlie Pleistocene glacial drift in Sandusky Bay and other shallow areas of the west end of Lake Erie. Beaches are composed of sand, gravel, and shell material. Rock fragments come from upland sources via streams, from erosion of shore and nearshore deposits. Dredging of the major tributaries during the last century has significantly reduced the volume of sand and gravel provided from upland sources (Guy and Rockaway 2004). Organic material is often found on beaches. This is exhumed from wetland deposits that are exposed on the lake bed as barrier beaches recede.

Cedar Point Peninsula formed about 12,000 years ago as lake levels gradually rose to their present levels following retreat of the continental glaciers. Large quantities of sediment supplied by rivers and eroding bluffs along the south shore of Lake Erie formed a spit and baymouth bar across Sandusky Bay. The spit was probably a stable or even a growing geomorphic feature before the mid-1800s, when settlement of Ohio and industrialization caused profound changes to the coastal sediment regime.

Many factors contributed to a reduction of the littoral sediment along the Ohio shore. Starting in the mid-1820s, jetties were built at river mouths to improve navigation into the harbors. The jetties trapped sand transported in the nearshore zone. To keep them functional, they were periodically lengthened to maintain open harbor mouths (Carter et al. 1981). Material dredged from the mouths of harbors was typically deposited in deep water or on land, further depriving the lacustrine environment of sediment. Countering this trend, it is likely that the sediment load of rivers increased as forests were cut down and the land was converted to farming. However, much of this sediment may not have entered the littoral system because of river-mouth jetties and dredging of harbor entrances.

A second factor contributing to a reduction of available sediment was the armoring of bluffs. As towns grew along the shore, attempts were made to protect bluffs and prevent their erosion. This reduced the supply of sediment formerly derived from eroding bluffs. Especially after World War II, as Americans moved to suburban communities, houses were built along the lakeshores, leading to more and more attempts to retard erosion, and therefore further depriving the beach of sediment.

### Littoral sediments

The predominant littoral drift direction between Sandusky Bay and Avon Point is from east to west. Several morphologic indicators verify this direction. First, the shape of Cedar Point Peninsula, which projects northwest out into Sandusky Bay, indicates that it was fed by a sediment source from the southeast. Second, significant quantities of material have accumulated on the east sides of the jetties within this reach (Lorain, Vermilion, Huron, and Sandusky Bay east jetty).

The closest structure updrift (east) is Huron Harbor, whose west pier was built between 1827 and 1931 (Bottin 1988). In 1907-1908, a 440-m (1,440 ft) rubble-mound east breakwater was completed, and in 1933-1934, the west pier was extended with a 415-m (1,360 ft) rubble-mound section. Over time, the jetties blocked littoral sand movement, forming a protective beach east of the harbor and depriving downdrift beaches to the west. As a result, the eastern end of Cedar Point Peninsula was the first part of the peninsula to suffer from sand loss, while the west end was largely unaffected. Carter and Guy (1980) documented that erosion is dominant west of Huron until about 1,800 m (5,905 ft) east of the Sandusky Bay east jetty at Cedar Point. Sheldon Marsh is 9,000 m (29,527 ft) east of the east jetty, well within the erosion zone.

The 1,800-m- (5,900-ft-) long Sandusky east jetty was built between 1897 and 1922. A significant quantity of sand (hundreds of thousands of cubic meters) has accumulated in the fillet on the east side of the jetty, clearly indicating that at least during the early decades of the 20th century, when the shore was less heavily armored than it is now, sand was moving west along the peninsula.

Up to the late 1930s, the sand barrier at Sheldon Marsh extended east to Sawmill Creek. As long as most of the shore remained unarmored, it eroded relatively uniformly, and the shoreline was straight. Bray (1988) documented that once the pump was armored, the shoreline west of the pump began to retreat. To the west, most of the Cedar Point spit was privately or commercially owned. In 1937, its shore was still natural, but by 1956, most of it was fronted by rock shore protection structure, which anchored the position of the shoreline. However, at Sheldon Marsh, the beach remained unprotected, and over time, the overall feature became narrower as sand was lost from the system (discussed later). In November 1972, a rise in lake level coupled with a major northeast storm caused several 15-m- (50-ft-) wide breaches in the northwest end of the barrier. This separated the remaining (eastern) portion of the barrier from the Cedar Point spit (Figure 4). Thereafter, the entire beach retreated rapidly. By 2003, the beach had retreated 230 m (750 ft) immediately west of the pump (Figure 3).

Although the net drift is to the northwest, reversals caused by wind and wave conditions do occur, and there is morphologic evidence of transport to the east. In 1975, the Corps built a confined disposal facility (CDF) along the outer portion of the Huron Harbor west jetty. Originally, the water between the armored shoreline and the CDF was as deep as the adjacent areas offshore. As of April 2005, however, the water had become shallow enough for a person to wade across because of the sand accumulation in this protected pocket (indicated by a dashed line in Figure 13). Because of the sheltering effect of the CDF, northwest waves can push material into this pocket, but northeast waves are unable to cause westward transport.

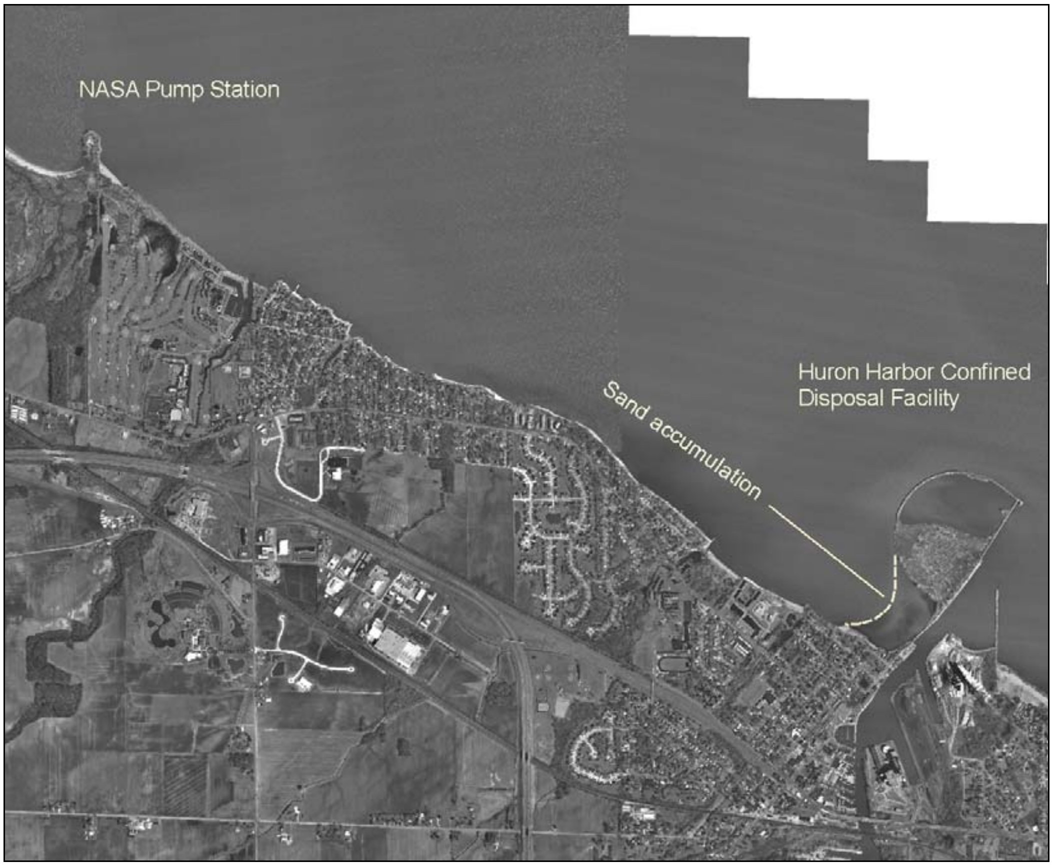


Figure 13. Coast between NASA pump station and Huron Harbor, 12 April 2003, showing sand accumulation in protected pocket west of CDF (photograph courtesy of Erie County Auditor's Office)

## Shoreline Change at Sheldon Marsh

### 1937

The first known orthogonal aerial photograph of the site was taken in 1937 (Figure 14). The shore was almost straight at this time because little or none of it had been armored, including the section of Cedar Point Peninsula that is now developed with condominiums. Therefore, shoreline retreat was uniform in this area. Only a short section of the former Chaussee Road still remained on the west portion of the barrier. Further east, the beach was so narrow, the lake appeared to reach almost to the base of the trees.

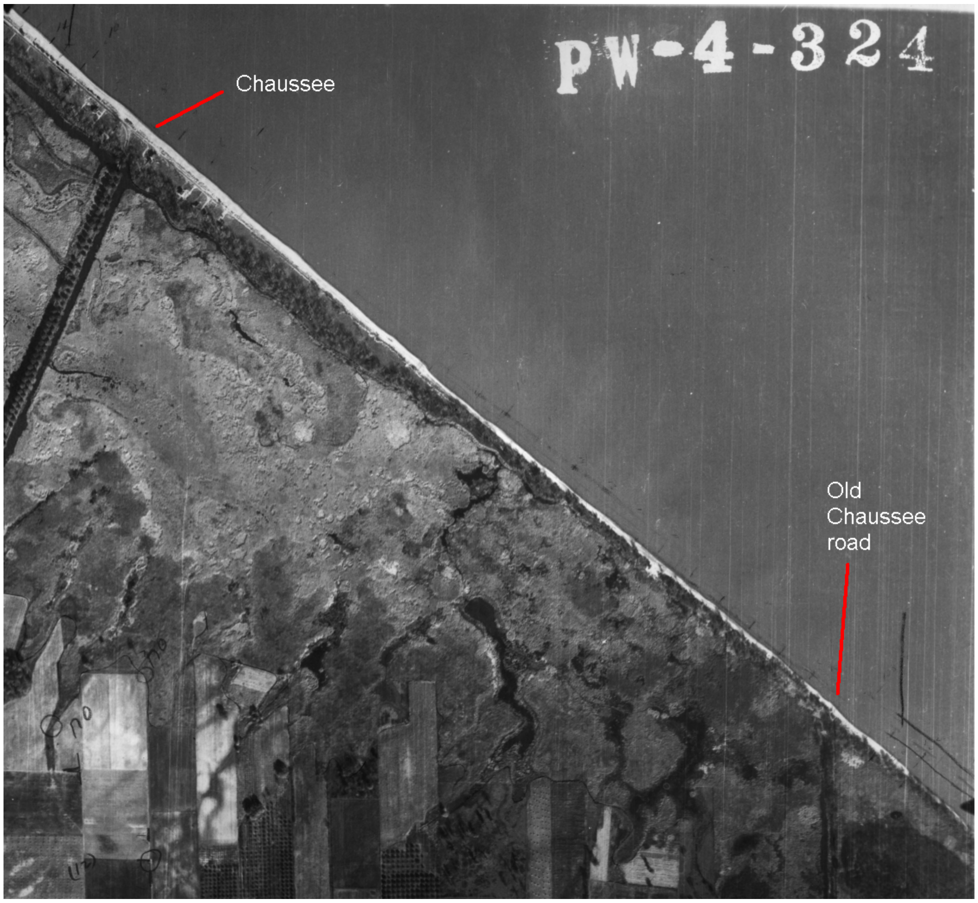


Figure 14. Sheldon Marsh, 1937. Shore was almost straight at this time, and former Chaussee Road along barrier had been abandoned. Pump station was built in 1941 at spot where old Chaussee Road reached lake (photograph courtesy of U.S. Army Engineer District, Buffalo)

### 1950

By 21 October 1950, the beach at Sheldon Marsh was already suffering the erosion that would continue for another five decades (Figure 15). The pump station was built in 1941 at the end of the former Chaussee Road and had been armored. As a result, immediately west of the pump, the downdrift shore had already retreated over 20 m (65 ft). About half of the beach had lost its tree cover, to be replaced by a broad washover apron. To the east (right) of the pump station, the sandy and partly vegetated shore was still almost flush with the station. However, further east it had retreated from a projecting area (armored or naturally more resistant to erosion). This suggests that there was little sediment available in the littoral system, and some of that was diverted by washover into the marsh. In addition, the period from 1940 to 1950 was one of rapidly rising lake level (see Figure 8), which would have made the beach more vulnerable to storm waves.

West of the Chaussee causeway, Cedar Point Peninsula had been armored with a series of closely-spaced shore-perpendicular groins. East of the causeway, the shore appeared natural, similar to the beach at Sheldon Marsh.


Figure 15. Sheldon Marsh, 21 October 1950. Ten years after pump's construction, beach had already retreated and lost most of its tree cover, to be replaced by washover fans (photograph courtesy of U.S. Army Corps of Engineers' Beach Erosion Board archives)

### 1956

In another 6 years, the downdrift beach had retreated further, and a narrow opening had formed immediately next to the pump station (Figure 16). A sand fan on the marsh resembled a flood shoal delta on an ocean coast. On the updrift (east) side of the pump station, the beach had retreated, lost its tree cover, and developed washover fans. On the Sheldon Marsh barrier, the zone of washover had not grown westward, but the vegetation-covered beach further west was narrower, making the trees more vulnerable to being washed away in storms. Cedar Point Peninsula had been armored with groins and rock rubble about as far east as the current end of the peninsula (where the condominiums and lighthouse have been built).

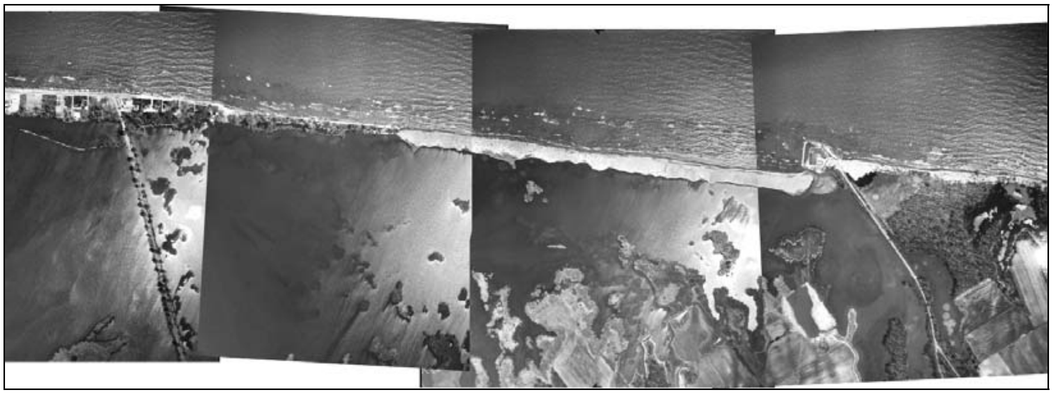

Figure 16. Sheldon Marsh, 1956. Beach downdrift (left) of pump had retreated further, and updrift side had also retreated and been overwashed compared to 1950. Light areas in each frame are sun glint (photographs courtesy of U.S. Army Engineer District, Buffalo)

### 1968

Compared to 1956, only minor morphological changes occurred. Shrubs and grass had grown on the marsh side of the washover fans, suggesting no recent overwash (Figure 17). The tree covered section of beach further west had retreated compared to the revetted shoreline at the houses, but the narrow beach had not been breached. Much of this period of relative stability coincided with dropping lake level, whose lowest stage of 173.4 m (568.9 ft) (IGLD85) occurred in December 1964, during the drought that affected much of the northeast. Thereafter, lake levels began to rise, and by 1968 had gone up about 0.6 m (2.0 ft).

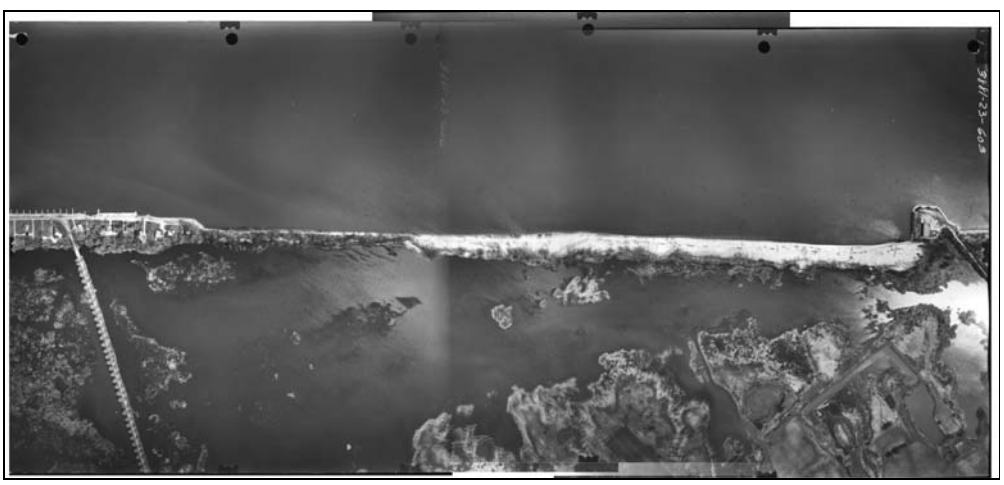

Figure 17. Sheldon March, 1968. Brush and grass had grown on section of beach that was formerly bare washover sand. To west, tree covered section of beach had retreated, leaving a step from protected shore near houses (photographs courtesy of U.S. Army Engineer District, Buffalo)

## 1972

By 1972, the lake level had risen more than 0.8 m (2.6 ft) above the 1964 low, and the narrow barrier was increasingly vulnerable to a major storm. On 13-14 November 1972, a northeaster caused at least three breaches in the northwest end of the barrier, in the area that had become progressively narrower after 1950 (Figure 18).

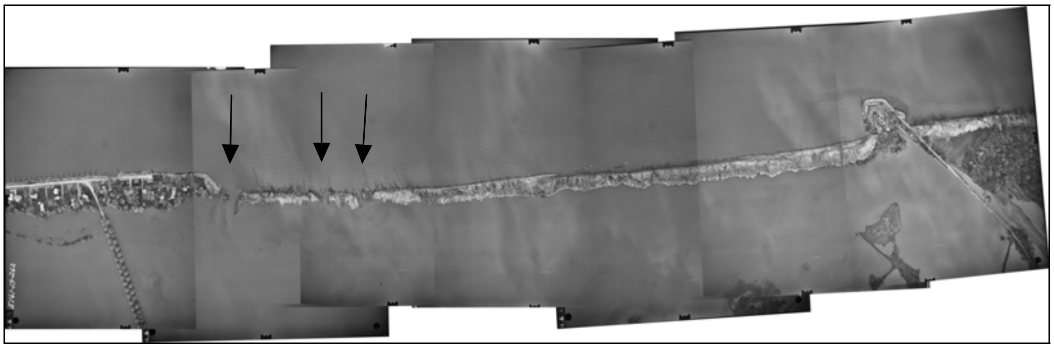

Figure 18. Sheldon Marsh, 1972. Three breaches occurred on west portion of barrier during 14-15 November storm (shown by arrows). Southeastern section of beach was more completely covered with vegetation than in 1968. Shoreline curvature is an artifact of mosaicing software (photograph courtesy of U.S. Army Engineer District, Buffalo)

## 1984

By 1984, the barrier west of the pump station was a narrow ribbon of sand with tree cover (Figure 19). Trees and brush had grown on the overwash fan next to the pump station (visible in the 1972 photograph). The east and west shorelines had retreated a similar degree.

Figure 19. Sheldon Marsh, 1984. Oblique aerial photograph looking approximately south. (NASA photograph 5382, courtesy of NASA Plum Brook Station)

## 1985

One year later, the beach had fewer trees and had been overwashed in some areas (Figure 20).

Figure 20. Sheldon Marsh, 1985. Oblique aerial photograph looking east. Trees in water attest to recent shore retreat and damage from storms (NASA photograph 2866, courtesy of NASA Plum Brook Station)

### 1987

High water and storms had wrought major damage to the barrier by 1987. The beach had been severed from the peninsula where the NASA pump was located, and major areas of overwash had occurred on the western part of the barrier (Figure 21). There were no trees at all on the low remnants of the beach.

Figure 21. Sheldon Marsh, 1987, view looking southwest (NASA photograph 401, courtesy of NASA Plum Brook Station)

### 1997

By 27 March 1997, the barrier had assumed the arcuate shape that it has today (Figure 22). The straight red line in the figure represents the alignment of the 1937 shoreline. In 60 years, the maximum retreat of the lake edge of the beach was 360 m (1,180 ft). Two areas near the northwest end of the beach had become precariously narrow and were subsequently overwashed.

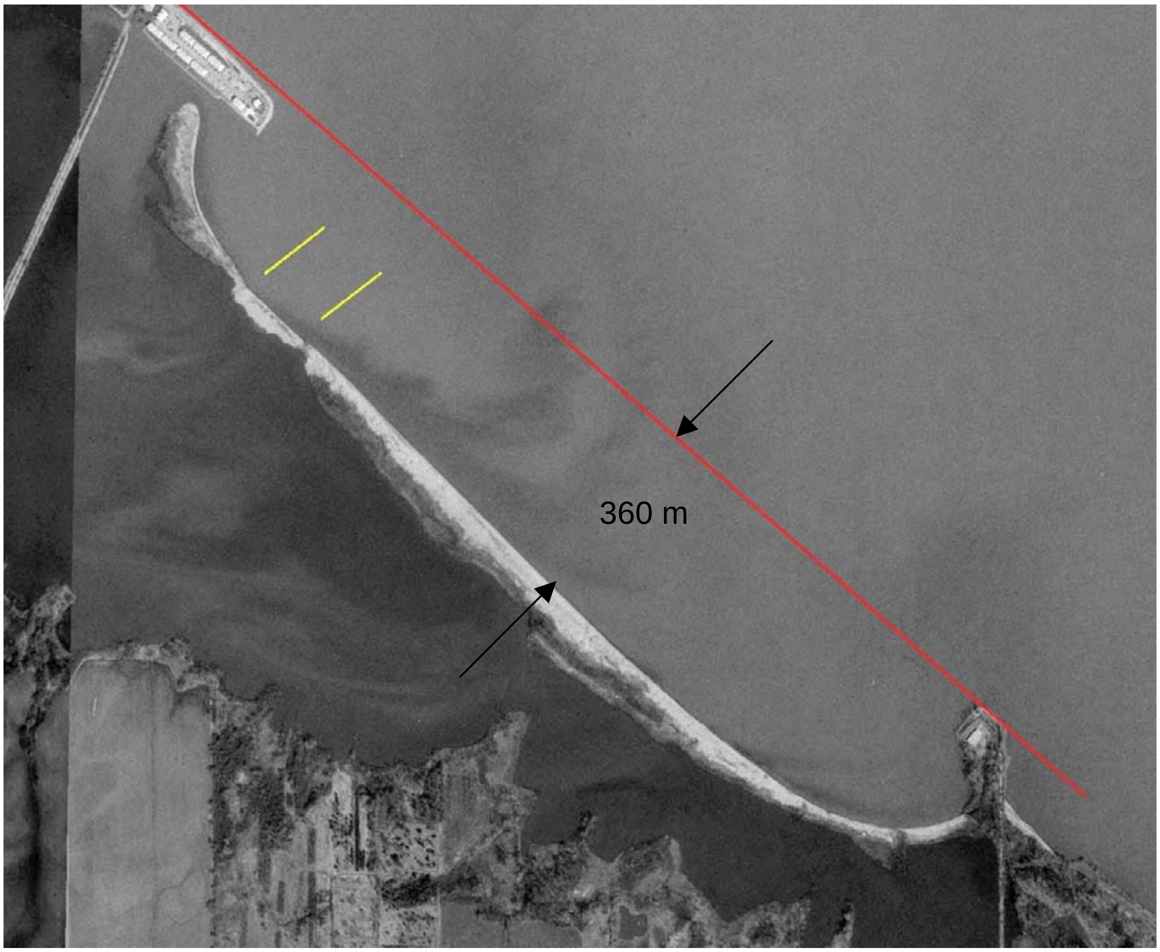


Figure 22. Sheldon Marsh, 27 March 1997. Beach had retreated as much as 360 m from straight line representing 1937 shoreline. Two yellow lines mark narrow sections of beach that were later overwashed (north is top). (Digital Orthophoto Quarter Quadrangle photograph courtesy of Ohio GIS Support Center, projected in ArcGIS software)

## 2000

The beach on 10 October 2000 was in approximately the same position as in 1997, with some advance on the southeast end and retreat on the northwest (Figure 23). The relative stability may have been partly due to lower lake levels following the peaks of the late 1990s. The narrow area at the northwest end of the beach, as noted in the 1997 photograph, was overwashed (Figure 24).

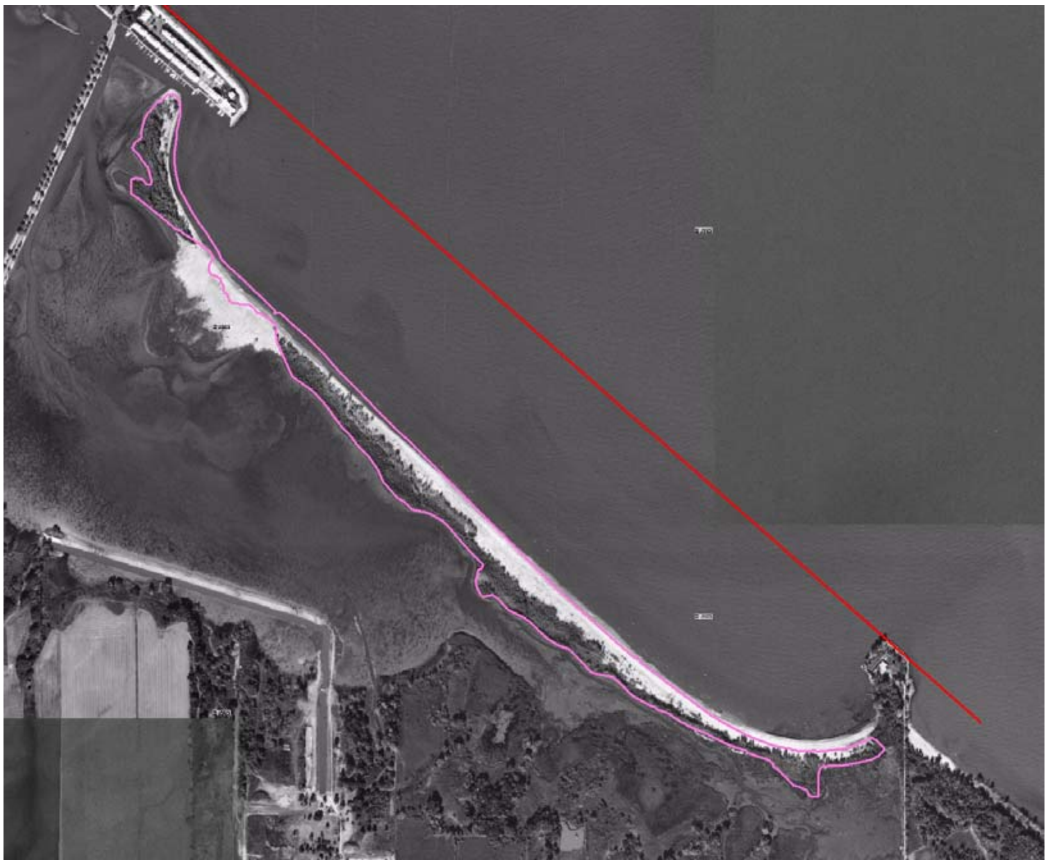

Figure 23. Sheldon Marsh, 10 Oct 2000. Overall position of beach is little changed compared to 1997 (purple outline). Washover occurred between two narrow portions of 1997 beach (north is top). (Digital photographs from U.S. Geological Survey, downloaded from TerraServer USA Web site (http://terraserver-usa.com/default.aspx), projected in ArcGIS software)

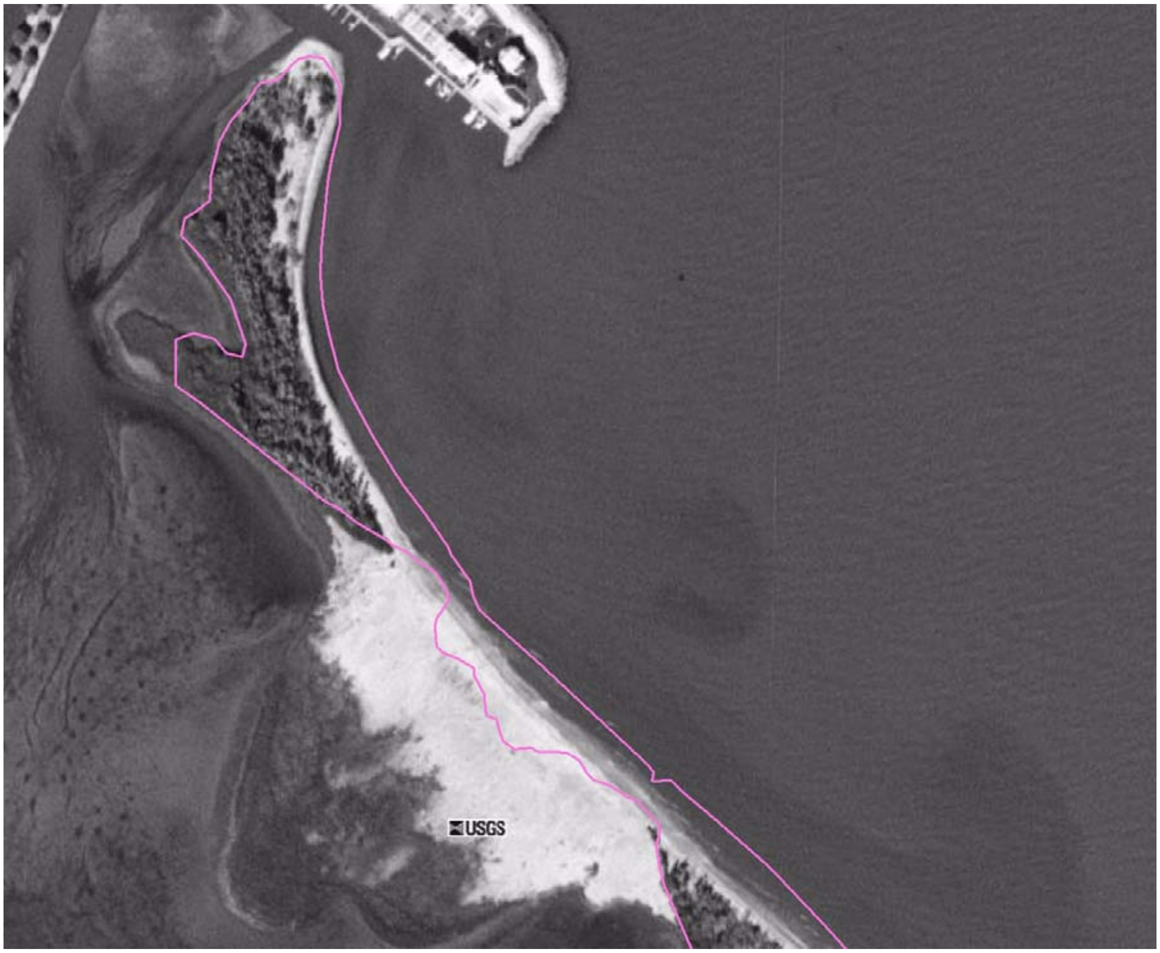


Figure 24. Sheldon Marsh, 10 October 2000. Washover near northwest end of barrier. Purple lines show outline of 1997 beach

**2003**

On 12 April 2003, the beach was essentially in the same position as in 2000. Much of the overwash area had become vegetated, and there did not appear to be any recent overwash (Figure 25).

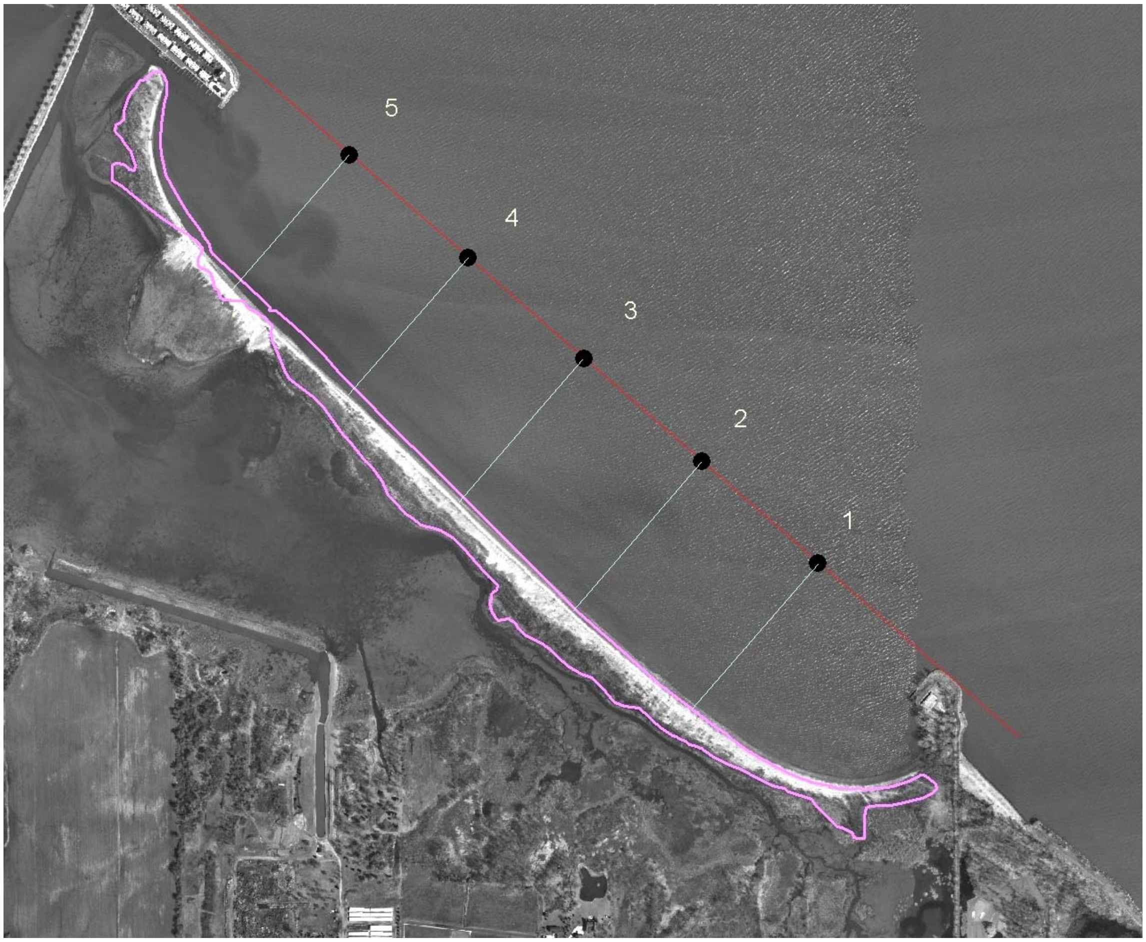


Figure 25. Sheldon Marsh, 12 April 2003. Purple outline is 1997 beach. Cross-section lines were used for shoreline retreat measurements (photograph courtesy of Erie County Auditor's Office)

## Summary Statistics and Continuing Erosion

To quantify the overall shoreline retreat at Sheldon's Marsh, the position of the dry beach in the 2003 photograph was measured with respect to the 1937 baseline (Table 2 and Figure 25). The average retreat of the barrier over 66 years was 360 m (1,180 ft), or about 5.4 m/year (18 ft/year). The retreat was not uniform but was greater during high-water years. During the high-water period from 1973 to 1997, the barrier retreated at almost 18 m/year (59 ft/year) (Guy 2002), but during the lower water period of 1997 to 2003, the barrier was relatively stable.

**Table 2**
**Shoreline Change 1937-2003**

| Cross-section line | m | ft |
|---|---|---|
| 1 | 366 | 1,200 |
| 2 | 377 | 1,240 |
| 3 | 364 | 1,190 |
| 4 | 344 | 1,130 |
| 5 | 339 | 1,110 |
| Average: | 358 | 1,175 |
| Annual: | 5.4 | 18.0 |

The narrow sand barrier at Sheldon Marsh continues to be vulnerable to storms. During a site visit on 27 April 2005, evidence of continued sand loss from the system was visible. On the east end of the barrier, washover fans could be seen within the woods (Figure 26). Further west along the barrier, trees were bent over in response to wave action (Figure 27), and exposed tree roots showed that about 0.7 m (23 ft) of sand had been washed away (Figure 28). The DNR preserve manager was not aware of any particular storm that might have been responsible for the fans.[1] Therefore, ordinary winter storms, coupled with increased water levels, caused the sand loss. If lake levels continue to rise, the barrier will be increasingly vulnerable to storm waves.

Sediments on the beach consisted of sand, organic debris, and rounded shale fragments. The shale comes from outcrops of the Devonian-age Ohio shale unit or from till overlying the unit. The nearest outcrops are west of Huron, indicating that some material bypasses the NASA pump, although the quantities are minimal.

[1] Personal Communication, 27 April 2005, John McFadden, Ohio Department of Natural Resources.

Figure 26.  Overwash fans in woods on southeast end of barrier (27 April 2005)

Figure 27.  Trees damaged by storm waves (27 April 2005)

Figure 28.  Horizontal roots that were formerly buried (27 April 2005)

# 5 Summary

Retreat of the shoreline at Sheldon Marsh has been a continuing problem throughout the 20th century. As long as the shore was unarmored, it retreated uniformly and remained straight. When the NASA pump station was armored in the early 1940s and Cedar Point Peninsula was armored following World War II, these portions of the shoreline became fixed, but the natural barrier at Sheldon Marsh continued to retreat.

The main cause of erosion along the Ohio shore is a lack of littoral sediment. The loss of sediment began in the early 1800s as a result of industrialization, land-use changes, urbanization, and dredging practices. The most immediate contributor to the sediment loss in this area is the Huron jetties, only 4,900 m (16,000 ft) southeast of the NASA pump station. Because of the sheltering effect of the confined disposal facility at the Huron west jetty, significant amounts of sediment have been trapped next to the west jetty, thereby further depriving the littoral system of sediment.

The NASA pump station now projects out from the shore like a groin. The lack of sediment in this system is underscored by the fact that even the east (updrift) side has retreated over 100 m (330 ft) compared to the 1937 (prearmored) shoreline. A limited amount of new material enters the embayment in front of Sheldon Marsh, as shown by shale fragments on the beach at the nature preserve.

The net littoral transport direction along this section of the Ohio shore is to the northwest, but reversals occur when waves are from the west. Sediment trapped behind the Huron Harbor CDF verifies the occasional eastward drift.

A lack of sediment indicates that erosion of the Sheldon Marsh barrier will occur under all Lake Erie water levels. However, higher water level will make the barrier narrower and therefore more vulnerable to breaches or overwash. During low water periods, downcutting may occur offshore, allowing storm waves to reach the beach with less frictional loss.

Lake Erie is subject to sudden and violent storms. Because of the shape of the lake, seiching can cause the water to rise in only a few hours. For example, during the violent storm of 14 November 1972, the water rose over 0.8 m (2.6 ft) at Marblehead (see Figure 10). It was during this event that the Sheldon barrier was breached at its west end in three places. Thereafter, the barrier proceeded to retreat rapidly and was never reattached to Cedar Point Peninsula.

Between 1937 and 2003, the beach at Sheldon Marsh retreated an average of 360 m (1,180 ft) (see Table 2). This averages to 5.4 m/year (17.7 ft/year), but the retreat was episodic, with years of rapid retreat interspersed with periods of relative stability. The relative stability occurred during lower water levels (e.g., post-1998). A water level rise in the future due to climatological factors (e.g., increased rainfall, less evaporation because of cloud cover, unexpected snowmelt), would subject the barrier to significant damage from storm waves.

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# REPORT DOCUMENTATION PAGE

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**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

Sheldon Marsh Nature Preserve is located on the southwestern shore of Lake Erie on the southeast end of the 10.5-km-long Cedar Point sand spit. The preserve resembles an inverted "L" with a 1.8-km-long barrier beach that fronts Lake Erie and shields a wetland area. The center of the beach is at 82°36'42"W longitude and 41°25'26"N latitude (NAD83).

Sheldon Marsh only covers 465 acres, but its ecological importance cannot be overemphasized. The marsh is a unique habitat and is a critical stopover for migratory birds. The beach has suffered severe erosion since the 1950s, and protection and partial restoration of the sand barrier is essential to the survival of existing and future plant and animal communities.

Retreat of the shoreline at the preserve has been a continuing problem throughout the 20th century. Between 1937 and 2003, the beach retreated an average of 360 m. This averages to 5.4 m/year, but the retreat was episodic, with years of rapid retreat interspersed with periods of relative stability. The beach has been relatively stable during lower lake levels (post-1998). A water level rise in the future due to climatological factors (e.g., increased rainfall, less evaporation because of cloud cover, unexpected snowmelt), would subject the barrier to significant damage from storm waves.

*(Continued)*

**15. SUBJECT TERMS**

| | | |
|---|---|---|
| Beach erosion | Lake Erie | Sediment loss |
| Cedar Point | Littoral transport | Sheldon Marsh Nature Preserve |

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**14. ABSTRACT (concluded)**

The main cause of erosion along the Ohio shore is a lack of littoral sediment. The most immediate contributor to the sediment loss in the Sheldon Marsh area is the Huron jetties, only 4,900 m to the southeast. Because of the sheltering effect of the confined disposal facility at the Huron west jetty, significant amounts of sediment have been trapped next to the west jetty, thereby further depriving the littoral system of sediment. A lack of sediment indicates that erosion of the Sheldon Marsh barrier will occur under all Lake Erie water levels. However, higher water level will make the barrier narrower and therefore more vulnerable to breaches or overwash. During low-water periods, downcutting may occur offshore, allowing storm waves to reach the beach with less frictional loss.