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Coastal Geologic and Engineering History of Presque Isle Peninsula, Pennsylvania

by Richard J. Gorecki
U.S. Army Engineer District, Buffalo

Joan Pope
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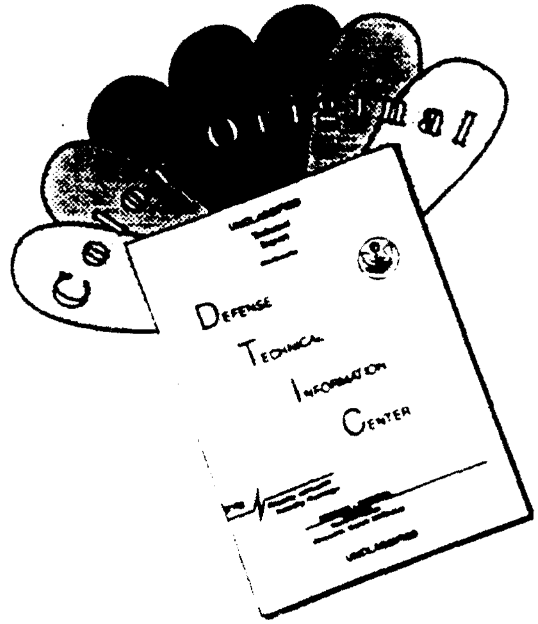

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by Richard J. Gorecki

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Buffalo, NY

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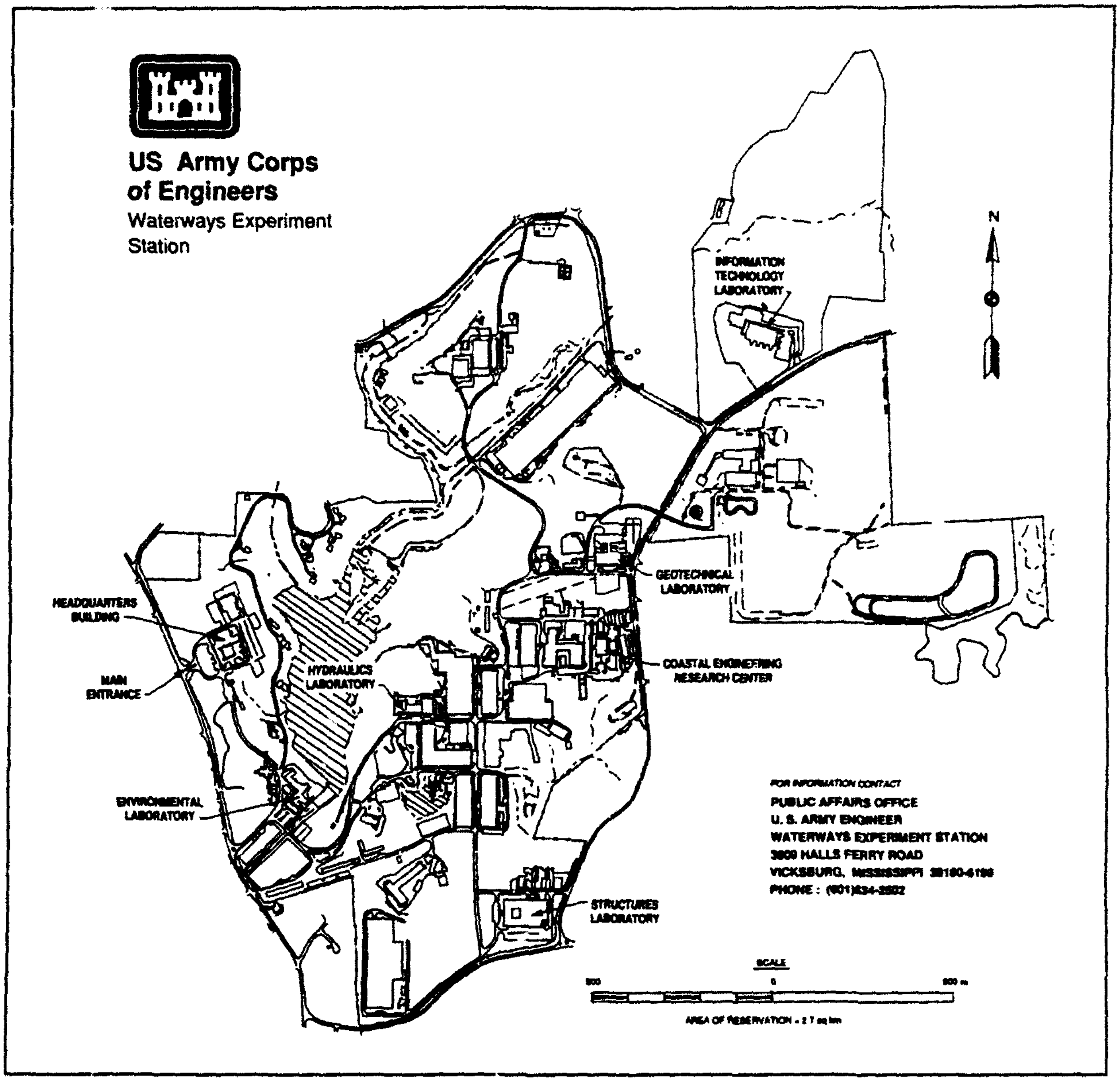

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Preface

This report was authorized as a part of the Civil Works Research and Development Program by the Headquarters. U.S. Army Corps of Engineers (HQUSACE). The work was begun under Work Unit 31232, "Evaluation of Navigation and Shore Protection Structures," and completed under Work Unit 32748, "Detached Breakwaters for Shoreline Stabilization," both under the Coastal Structure Evaluation and Design Program at the Coastal Engineering Research Center (CERC) at the U.S. Army Engineer Waterways Experiment Station (WES). Messrs. J. H. Lockhart, Jr. and J. G. Housley were HQUSACE Technical Monitors.

This report was prepared by Mr. Richard J. Gorecki, Chief, Design Branch, U.S. Army Engineer District, Buffalo (NCB), and Ms. Joan Pope, Chief, Coastal Structures and Evaluation Branch, CERC. Ms. Monica Chasten, CERC and Mr. Michael Mohr, NCB assisted with final preparation of this report. The study was conducted under the general administrative supervision of Mr. Denton R. Clark, Jr., former Chief of the Coastal Engineering Section, NCB; Mr. Joseph A. Foley, former Chief, Design Branch, NCB; Mr. George Brooks, present Acting Deputy District Engineer for Project Management, NCB; Mr. Kenneth R. Hallock, Chief, Engineering Division, NCB; and Mr. Thomas W. Richardson, Chief, Engineering Development Division (CD), CERC. Director of CERC during the investigation was Dr. James R. Houston, and Assistant Director was Mr. Charles C. Calhoun, Jr.

Director of WES during publication of this report was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	30.48 0.3048	centimeters meters
knots	1.852	kilometers per hour
miles (U.S. statute)	1.6093	kilometers
cubic yards	0.7645549	cubic meters
tons (2,000 pounds, mass)	907.1847	kilograms

1 Introduction

The Report

This report summarizes the geological and engineering background of the Presque Isle Peninsula at Erie, PA, and was developed by the authors in support of the 1980 Phase I General Design Memorandum (GDM), which the Buffalo District Office of the Corps of Engineers prepared for Congressional review and approval. This report also updates the results of previous investigations with additional information that was developed in support of the project. This project is designed to attenuate wave action to such a degree as to reduce littoral drift and, thus, the erosion of the Presque Isle Peninsula.

In the interest of brevity, many of the complex geologic, environmental, engineering, and socioeconomic issues, which we _ part of the Buffalo District's studies, could not be reproduced herein. Most of this report is taken from the context of the official studies, and its purpose is purely academic. The report is designed to enlighten the reader by providing an understanding of the fascinating geologic evolution of Presque Isle Peninsula and the history of man's attempts at stabilization. For additional insight into the Buffalo District's studies, the reader is directed to the 1980 Phase I and 1986 Phase II GDMs (U.S. Army Engineer District (USAED), Buffalo 1980, 1986).

Background and Setting

Presque Isle is a unique and significant coastal feature on the south shore of Lake Erie at Erie, PA. It is a compound, recurved sandspit that arches lakeward about 2-1/2 miles[1] from an otherwise straight shore (Figure 1). The peninsula has a lake shoreline of about 6-1/4 miles from its narrow connection with the mainland to its distal end where it turns sharply shoreward. It is the only major accretionary feature along the generally

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page ix.

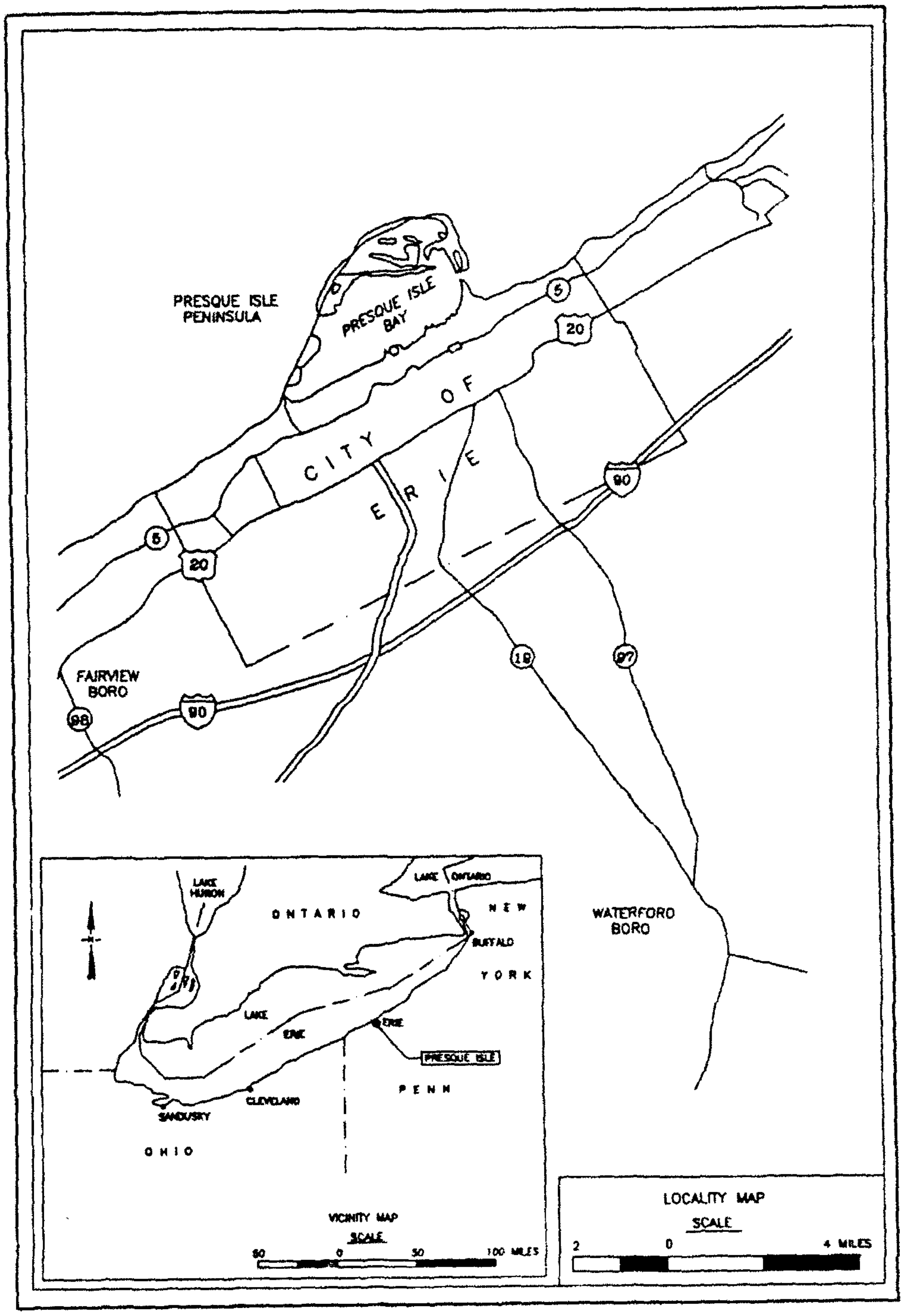


Figure 1. Presque Isle study area location

sand-starved south shore of Lake Erie.

Presque Isle Peninsula is an old-age geomorphic feature that is migrating eastward into deeper water, thereby resulting in a net annual sediment loss. The processes responsible for the geological evolution of this feature will also be responsible for its eventual destruction unless attempts are undertaken to slow or stagnate its migration. The history of shore protection since the 1800's has been played out on the peninsula beaches as man has employed a myriad of engineering efforts to preserve this migrating and diminishing feature.

The peninsula is a rare ecological laboratory that supports the process of primary plant and animal succession in habitat diversity ranging from pioneer vegetation on newly formed shore zones to climax woodland communities on old beach ridges, all within a distance of about 3 miles. The peninsula is also a popular state park and recreational area, which provides facilities for bathing, boating, hiking, fishing, bird watching, picnicking, and other recreational opportunities. The public has free and unrestricted access to the park and approximately 4,512,000 persons have visited the park annually for the past 10 years.

In 1922 Presque Isle Peninsula was conveyed from the Federal Government to the Commonwealth of Pennsylvania for park purposes. Although care and protection of the peninsula continued to include prevention of breaches, the purpose for breach prevention shifted from preserving Erie Harbor to providing recreational beaches. In 1956 the Federal Government, in cooperation with the Commonwealth of Pennsylvania, completed an erosion control project on Presque Isle Peninsula. Since that time, the project has proven to be inadequate, and sand replenishment measures have been required in order to protect the Federal structures and the state's park facilities. The Commonwealth of Pennsylvania, in 1968, requested the Corps of Engineers to make a complete restudy of the Presque Isle beach erosion control project in order to develop a more effective and long-term solution to the erosion problem.

Site Description

Presque Isle Peninsula, from its mainland root to its distal end where it turns sharply shoreward, is about 6-1/4 miles long. The eastern end of the peninsula terminates in several low, flat, recurring long-shore bars. For a distance of about 2 miles from the westerly root, the peninsula is narrow and has an average width of generally less than 800 ft (Figure 2). This narrow section of the peninsula is called the neck. East of this narrow neck, the peninsula widens abruptly to a width of over 1 mile. Presque Isle Peninsula consists almost entirely of fine sand reworked from glacial deposits.

The general ground elevation of the peninsula is relatively low, averaging about 7 or 8 ft above low water datum (LWD) which for Lake Erie is elevation 568.6 ft above the mean water level at Father Point, Quebec, International Great Lakes Datum (IGLD 1955). There are four major and several minor beach ridges that extend across the peninsula, generally in an east-west direction and that rise to a maximum elevation of about 20 ft above LWD. The higher ground on the peninsula sustains a thick growth of a wide variety of trees and shrubs. The low areas between the beach ridges are comprised of several elongated lagoons and marshes.

The lakeward perimeter of Presque Isle is about 9 miles. The lakeward shoreline has been segmented into 11 bathing beaches by the Pennsylvania State Park Services. These beaches vary in width and, with the exception of Beach No. 11, have had a history of serious erosion for at least 160 years. The bathing beaches are backed by picnic areas, and five major beach areas are provided with bathhouse and parking facilities. Roadside parking provides beach access to intervening beach and picnic areas. Over the last 16 decades, numerous protective works consisting of groins, revetments, bulkheads, and offshore breakwaters have been constructed to halt erosion.

The bay shoreline is characterized by numerous small bays, coves, and inlets. Encircled between the peninsula and the mainland is Presque Isle Bay, the easterly part of which has been improved as Erie Harbor. The north jetty for the Erie Harbor entrance channel is joined to the distal east end of Presque Isle Peninsula.

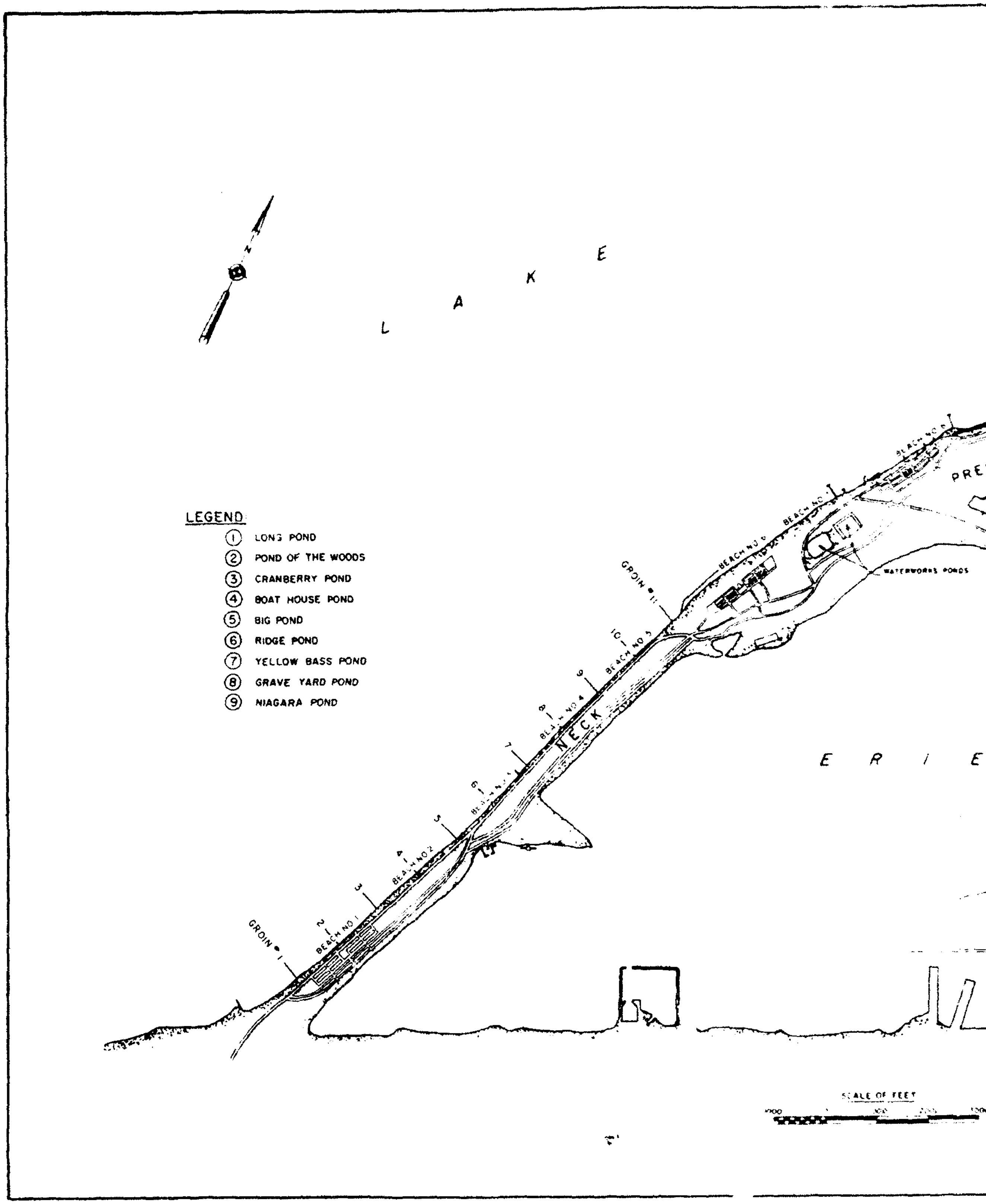
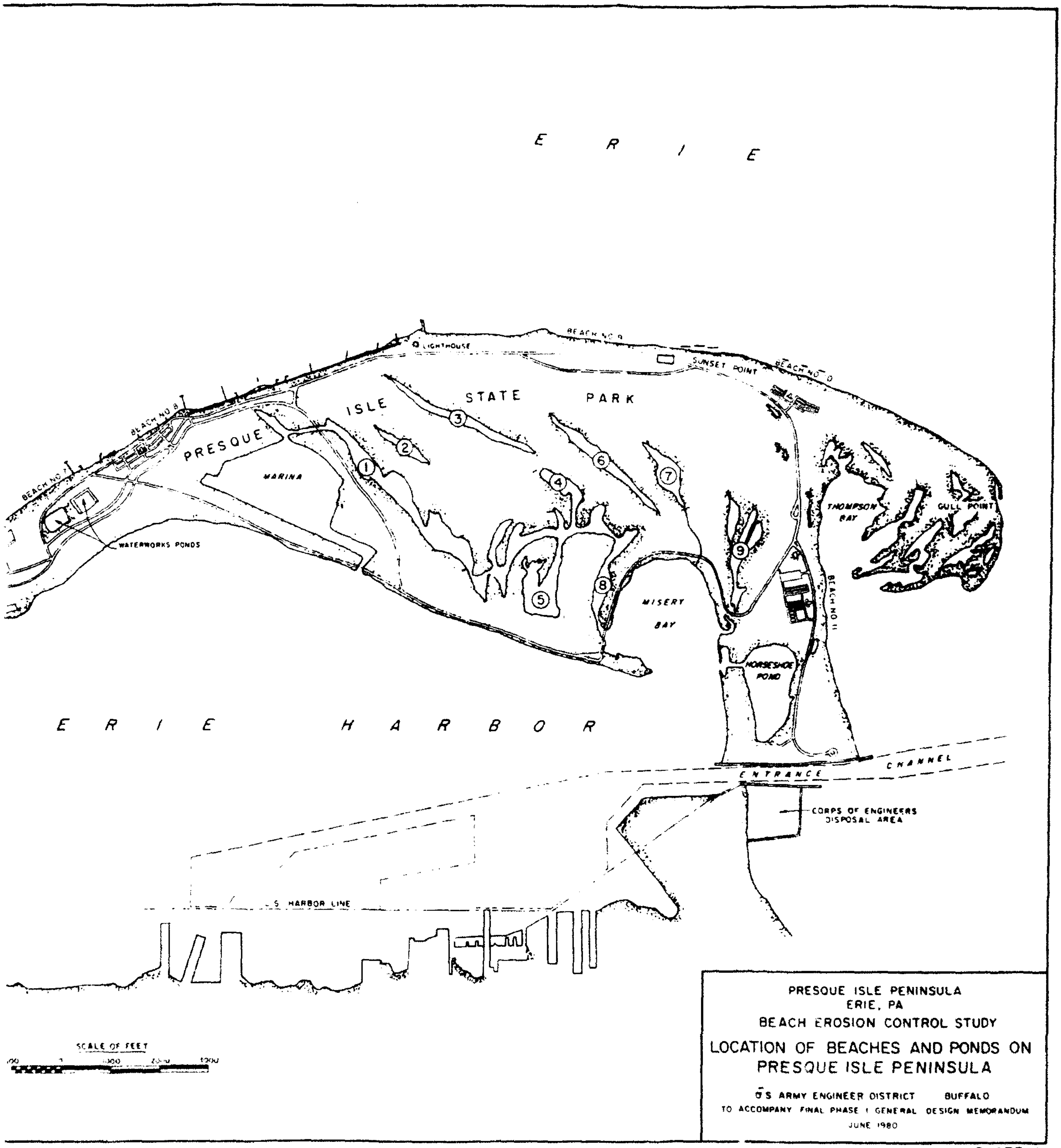


Figure 2. Location of beaches and ponds on Presque Isle Peninsula (USAED, Buffalo 1980)



PRESQUE ISLE PENINSULA
ERIE, PA
BEACH EROSION CONTROL STUDY

LOCATION OF BEACHES AND PONDS ON PRESQUE ISLE PENINSULA

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY FINAL PHASE I GENERAL DESIGN MEMORANDUM
JUNE 1980

PLATE 4

2

2 Geologic Setting

Physiography

The major physiographic divisions in northwest Pennsylvania are the eastern lake section of the Central Lowland Province and the glaciated section of the Appalachian Plateaus Province. The eastern lake section is a 2- to 5-mile-wide plain bordering Lake Erie. Bluffs along the Lake Erie shore in Pennsylvania are greater than 80 ft in height and are composed of glacial and lacustrine deposits. Bedrock is often found at the base of the bluffs. Sandy beach ridges, representing post-glacial lake strands, cross the lake plain on top of the bluffs. The topography of the glaciated section of the Appalachian Plateaus Province is that of an eroded plateau with gently rolling hills.

Bedrock

Bedrock exposed in Erie County, Pennsylvania, is predominantly Upper Devonian shales and siltstones of the Conneaut and Canadaway Groups. Figure 3 is a geologic column of exposed rock. At Presque Isle, there is a lakeward slope of the rock surface with contours parallel to the mainland. At the junction of the neck of the peninsula with the general shore, the bedrock surface is only 2 ft below LWD. A gas well drilled near the northeast corner of the Waterworks ponds on Presque Isle (Figure 2) shows rock to be about 112 ft deep. Borings taken in 1965 by a consulting firm for the state of Pennsylvania extended in a line across the harbor entrance channel and showed that the rock surface sloped lakeward with a 1 on 125 slope and a depth approximately 60 ft below LWD near Beach No. 11 (Rummel, Klepper, and Kahl-Fertig Engineering Company 1968). The bedrock here is likely to be the gray shale of the Java Formation of the Venango Group (Socolow 1980).

The subsurface exploration program that was performed in 1985 during preparation of the Phase II GDM (USAED, Buffalo 1986) encountered bedrock in several of the borings along the neck. The depth to rock along the neck was approximately 7 ft below the top of bottom sediments. Along most of the peninsula, rock was encountered; thus, the depth to rock was at least

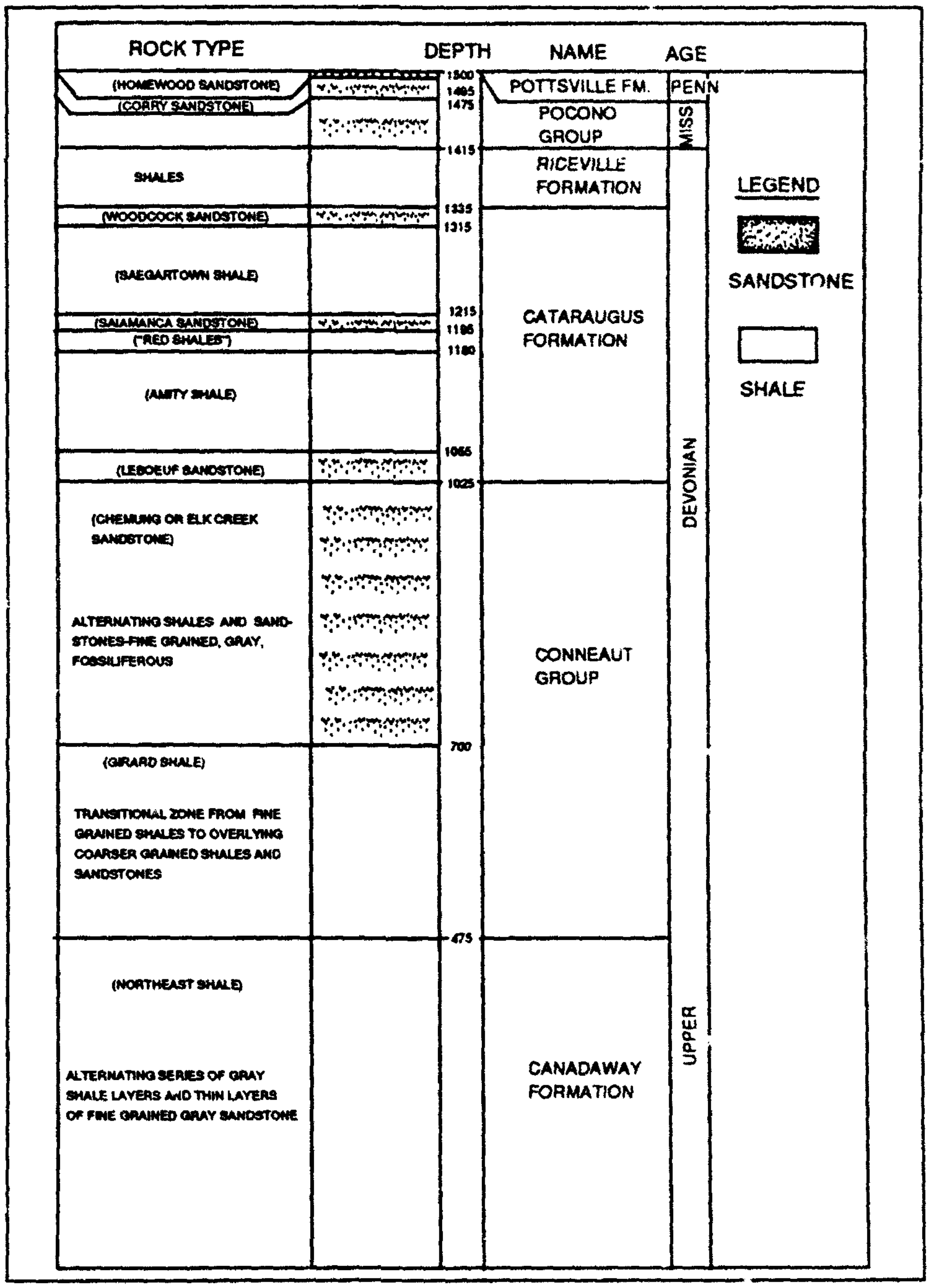


Figure 3. Bedrock exposed in Erie County Pennsylvania (*modified from* Tomikel and Shepps (1967))

30 ft below LWD. Bedrock at the project site is from the Java Formation of the Venango Group. The Java formation is a fissile, horizontally bedded gray shale.

Lake Erie Basin Deposits

Lake Erie can be divided into three separate subbasins (Figure 4). Presque Isle is located at the eastern end of the central basin. The bathymetry of the lake is mostly controlled by lithology and dip of bedrock. Superimposed on the bedrock are Pleistocene and recent deposits as shown in Figure 6. The most prominent glacial features in the lake are three ridges which traverse the lake between Pelee Point and Lorain, Erieau and Cleveland, and Long Point and Erie. These are thought to be end moraines and are composed of clay till veneered with sand or gravel (Lewis 1966). The Long Point-Erie Moraine, largest of the three, is broad, flat-topped, and about 25 miles (40 km) wide (Figure 7). Coring studies indicate that the layer of sand and gravel overlying the moraine on the United States side is as much as 12.7 ft thick and averages about 7.4 ft (Williams and Meisburger 1982). Seismic profiling shows the sand to be 15 to 20 ft thick along the ridge surface. Recent soft, gray mud covers most of the rest of the central basin. In some areas, the mud is 60 to 80 ft thick (Lewis 1966).

Surficial Deposits

The surficial deposits of northwest Pennsylvania are dominated by the glacial history of this area. During the Pleistocene Epoch, a series of glacial advances and retreats modified the landscape and deposited material. Glacial deposits on the mainland consist of till and stratified drift. The till units are variable in texture and found in hilly end moraines and as ground moraines blanketing much of the area. The stratified deposits are in the form of kames and outwash. Petrographic analysis of the stratified deposits show them to be composed of hard and tough sandstone, siltstone, limestone, dolomite, quartz, and quartzite particles. Strand deposits of glacial Lakes Whittlesey and Warren also consist of sand and pebble gravel. These deposits, formed about 12,800 years ago (Schooler 1974), have not been found to be suitable for use as beach fill because of a predominance of shale and siltstone fragments.

Glacial History

The Late Wisconsin stage left the greatest impacts on the topography and the deposits of this region and starts the evolutional trail toward the existence

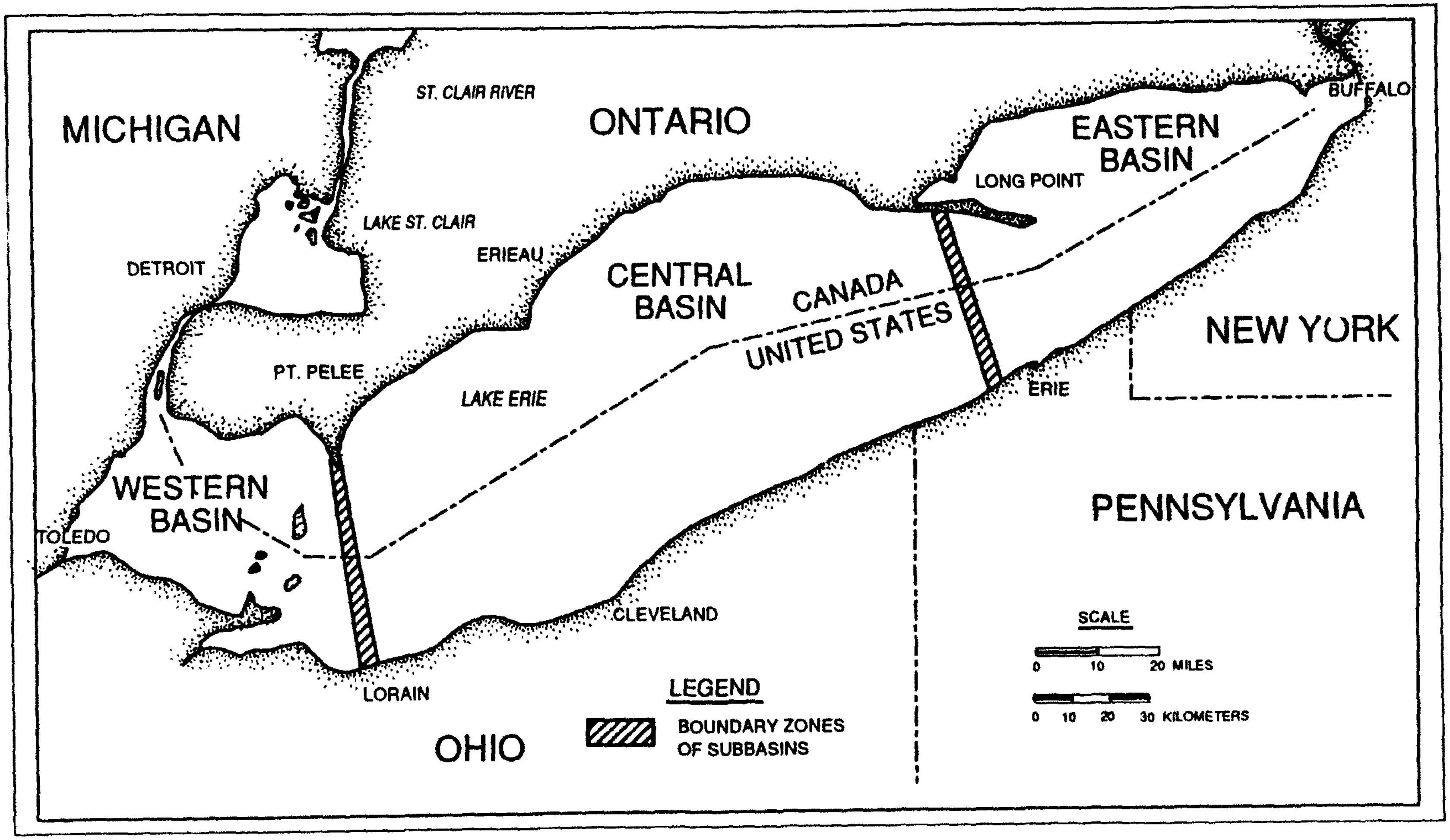
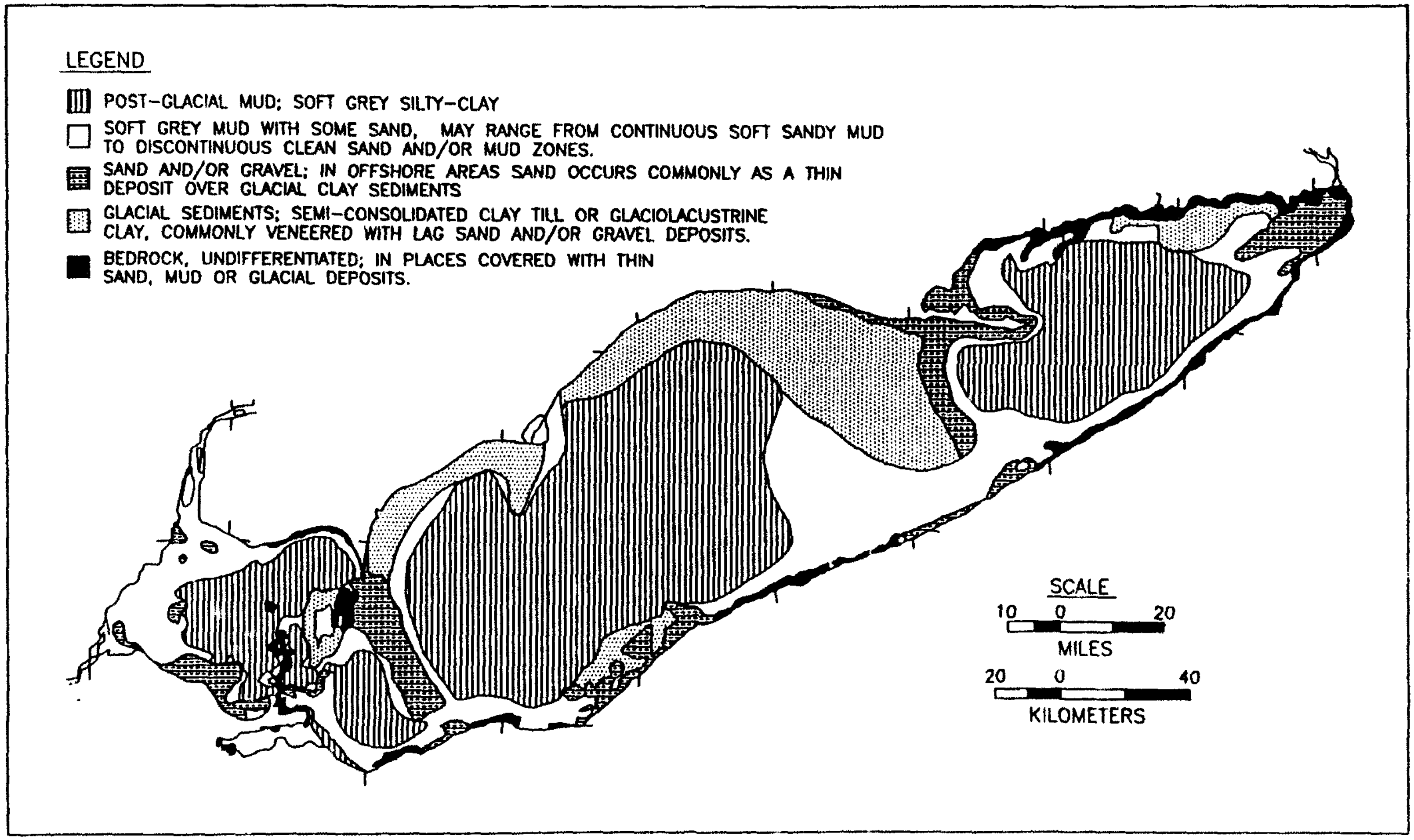


Figure 4. Three subbasins of Lake Erie



Figu.e 5. Bottom sediment dis tribution in Lake Erie (modified from Argonne National Laboratory (1978))

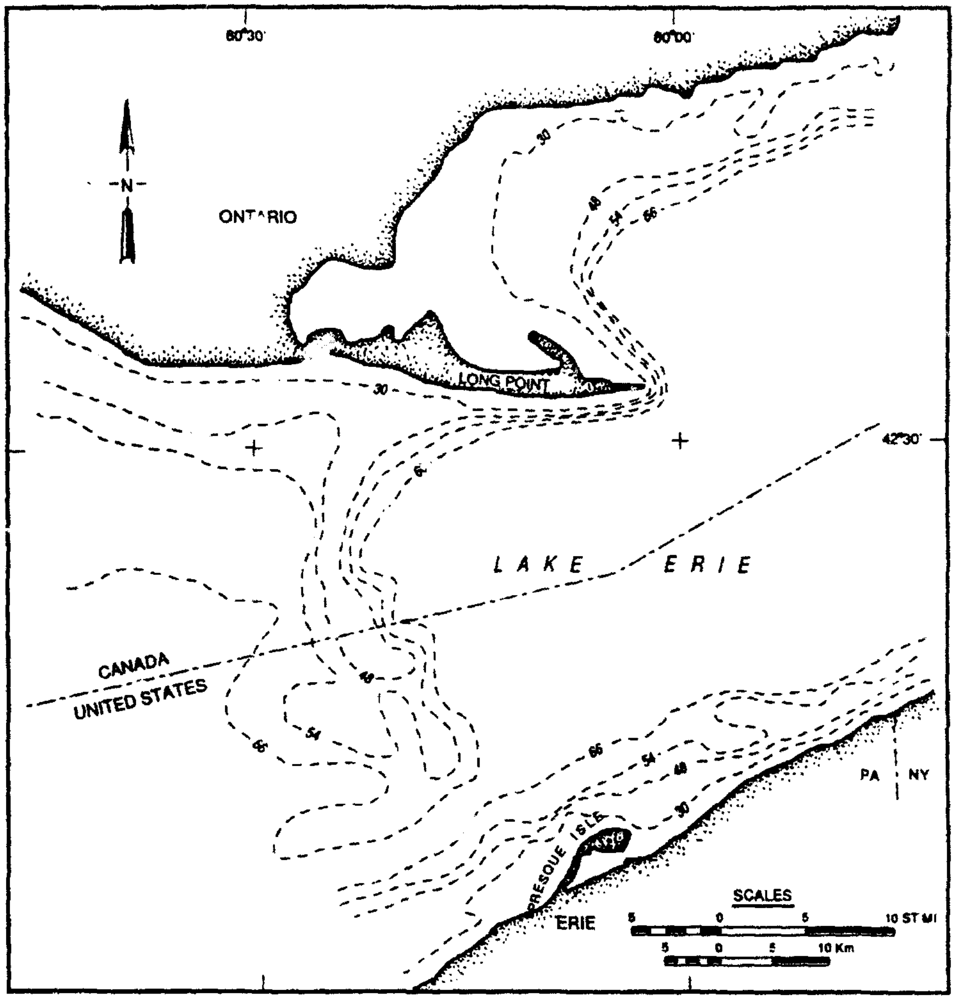


Figure 6. Long Point-Erie morainal ridge (modified from Pope and Gorecki (1982))

of modern Presque Isle Peninsula. The earliest event of the late Wisconsin significantly affecting the project area occurred about 20,000 years before present (B.P.) during the Kent Phase. Deposits of Kent drift include till and stratified drift in the form of kames, crevasse fillings, and outwash. The main characteristic of the Kent Advance is extensive kame deposition. Kames are found on valley bottoms or perched on valley walls. Most of the sand, which has been used in recent years for beach replenishment at Presque Isle, is derived from these deposits.

During the next event, the Lavery Phase, a glacier advanced to a location marked by the Lavery End Moraine. This occurred about 17,000 years B.P. The surface expression of this deposit varies from smooth hills and swales to moderately hummocky topography. Shepps et al. (1959) have mapped morainal kames in locations where the Lavery Moraine crosses valleys. Kames and outwash, deposited in valleys, supply some of the sand used for beach replenishment at Presque Isle.

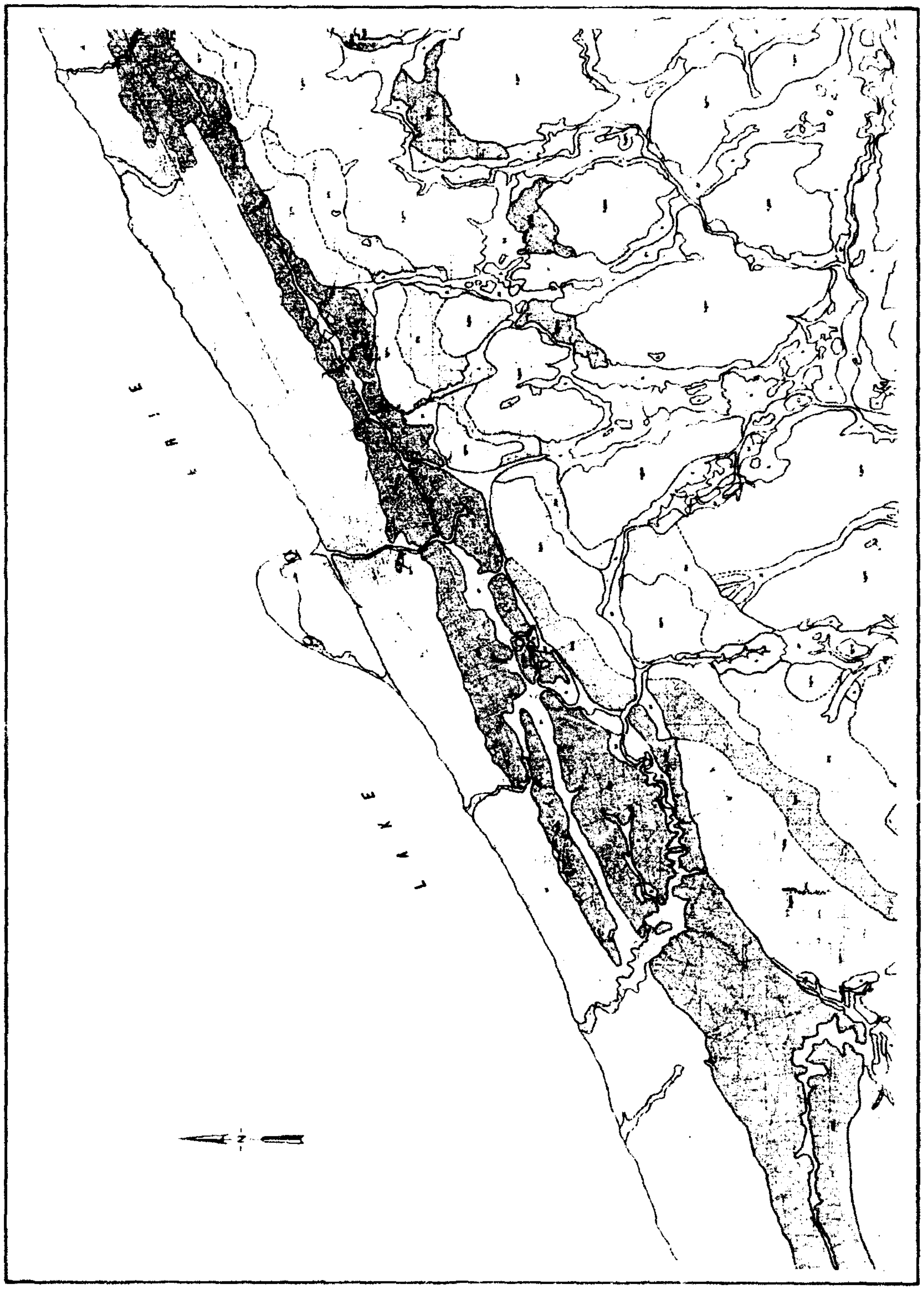


Figure 7. Surficial deposits of northwestern Pennsylvania (Shepps et al. 1959 (Continued)

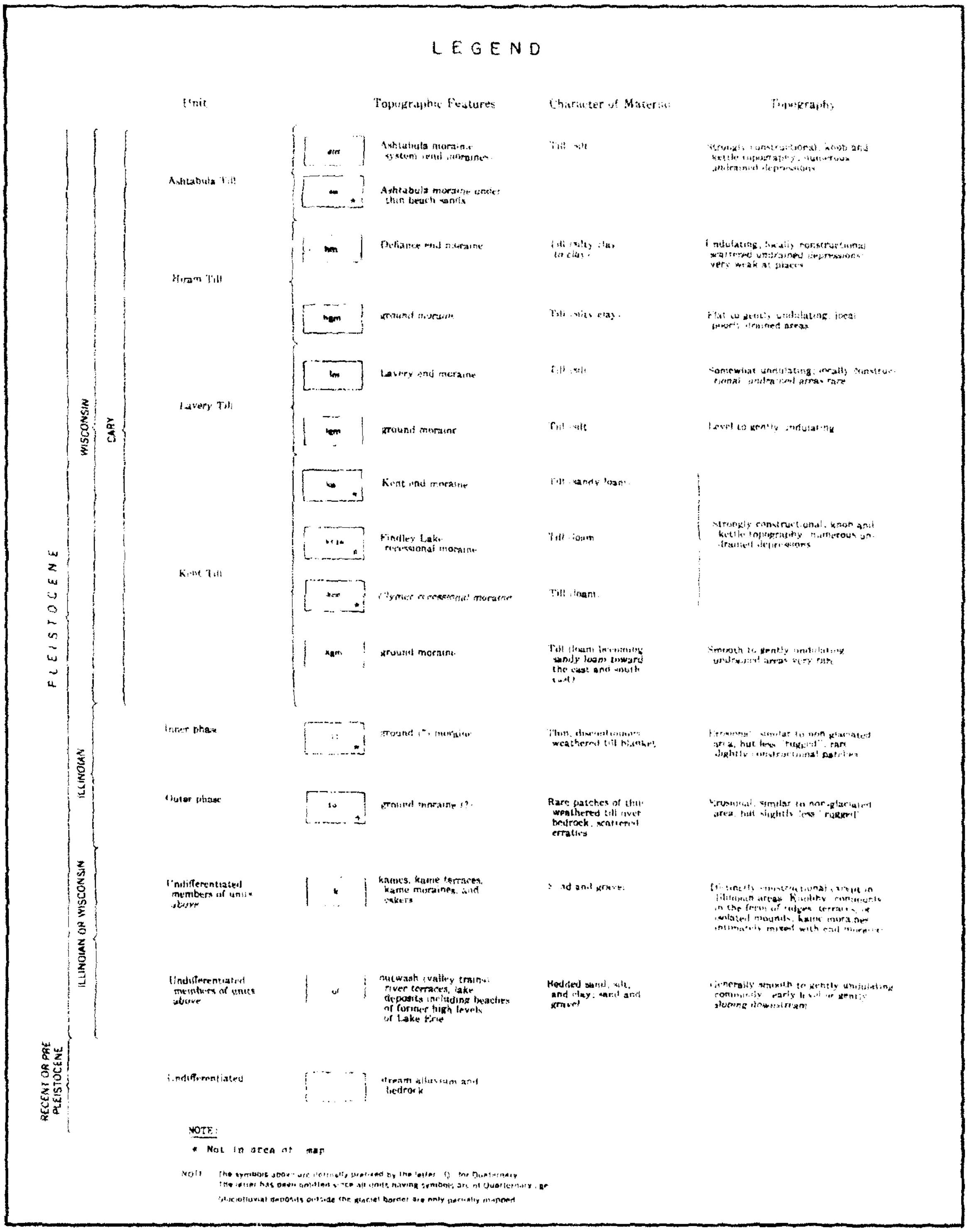


Figure 7. (Concluded)

After the Lavery advance, Fullerton (1971) believes that the ice margin retreated as far northeast as Toronto, Ontario; and he refers to this period as the Lake Erie Interval(approximately 15,500 years B.P.) during which both Lakes Erie and Ontario drained eastward through the Mohawk Lowland, resulting in the deposition of the Hiram Moraine. Kames were not as well-developed as during the preceding Kent and Lavery advances. Outwash deposits also are not as extensive.

The last glacial advance into northwestern Pennsylvania, according to Shepps et al. (1959) and White, Totten, and Gross (1969), was the Ashtabula Advance. Fullerton (1971) shows this to have begun 14,100 years B.P. Its limit is marked by a series of end moraines exhibiting knob and kettle topography. Kames are more common in the eastern portion of the moraine than in the western portion. Outwash occurs between the ridges.

The next major event of the Pleistocene is known as the Cary-Port Huron Interval when the ice margin was north of the Lake Erie Basin. At this time, a series of glacial Great Lakes developed in the Erie Basin. Strand lines of Lakes Maumee I, II, III, and Arkona were fairly well-developed in the western portion of the basin but are faint or absent in the eastern part (Leverett and Taylor 1915). These lakes drained westward, outletting at Fort Wayne, IN, through the Wabash River and also through the Huron Basin (Hough 1958).

At 12,900 years B.P., a major glacial readvance, known as the Port Huron Advance, took place resulting in a rise of water in the Erie Basin to form glacial Lake Whittlesey (Calkin 1970). The Long Point-Erie Moraine of Lake Erie has been correlated with the deposits of the Port Huron Advance by Lewis (1966), Wall (1968), and Fullerton (1971).

Features of Lake Whittlesey can be found in the vicinity of Presque Isle at an elevation of about 735 ft above mean sea level (MSL). The Whittlesey strand occurs as a 10-ft-high wave-cut cliff near the Pennsylvania-Ohio state line. About a mile east, it becomes a 15-ft-high, gravelly ridge and then changes to a series of sand dunes south of West Springfield, PA. Across the rest of Erie County, PA, it is a well-defined ridge 15-20 ft high with a steep north slope and gentle south slope. East of Erie, the ridge is replaced by two low, wave-cut cliffs consisting of glacial material and bedrock (Schooler 1974).

Further retreat of the Port Huron glacier resulted in a series of lower lakes. The most important of these is Lake Warren, which is evidenced as two ridges occurring at elevations of 725 to 735 ft and 715 to 725 ft (Schooler 1974).

After the ice had retreated north of the Niagara Escarpment, water in the Erie Basin was allowed to drain into the Ontario Basin. Due to crustal depression caused by the weight of glaciers, the outlet at the escarpment was relatively much lower than the present outlet at Niagara Falls. The lake occupying the Erie Basin at this time was at an elevation of 470 ft MSL, approximately 100 ft lower than today. This stage, known as Early Lake Erie, existed between 12,370 and 12,790 years B.P. (Lewis, Anderson, and Berti 1966). It was during this time that Lewis (1966) and Lewis, Anderson, and Berti (1966) believed that the sand and gravel overlying the Long Point-Erie Moraine developed.

As the outlet of Early Lake Erie was uplifted by crustal rebound, the elevation of the water surface was raised to its present level. Wave erosion of bluffs along the present shore and streams, in addition to the Long Point-Erie Moraine, contributed sand and gravel for the development of beaches and the original Presque Isle sand body.

Modern Lake Erie

The water levels in the Lake Erie Basin have changed much in post-glacial times. This is due to crustal uplift, climatic changes, and diversion of water. Flow through the present outlet, the Niagara River, is controlled by a bedrock threshold at Buffalo, NY. During glacial times, this was blocked by ice, and lake water was diverted through higher elevation outlets such as the Wabash, Grand, and Mohawk Rivers. After glacial retreat, the Niagara outlet opened; but due to crustal downwarping caused by the weight of glaciers, this outlet was then more than 100 ft lower than today.

Early investigators (Leverett and Taylor 1915, and others) determined the differential uplift in the region by comparing the elevations of southern beaches with northern beaches of the glacial Great Lakes. They found that the beaches are horizontal to a point, known as a hinge line, from which the beaches rise vertically to the north. For example, Lake Whittlesey beaches are at an elevation of 735 ft (MSL) throughout most of Ohio and Pennsylvania; but starting at a point east of Erie, PA, they begin to rise up to an elevation of 910 ft (MSL) in New York State (Leverett and Taylor 1915).

In another study of water levels, Lewis (1969) compared radiocarbon dates with known lake levels and developed the diagram shown as Figure 8. This shows the rate of change in water level in the Erie Basin during post-glacial time. Lewis prefers to use the curve near the upper envelope. If the lower curve is adopted, it would mean that levels in the eastern basin of the lake would have been lower than the channel along the southern margin of the Long Point-Erie Moraine for more than 1,500 years. Lewis' diagram also shows the steep rise of water from 5,000 to 3,800 years B.P. This initial rise corresponds to the abandonment of the North Bay, transferring more flow into the lower Great Lakes.

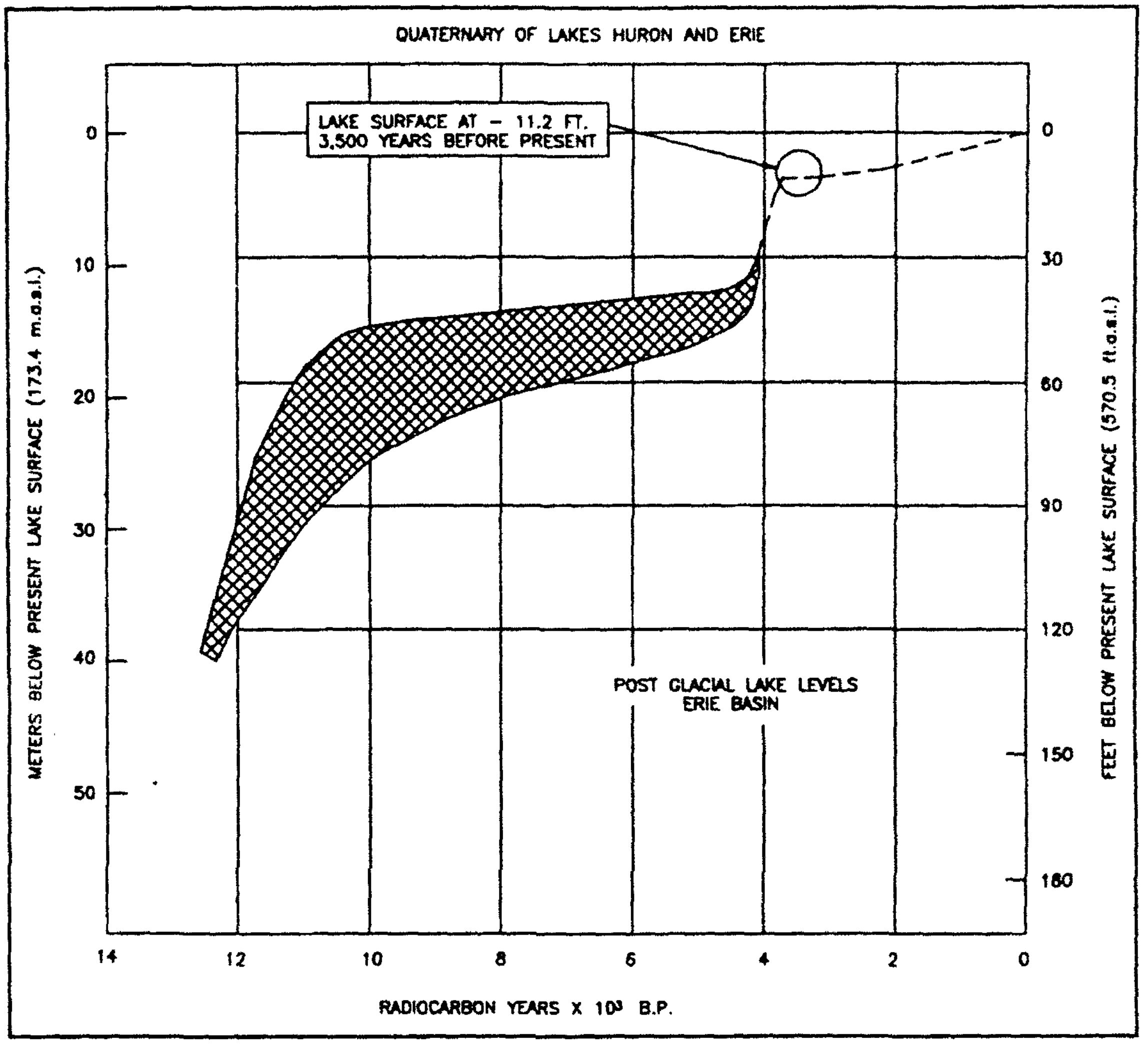


Figure 8. Post-glacial history of Lake Erie water levels (modified from Lewis (1969))

3 Geology of Presque Isle

Introduction

The observed sediment transport patterns at Presque Isle are the result of a modern wave climate acting on the glacial and post-glacial deposits of the area. Glacial deposits reworked during post-glacial lake level fluctuations serve as the source for the littoral material. Lake level fluctuation and drainage pattern changes have been frequent in post-glacial time (over the past 12,000 years) and are responsible for denudating the glacial topography and producing many of the present onshore, offshore, and coastal features of central Lake Erie, including Presque Isle Peninsula. However, Presque Isle is unique. It is the only major positive depositional feature along the southern shore of Lake Erie and is an inherited feature that is in disequilibrium with present littoral process. Any explanation of its existence must be tied to specific geologic events.

An understanding of the origin and historical development of Presque Isle Peninsula is necessary in order to interpret the processes currently at work and to predict the future condition. Thus, the following discussion concerning the post-glacial development of Presque Isle is presented as a brief overview in order to provide a better understanding of the observed condition. This discussion is hypothetical and, although it fits with the existing glacial information and theory, has not been rigorously tested.

Historical Origin

In order for Presque Isle Peninsula to exist prior to recent lake levels, there must have been a substantial source of sand and a reason for that sand to collect in one area. The existence of the platform to the west of Presque Isle may very well be the key that explains how Presque Isle Peninsula evolved (Figure 7). The platform has a total length of 12 miles, with the eastern 5 miles currently covered by the peninsula. Its average width is about 3 to 3-1/2 miles, and the average depth is 25 to 30 ft below LWD. Map documentation from the past 150 years shows that the sand of Presque Isle does migrate from west to east across this platform, building a new platform to the east as it moves in that direction.

The origin of the platform can be explained as a total sand terrace that has been wave planed by rising lake levels or as a pre-existing topographic high rock or glacial till which served as the original base for Presque Isle and was added to as the peninsula grew. Data collected by Williams and Meisburger (1982) suggest that the western end of the platform is underlain by till. If the original platform at the western end is composed of glacial morainal till, it is probably the southern end of the Long Point-Erie Ridge (Figure 7) that has been traced to the Post-Huron glacial advance (12,800 ± 250 years B.P.).

Hough (1958) describes the moraine as a distinct ridge on the bottom of Lake Erie lying west of the eastern deep basin, emerging on the south side of the lake where it extends eastward into New York as the Lake Escarpment Moraine System (Messinger 1977). The surface of this moraine, both the ridge and the platform, was probably planed by wave action during lower lake levels, and the silts and clays were carried offshore, leaving a lag deposit of sand and gravel. The platform lag deposit was well-sorted by wave action and possibly served as a depositional area for littorally transported material during the Early Lake Erie stage. As lake level rose to approximately 25 ft below today's lake level, about 4,000 years ago, littoral currents transported the sand on the platform toward the east, remolding it into an elongated sand beach. This historical sequence is described in Table 1 and shown in Figure 8.

Migration caused by waves from the west and rising lake levels caused the sand body to move toward the east side of the morainal root. As sand slumped off of the east side of the moraine, a sand platform was built. The feature currently recognized as Presque Isle Peninsula evolved as it migrated across this platform. As the platform built, the sand volume available for transport diminished. How much of the platform is till or rock and how much is littorally deposited sand is unknown.

Modern Coastal Processes - Migration

The west-to-east migration of Presque Isle has long been recognized. Figure 9 demonstrates Jenning's (1930) understanding of the development of the peninsula. Presque Isle Peninsula was originally surveyed in 1819. In 1824, the original Erie Harbor project included action as needed to maintain the integrity of Presque Isle Peninsula in order to assure the harbor's future success. Since then, the migratory character of the peninsula has become very evident as erosion and breaching of the neck have demanded continual attention and as accretion at the east end of the peninsula has required jetty extension and dredging to remove shoal buildup in the entrance channel.

Table 1
Hypothetical Chronology of Presque Isle Origin*

Period (Years B.P.)	Event	Discussion
12,900	Port Huron Advance	Long Point-Erie Moraine formed.
12,500-11,500	Early Lake Erie	Rapidly rising lake level from 120 to 60 ft below current LWD.
11,500-10,000	Early Lake Erie	Slower rising lake level (from 60 to 50 ft below current LWD). Crest of Long Point-Erie Moraine planed by rising lake level and beach deposits, and dune field develops from lag deposit.
10,000-4,500		Slowly rising lake level (from 50 to 40 ft below current LWD). Long Point-Erie Morainal Ridge inundated.
4,500-3,500		Rapid rise in lake level (from 40 to 10 ft below current LWD). Platform of Presque Isle (landward extension of the Long Point-Erie Moraine) is subjected to wave attack. Sand and gravel lag deposit from till released as source material for Presque Isle.
3,500 to present	Modern Lake Erie	Lake level rises at approximate rate of 1 ft per 300 years.

*Based on the historical Lake Erie water levels presented in Lewis (1969) and on a hypothetical development sequence for Presque Isle.

Evidence of long-term migration of Presque Isle is clearly defined by the morphology of the peninsula's internal features, the platform to the west, and the shoreline of the mainland. A comparison of the sheltered shoreline inside Presque Isle Bay to the open shoreline east and west of Presque Isle Peninsula shows no offset. The bay shore should be a positive shoreline and be characterized by a gently sloping shore if it had experienced long-term sheltering by the peninsula. This is not the case. The shoreline is continuous from the west, through the bay, and to the east. The bay shore is characterized by steep, wave-cut bluffs identical to those outside the bay. The sequence of beach ridges, elongated beach ridge ponds, and fingering distal end ponds is repeated and preserved within the interior of the peninsula, documenting previous stages in Presque Isle's migration. The unknown factor is what has been the change in shape and size as Presque Isle has migrated.

The presence of relict features within Presque Isle Peninsula documents the migration from west to east and a continuation of the same general pattern and process of evolution to this day. Presque Isle Peninsula has probably developed in cycles in order for the specific depositional features to be preserved. One can witness the yearly cycle and the long-term cycles of growth related to annual lake fluctuations, but Presque Isle Peninsula may also be influenced by longer period climatic patterns about which we have no knowledge. High

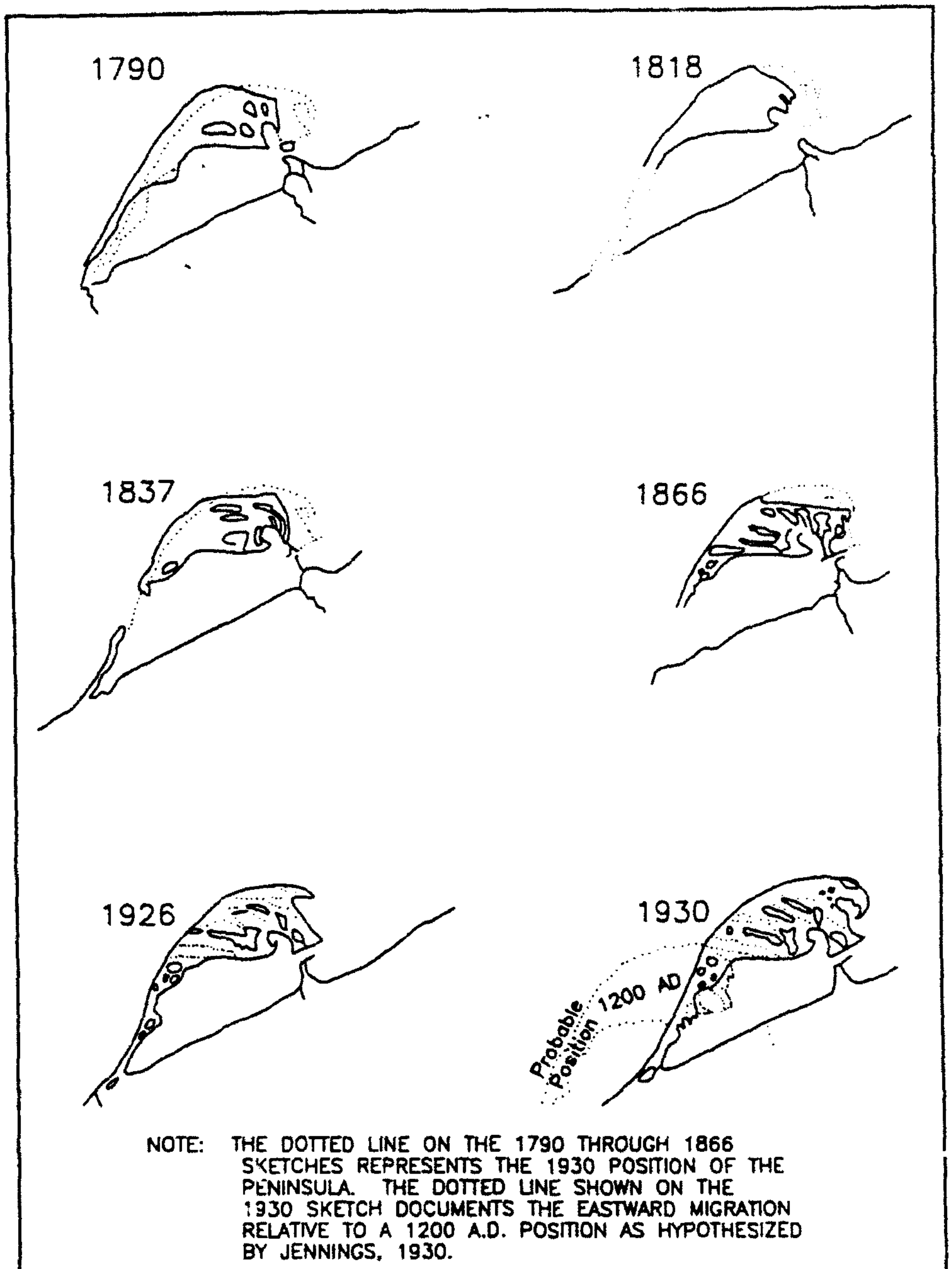


Figure 9. Growth and migration of Presque Isle (modified from Jennings (1930))

lake levels increase littoral transport rates, causing rapid loss of material from the neck area and rapid growth of the distal east end as sand is fed to the growing eastern platform. During lower lake levels, the distal east end matures as the bars are recurved and become subaerial and new material enters the system at the neck, partially healing the eroded areas and widening the neck.

The beach ridges evolve as the offshore bars migrate onshore and weld onto the shore as a subaerial bar. They probably build in height as they migrate onshore in response to the steeper waves of the surf zone. Sand is deposited in front of the bar; a lagoon is trapped behind it. Cottonwoods and other vegetation take root on the beach ridge, and dunes build on top of the ridge, increasing its height to about 20 ft above LWD. Low areas behind and between the beach ridges are submerged and appear as a series of elongated ponds oriented WNW-ESE. Examples of these ridge ponds are Long Pond, Cranberry Pond, and Ridge Pond (Figure 2). The recurving offshore bars at the distal east end form a finger-shaped array of ponds, which are oriented north-south. These distal ponds include Big Pond, Yellow Bass Pond, and Niagara Pond (Figure 2). The Presque Isle system is an eastward-migrating system which feeds upon itself as it migrates. Within the system, material is eroded from the neck to the shifting nodal point, which has recently been in the vicinity of Beach 10, and is deposited along the depositional feature (Gull Point) or offshore to create a new platform to the east, or landward, where it shoals in the harbor entrance channel.

Recent rates for this migration are artificial and directly influenced by the large-scale replenishment operations of the late 1950's through the 1980's. The present estimated migration rate of 289,000 cu yd per year reflects the replenishment input, which has averaged 259,300 cu yd per year since 1955. Attempts to determine the natural migration rate suffer from a lack of sufficient historical data and the obvious masking influence of the 160-year effort to stabilize the neck. Historical maps extending back to 1819 and aerial photographs extending back to 1939 were used to document the natural drift rate.

Historical maps do suggest that the Gull Point feature is a recent morphological addition to the system. Maps from 1819 through 1907 show a smooth recurved east end to Presque Isle, which merges directly with the harbor entrance structures. Since the early 1930's, isolated growth has extended Gull Point as a "Mini Presque Isle" without sufficient recurving to weld this new growth back onto the shore. The original development of Gull Point may be related to a slug of sand that was released to the nearshore processes between 1917 and 1922 by breaching of the neck. The replenishment operations of the 1950's through 1980's continued adding new material to the accretionary end at a rate faster than easterly storms were able to recurve the bars and shoreline onto the Isle.

The incoming quantities of material never really replace the material left behind as the peninsula migrates and as the eastern end of the platform is built up. This continual loss of material plus the effect of a long-term, slowly rising lake level (post-glacial rise of about 1 ft every 300 years) has probably caused Presque Isle to shrink. Through time, Presque Isle has become smaller and migrates faster. Any attempt to identify the age, migration rate, and future condition of Presque Isle must be qualitative, as the background data for computing the rate of size change and the change in the rate of migration do not exist.

In summary, a few general statements can be made about Presque Isle's natural development trend:

a. Presque Isle is an old age geologic feature that is migrating with a net annual loss.

b. Gull Point is a recent feature that has grown at significant rates because of the effects of artificial nourishment.

c. Presque Isle Peninsula is a fluid feature; any attempt to permanently stagnate its migration will meet with eventual failure, with respect to geologic time, as all such attempts in the past have. An acceptable beach erosion control alternative will both retard the migration and/or lengthen the peninsula's life. New material will continually need to be added to the system to replace that which has been used to build the platform and is a net loss to the littoral system.

Modern Coastal Processes - A Sediment Budget

Gains

Any influx of sediments into the Presque Isle system must either come from the east, from the west, from offshore sources, or from artificial nourishment. Presque Isle Peninsula is probably largely dependent upon sediment influx from the west and artificial nourishment for littoral gains to the system.

Presque Isle is an eastward-migrating feature with the Erie Harbor entrance structure and channel blocking any sediment influx from the east. In addition, the morphology of Gull Point, plus dominant westerly wave climate for Lake Erie (Saville 1953) further support the conclusion of a lack of littoral material influx from the east.

Considering the historical development of Presque Isle and the offshore bathymetry, there is little evidence that the offshore is active in supplying any net sediment gain to the Presque Isle system. The platform to the west is below wave base and no longer part of the active Presque Isle system. The offshore is the trailing edge of the migrating feature and its deeper water prohibits it from keeping up with the subaerial part of Presque Isle. Thus, there is continual net offshore loss to the system.

Nearshore bars do migrate onshore, but this is simply a shallow-water redistribution of sand within the system, which may result in temporary beach gains. During lower water periods, the bar system is driven offshore. The importance of the nearshore bar system in influencing the littoral transport patterns of the Presque Isle system has been documented during studies to monitor the shoreline changes to Presque Isle Peninsula and by sand tracer studies (Sonnenfeld and Nummedal 1987).

Thus, all natural influx to the system must come from the west. The approximately 20-mile-long shoreline between Conneaut, OH and the root of the Presque Isle Peninsula is generally unbroken by any dominant structures, headlands, or other major littoral interruptions. The Federal harbor structures at Conneaut, OH are a very effective block to any littoral material exchange with shores further to the west. Therefore, for the purpose of developing a sediment budget, this 20-mile section of shore is considered as a single cell closed at the west and open at the east where Presque Isle Peninsula serves as the eventual site of deposition for any littoral input. Any littoral sediment input to this section of shore must come from fluvial sources, onshore movement of offshore sands, or bluff recession. The shore to the west is characterized by 20- to 100-ft-high eroding till bluffs. The typical bluff cross section is about 60 to 70 ft high, with shale at or just below the waterline, then a coarse-grained till (probably Ashtabula till), followed by a thick clay sequence, and overlain by a thin layer of lacustrine sands (Great Lakes Research Institute 1975). The recession rate of this sequence ranges from 0.5 ft/year to 2.0 ft/year (Carter 1977).

Streams in the area, for example, Elk Creek and Walnut Creek, flow through steep shale gorges and have drowned entrance mouths. This combination, plus field data gathered from Elk Creek in support of a proposed Elk Creek Small Boat Harbor Project, suggest that sand and gravel input from streams is minimal. However, these creeks have such potential for high velocity during periods of discharge (i.e., a steep gradient) that any material which may have collected within the riverbed could get washed out into the littoral zone. A field reconnaissance of the upper drainage basin would be necessary in order to ascertain the presence of any significant fluvial contribution to the littoral zone.

The beaches are generally small pocket beaches on the updrift side of structures or as bay mouth bar complexes at the mouth of each creek. Occasionally, during a period of low water, a narrow beach may collect in front of the bluff areas. These beaches are generally composed of fine to coarse quartz and lithic sands and gravels and are frequently dominated by shingles of shales and siltstones.

Little geologic information exists on the offshore to the west of Presque Isle Peninsula, but it is generally considered to be till or rock surfaced, with little evidence of an offshore sand source except in the area of the Presque Isle platform. The platform area is generally 20 to 30 ft below LWD and, therefore, is below the active wave base. At creek mouths, a delta develops where the bay mouth bars are washed outward during a period of heavy discharge. Some of these delta areas may serve as sites for temporary storage with some minor onshore return from the delta shoals.

Information to locate and delineate offshore sources of sand was gathered as part of an Intercontinental Shelf Sand Resource Study (ICON) during 1977 and 1978 (Williams and Meisburger 1982). Analysis of the collected data indicates that a broad ridge exists off the coast of Presque Isle. The ridge begins about 8 miles off Presque Isle Peninsula and trends to the northwest toward the Canadian shore. The ridge is mantled by fine to medium sand having a minimum thickness of 2.5 ft and a maximum thickness of up to 20 ft. The ICON study estimates that a total of 48.6 million cu yd of sand is present within the defined extent of the offshore source area. The material is, however, too fine to be used for beach nourishment without extensive processing. A second offshore sand area was identified during the ICON study as a small triangular deposit approximately 2 miles off Presque Isle. It was estimated that the deposit contains 1,900,000 cu yd of sand. The proximity of this deposit to the peninsula presents problems in its consideration as a viable offshore source site. Removal of sand from this nearshore deposit may affect both energy levels and energy concentrations due to waves on the adjacent shoreline and, consequently, sand removal may aggravate erosion problems.

In summary, sediment input from the west is dominated by bluff recession rates. There is probably some creek input of a much more minor level, but it is impossible to quantify the level of this contribution at this time. In order to develop a reasonable "ballpark" estimate of littoral transport rates from the west, it is necessary to make the following assumptions:

a. The drift rate is controlled directly by the amount of material available for transport. This is a high-energy shore, where the wave energy is capable of transporting all of the available littoral material.

b. The primary source of littoral material is bluff recession.

c. The major permanent littoral sink for this approximately 20-mile-long section of coast is Presque Isle Peninsula. Other losses to the drift regime are limited to temporary storage in fillets associated with stick-out structures and small beaches and to permanent offshore losses. Offshore losses occur, particularly where small creeks divert littorally transported drift offshore into deltas and as material travels around the end of stick-out structures into deeper water. Offshore losses are assumed to be 20 percent.

The annual littoral input to bluff recession between Conneaut and Presque Isle was calculated from bluff recession rates, bluff heights, reach length, and the stratigraphy presented by Carter (1977). Based on these computations, bluff recession contributes approximately 50,000 cu yd of sands and gravels per year. Considering that 20 percent of this material is lost to the offshore, only about 40,000 cu yd of littoral material is supplied to Presque Isle from the west per year (Figure 10).

Artificial nourishment has been a major factor influencing Presque Isle's development since 1955. The need for nourishment reflects the highwater periods of the mid-1950's and the early 1970's through mid-1980's which threatened to sever access to the outer peninsula. Over 7,591,000 cu yd of beach nourishment material have been added to the system since 1955. This input has forestalled breaching of the neck, thus maintaining the neck's position and causing rapid growth at the accretionary east end (Gull Point). Beach nourishment has caused Presque Isle Peninsula to become elongated and has caused a net gain to the system.

The 4,150,000 cu yd added in 1955-1956 was fine sand with a median size (50-percent size) of 0.20 mm and was obtained from borrow areas on the bay side of the peninsula. This sand was much finer than the natural-sized beach material (0.35 mm) and was quickly eroded. The small amount of fill placed in 1965-1966 was medium sand (median size of 0.75 mm) and was considered to be successful (Berg and Duane 1969). As a result of this experience, the sandfill placed during the mid-1970's through late 1991 was a medium to coarse sand with a median size of about 1.8 mm. Prior to this period of nourishment, the neck was frequently breached. A major effect of a breach would be to cause the neck to migrate eastward through overwash and shoal development. Evaluation of historical maps from the 1800's and early 1900's shows that the accretionary east end (Gull Point) has experienced sporadic growth, possibly in response to breaching and healing of the neck.

Losses

Although Presque Isle Peninsula is a depositional feature, the dominant present activity is erosion. In 1877 the peninsula was described as eroding along the neck and eastward to a point that was 500 ft west of the lighthouse. A hundred years later, erosion characterizes the shore as far east as the east end of Beach 10. Thus, the nodal point between which erosion and accretion occur has migrated 9,000 ft to the east in 100 years. Part of this nodal point shift is related to the natural migration of the system, and part is related to a net loss of material. The natural migration has been modified over the past 150 years by the many activities which have anchored and built the neck into a well-defined subaerial isthmus. According to Chief of Engineers reports from the early 1800's, the natural "neck" is a low, nominally vegetated, frequently overwashed, 3-1/2-mile-long sandspit. Efforts to stabilize the neck have resulted in the whole peninsula system being "stretched." As the distal end migrates and the neck remains fixed, the available littoral load is distributed over a longer shoreline. Thus, the isle thins, the beaches narrow, and a greater length of shore erodes. This results in an "apparent" loss to the system.

Actual net losses are caused by offshore movement and platform building. Material leaves the system offshore around the total peninsula perimeter and at the distal east end.

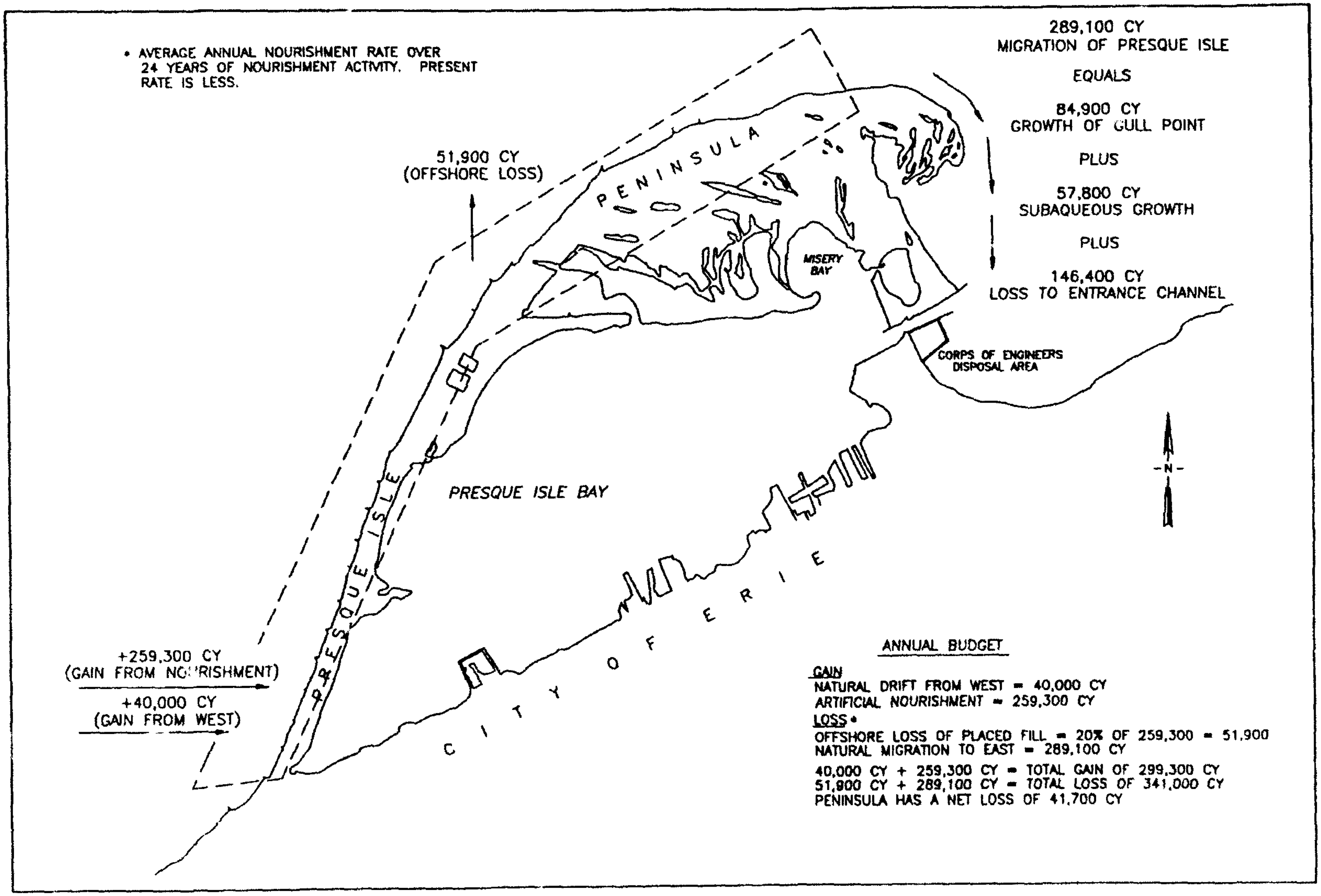


Figure 10. Present Presque Isle sediment with annual nourishment (modified from USAED, Buffalo (1980))

Material is lost offshore as a result of bar formation and the migration of the peninsula away from its offshore platform. Typically, the offshore bar system migrates onshore and offshore in response to lake level changes and severe storms. During these migrations, there is a continual net offshore loss. The offshore bars at Presque Isle have been observed to be both complex and dynamic (Sonnefeld and Nummedal 1987). Nummedal (1979) has identified four different bar forms and believes that substantial amounts of sediment may move along the bar systems. There are also offshore losses associated with the peninsula migrating eastward away from its western platform. That is, Presque Isle migrates east, leaving its platform behind. There are no present data on offshore losses from the Presque Isle system, but losses were estimated at 20 percent for use in developing a sediment budget (USAED, Buffalo 1980).

The main area of loss to the Presque Isle system is at the distal east end. Here the drifting sediment builds Gull Point, spills over the eastern end of the platform, building a new platform and is recurved shoreward and landward, shoaling across the Erie Harbor entrance channel. Estimates have been made to summarize losses at the east end based on historical changes at Gull Point, bathymetric charts, and dredging records for the Erie Harbor entrance channel (USAED, Buffalo 1980). Based on these figures, the present condition (with replenishment) is that an estimated 146,400 cu yd of littoral material accumulate in the entrance channel per year, 84,000 cu yd per year are involved in building Gull Point, and 57,800 cu yd per year build the new platform at the distal end (Figure 10).

From 1960 to 1977, the average annual volume dredged from the entrance channel has been about 225,950 cu yd. Computations presented in the Phase I GDM (USAED, Buffalo 1980) indicate that 146,400 cu yd of the dredged material per year come from Presque Isle and the rest from the mainland to the east or from siltation of suspended sediments. The 1930 to 1977 dredging record does not identify the amount dredged each year from the entrance channel, but the bulk of the annual dredging probably is material which originated from Presque Isle Peninsula and was deposited in the entrance channel. The 1930-1977 dredging records show that the dredging quantities since 1960 have averaged 95,150 cu yd per year more than for the 1930-1959 period. This probably reflects an increased influx of material as a result of the 1956-1971 beach nourishment operations and suggests that there is about a 5- to 6-year lag between replenishment and increased dredging volumes in the entrance channel. Since 1977, dredging of Erie Harbor has been conducted on a less frequent basis, usually every second or third year (i.e., 1979, 1981, 1983, 1986, 1990 and 1993). This reduction in frequency of dredging can be attributed primarily to a lesser amount of commercial shipping using the harbor.

The annual rate of growth of the distal end (Gull Point) varies from a minimum of 18,400 cu yd per year with shore protection structures, but no beach nourishment (1875-1950) to 84,900 cu yd per year with beach nourishment (1950-1988). The natural growth rate without structures or beach nourishment appears to be about 43,600 cu yd per year (1819-1875).

Therefore, the natural sediment budget for Presque Isle without beach nourishment as shown in Figure 11 is summarized as a 40,000-cu yd gain from the west, 51,300-cu yd permanent loss to the entrance channel, 17,400 cu yd used to build up the new eastern platform, and 18,400 cu yd to develop Gull Point. The resultant system, therefore, has a migration rate of 87,100 cu yd per year. Presently, the volume of Gull Point growth and the net loss to the entrance channel are higher (Figure 10), reflecting the available sediment load introduced by the beach nourishment activities.

Shoreline and Offshore Changes at Gull Point

Presque Isle, in general, experiences net erosion along the neck of the peninsula and net deposition to the east of the lighthouse (Nummedal 1983). Littoral material which travels along Presque Isle eventually reaches the depositional east end where some sediment accumulates at Gull Point, some travels beyond Gull Point to build up offshore bars, shoals, and the platform off Thompson Bay, and some is transported to the Erie Harbor entrance channel. The accretion at Gull Point can be documented by using historical maps of bathymetric change (U.S. Congress 1953, Messinger 1977). These maps show rapid accretion from the shoreface and along the spit platform, which extends to a depth of 18 ft below LWD offshore of Gull Point proper and to a depth of 24 ft below LWD farther north (Nummedal 1983). An average accretion rate at the east end of Presque Isle has been estimated at 148,000 cu yd per year for the period from 1875 through 1947 (Nummedal 1983). Since implementation of the cooperative erosion control project in 1955-1956, the growth rate of Gull Point has increased due to beach nourishment operations. With the beach nourishment program by which sand has been placed annually during the period from 1975 to 1991, the growth rate at Gull Point has been as high as 350,000 cu yd per year from 1976 to 1978 (USAED, Buffalo 1980).

The spit and its related bars do not provide a 100 percent effective sediment trap. Large quantities of sediment move across the platform offshore from Gull Point and are deposited in the Erie harbor entrance channel. The outer entrance channel to Erie Harbor is a permanent littoral sink, which must be maintained by dredging. The linear regression analysis presented in the Phase I General Design Memorandum (USAED, Buffalo 1980) illustrates that since the cooperative erosion control project was implemented (the initial replenishment in 1955 and periodic nourishments of the 1960's), there has been an increasing trend in the amount of dredging as more littoral sediment is available and an increase in transport into the entrance channel. The linear regression analysis shows that since the early 1960's, dredging of Erie Harbor has increased on the average by an additional 4,400 cu yd each year. Continual nourishment will eventually reach a critical point where almost all the

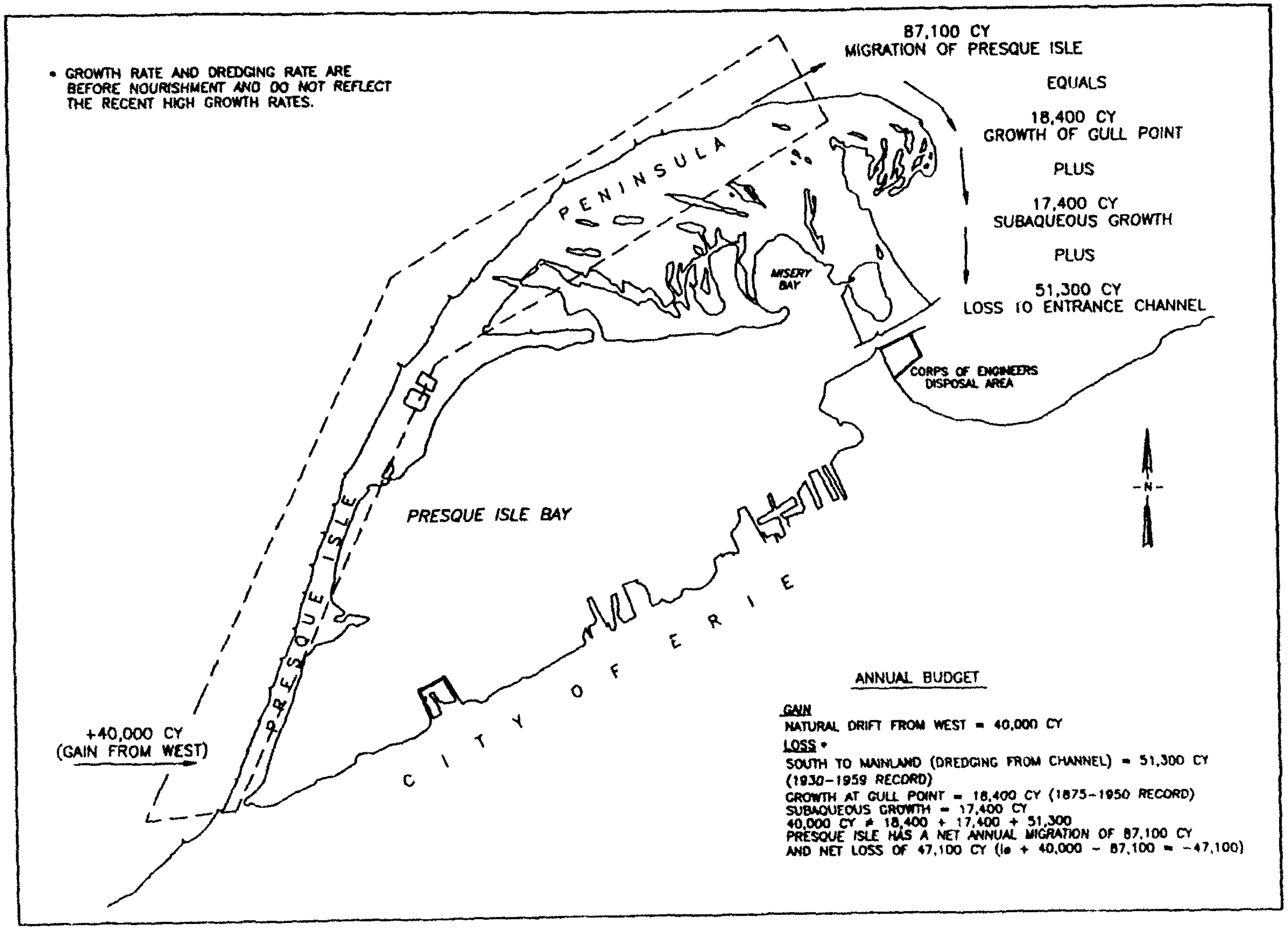


Figure 11. Presque Isle sediment budget without annual nourishment (modified from USAED, Buffalo (1980))

material placed on the beaches ends up in the entrance channel. This will occur as Gull Point continues to migrate along an axis which intersects the entrance channel. The historical maps of the shoreline, and the 6-, 12-, and 18-ft below LWD depth contours which were originally presented in House Document 231 (U.S. Congress 1953) were updated and are shown in Figures 12 through 15.

At Erie, PA, 65 percent of the winds originate from the southwest to northwest and about 20 percent originate from the north to northeast (Messinger 1977) (wind data based on records of U.S. Coast Guard at Erie Harbor for the period of 1 January 1928 to 31 December 1941 and 1 January 1945 to 31 December 1971.) The process variability for the Gull Point area is presented in Figure 16 and indicates the observed wave height and longshore current velocity for various wind speeds and directions. Figure 16 shows that for winds out of the southwest to northwest, the longshore current direction is mainly to the east along the northern shoreline, with a small component of transport to the south along the recurve. The longshore current velocity decreases toward the east due to the sheltering effect of the peninsula and wave shoaling/refraction on the platform.

During the occurrence of a northeast storm, transport along the northern shoreline of the peninsula is to the east rather than the west. Hence, littoral material necessary for the southwestward growth of the recurve is provided by erosion of the northeasternmost part of the peninsula. Northeast waves cause south and southwestward growth of the recurve, with the recurve often enclosing a pond as it connects with the old shoreline. With the resumption of southwest to northwest waves, a ridge is extended to the east or southeast making formation of a new pond possible with another sequence of north to northeast waves (Messinger 1977).

The growth of Gull Point, which has accelerated within recent times due to the beach nourishment program, is shown on Figures 17 through 19. Growth of Gull Point during the period from 1955 to 1972 (Figure 17) was greatest during the mid 1960's probably in response to the over 5,000,000 cu yd of sand that were placed on the peninsula beaches during construction of the initial beach erosion control project and early beach nourishment phases of the 1960's. During the period from 1975 to 1991, beach nourishment has been carried out on an annual basis to the order of about 160,000 to 185,000 cu yd per year. This has resulted in dramatic growth of Gull Point and the offshore platform (Figures 18 and 19) with dredging quantities in the Erie Harbor entrance channel increasing by about 4,400 cu yd per year. Continuation of the annual nourishment program at the present rate will continue to result in greater annual maintenance costs to Erie Harbor and will shorten the time frame of Gull Point/offshore platform advance to the entrance channel.

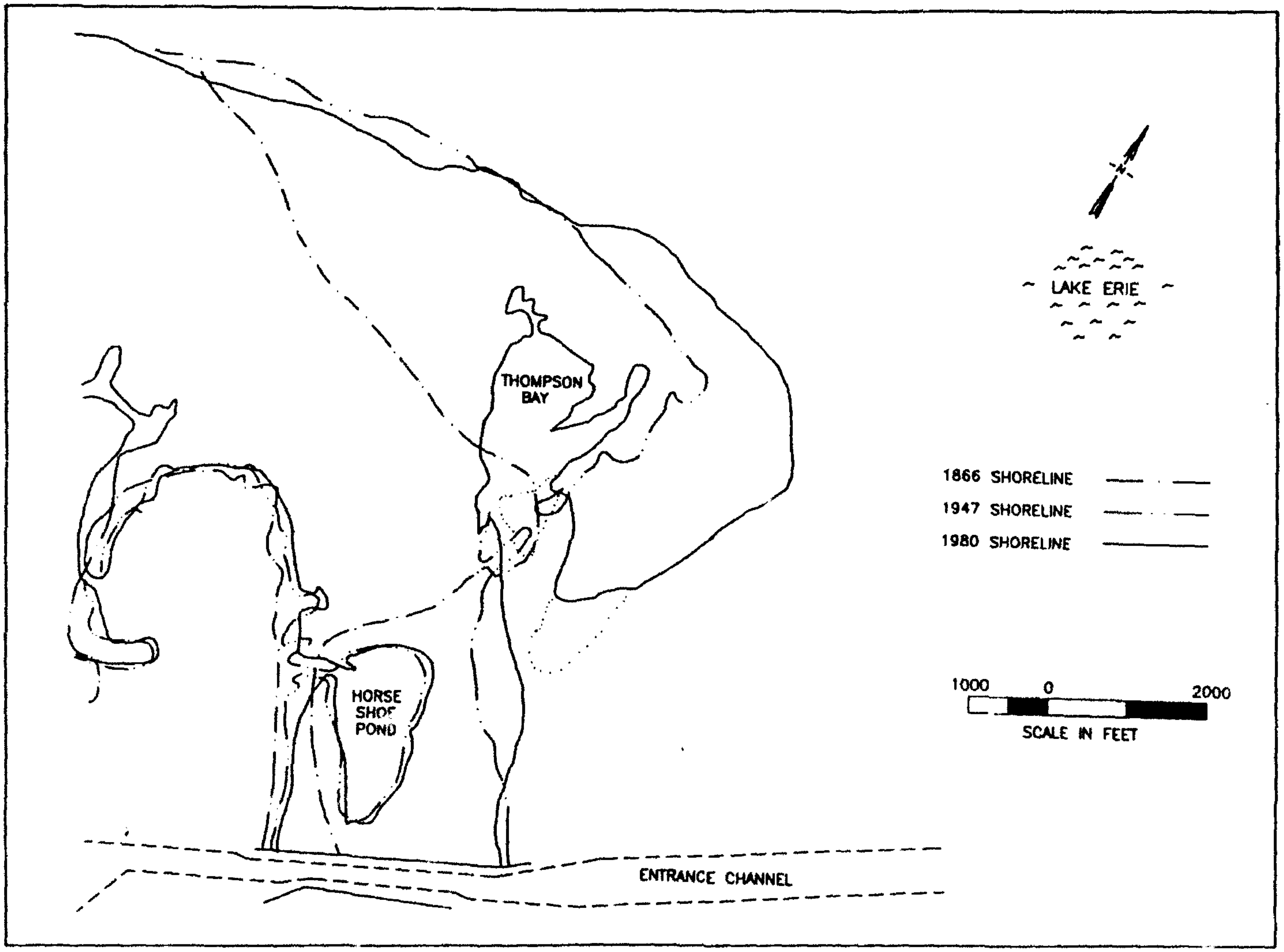


Figure 12. Presque Isle eastern 6-ft contour changes (1875-1980) (modified from USAED, Buffalo (1986))

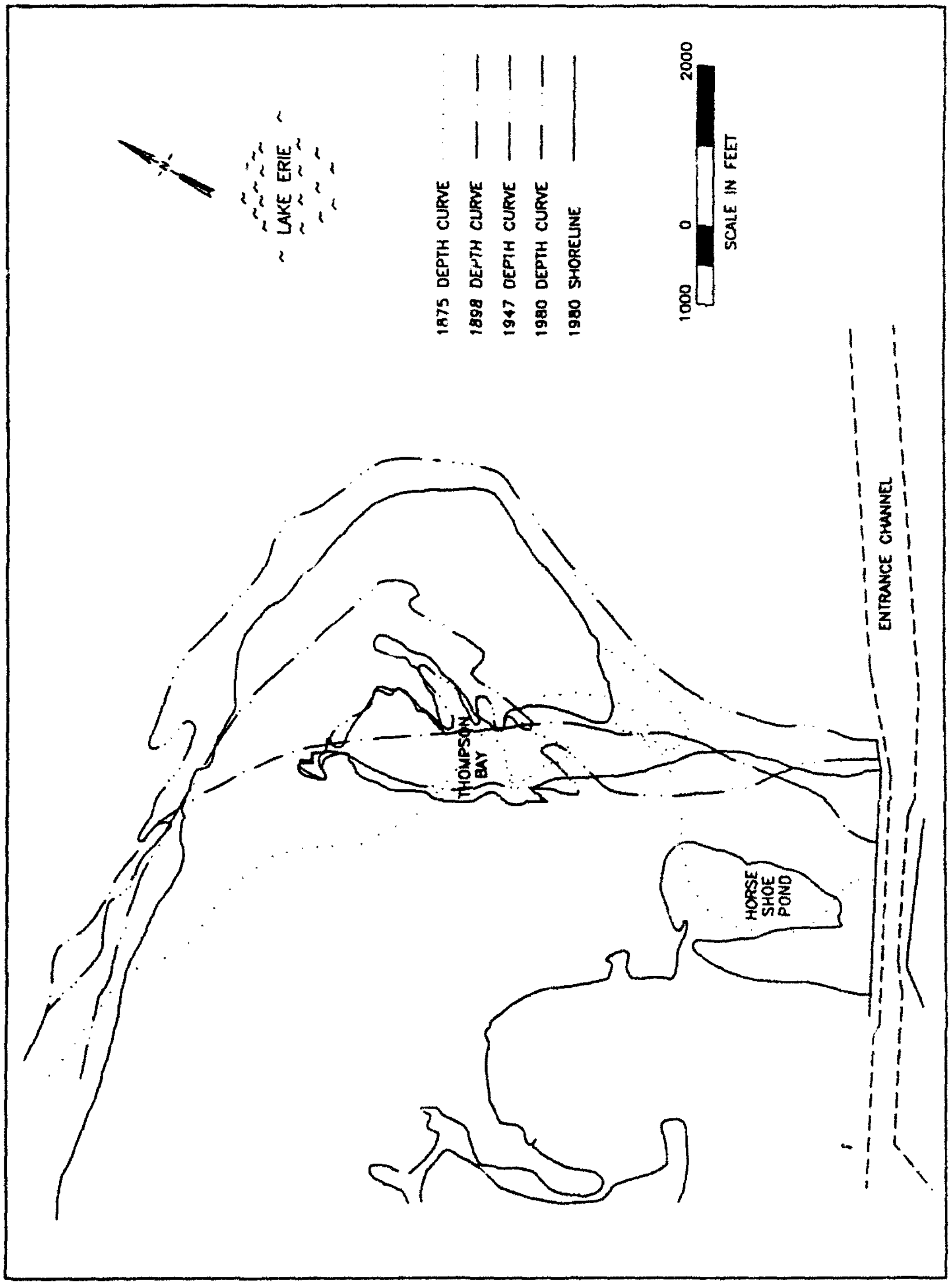


Figure 13. Presque Isle eastern 12-ft contour changes (1875-1980) (modified from USAED, Buffalo (1986))

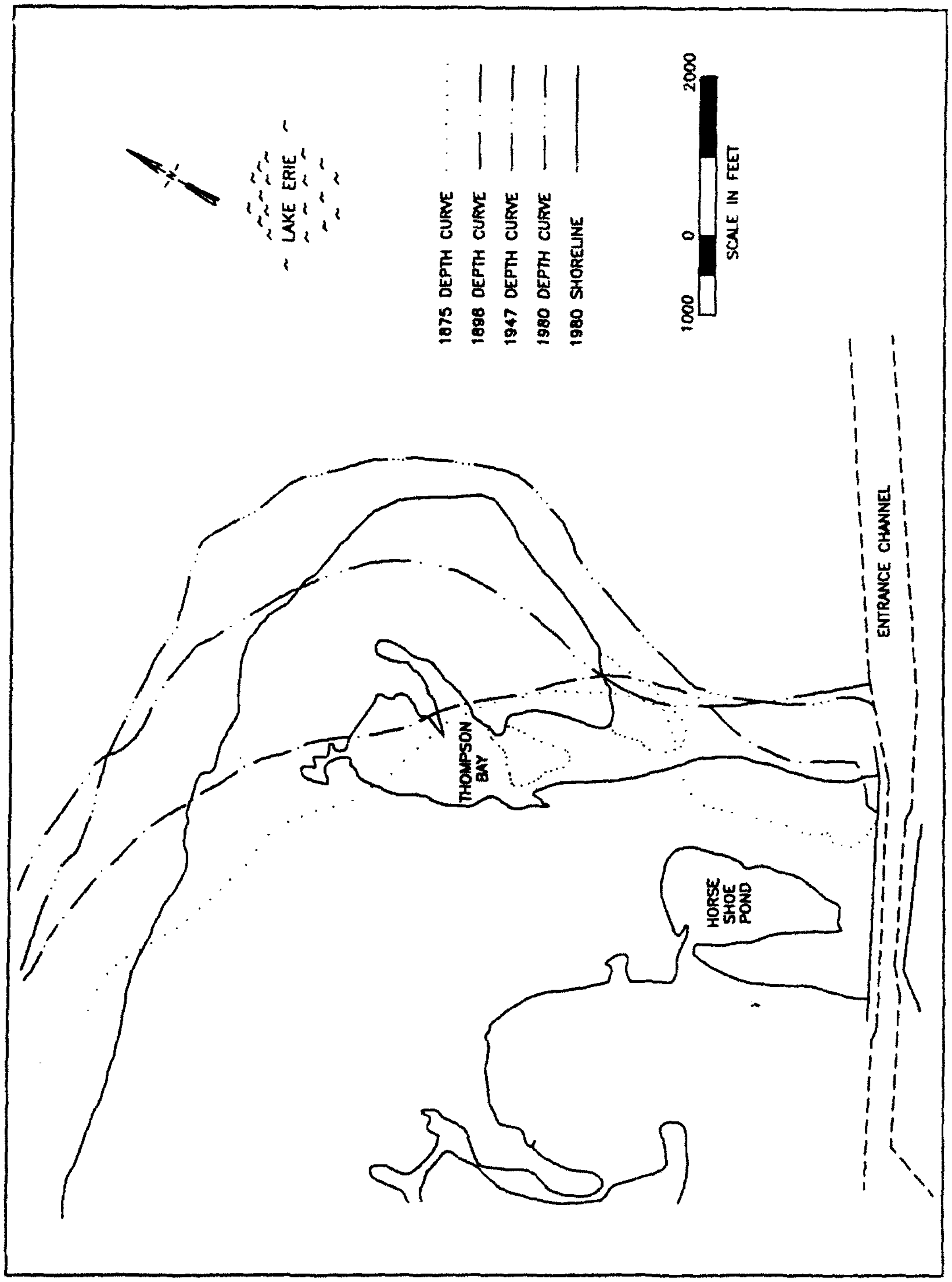


Figure 14. Presque Isle eastern 18-ft contour changes (1875-1980) (modified from USAED, Buffalo (1986))

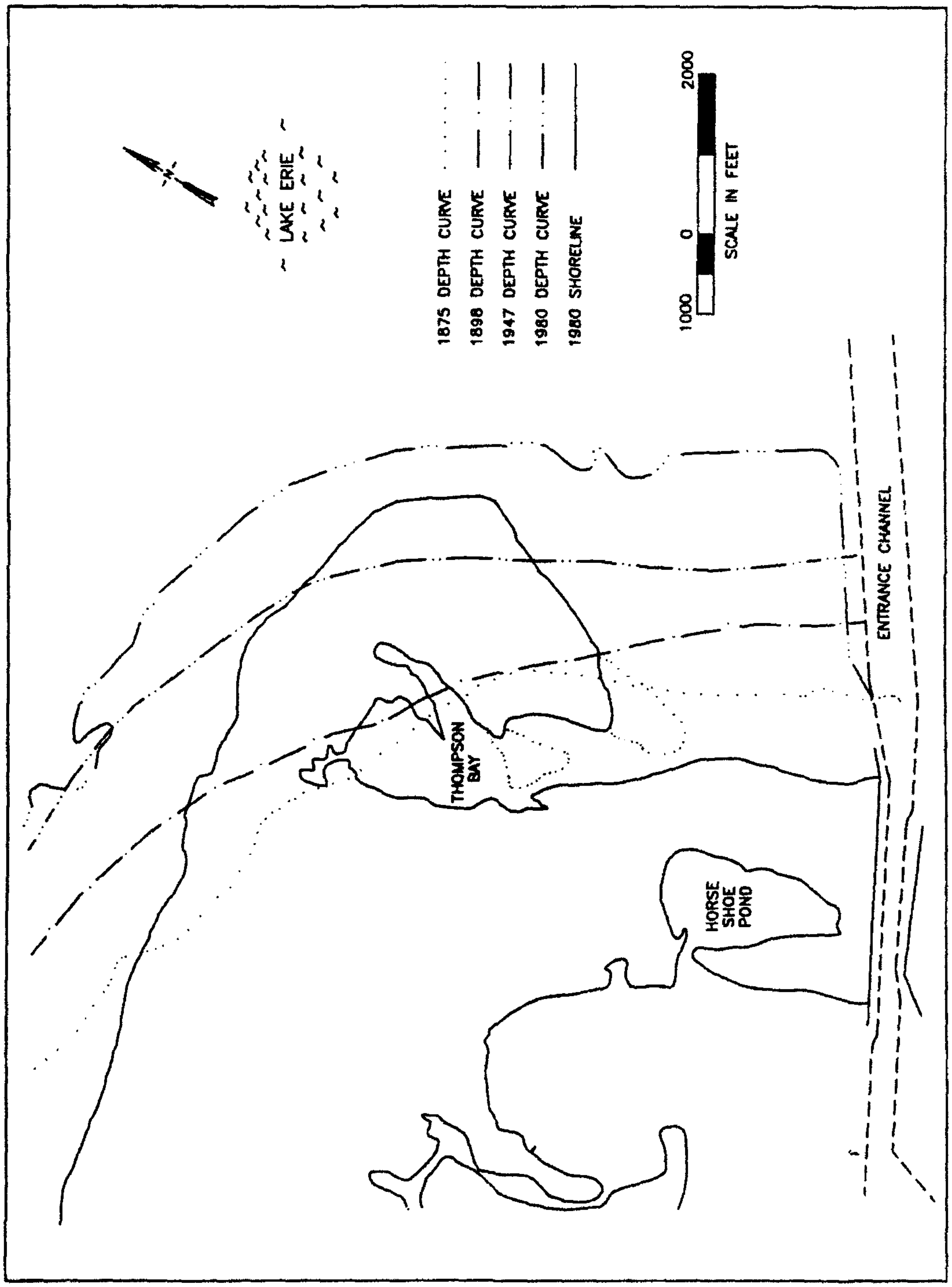


Figure 15. Observed wave height and longshore current velocity for various wind speeds and directions at Gull Point (modified from Messinger (1977))

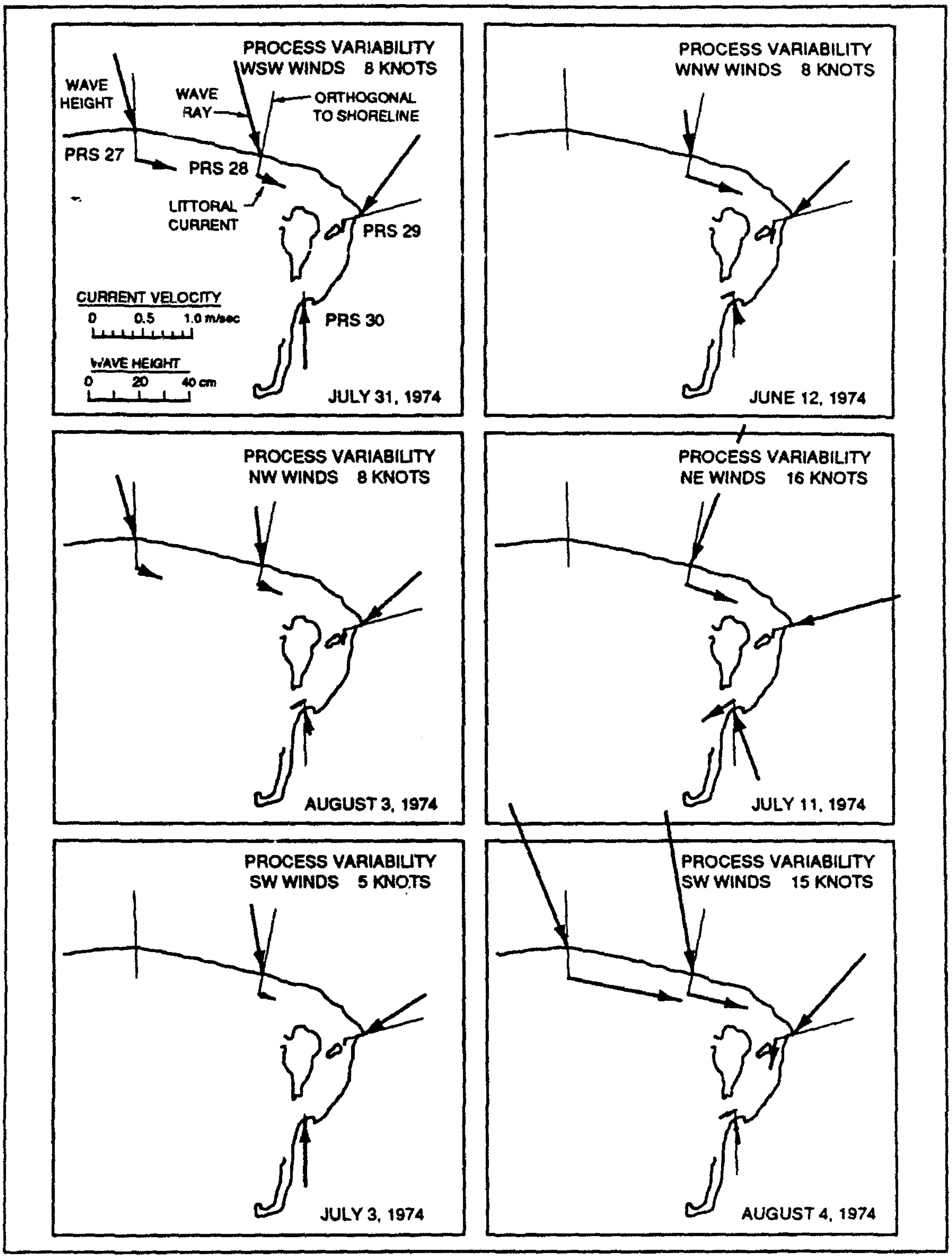


Figure 16. Observed wave height and longshore current velocity for various wind speeds and directions at Gull Point (modified from Messinger (1977))

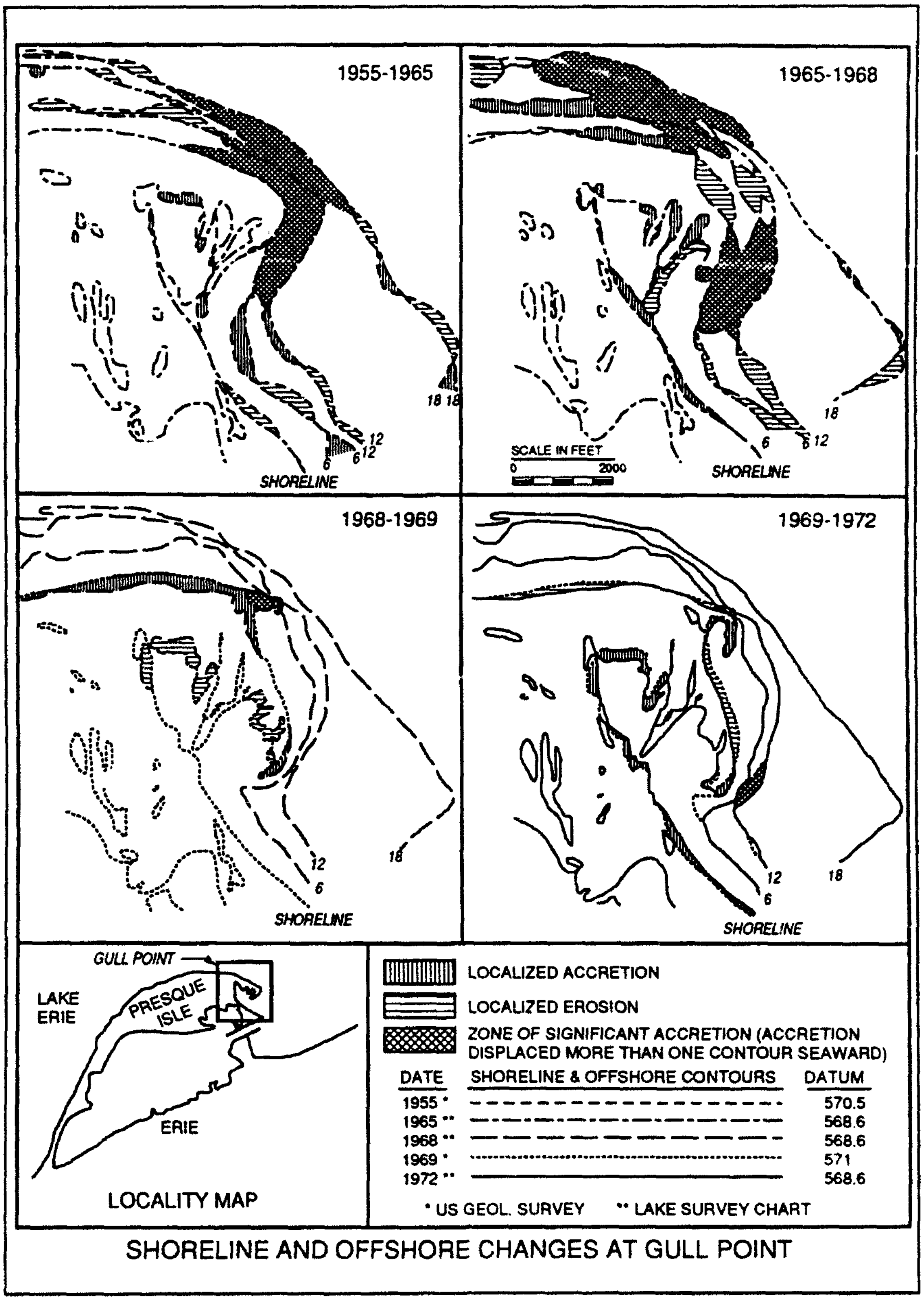


Figure 17. Growth of Gull Point from 1955 to 1972 (modified from Messinger (1977))

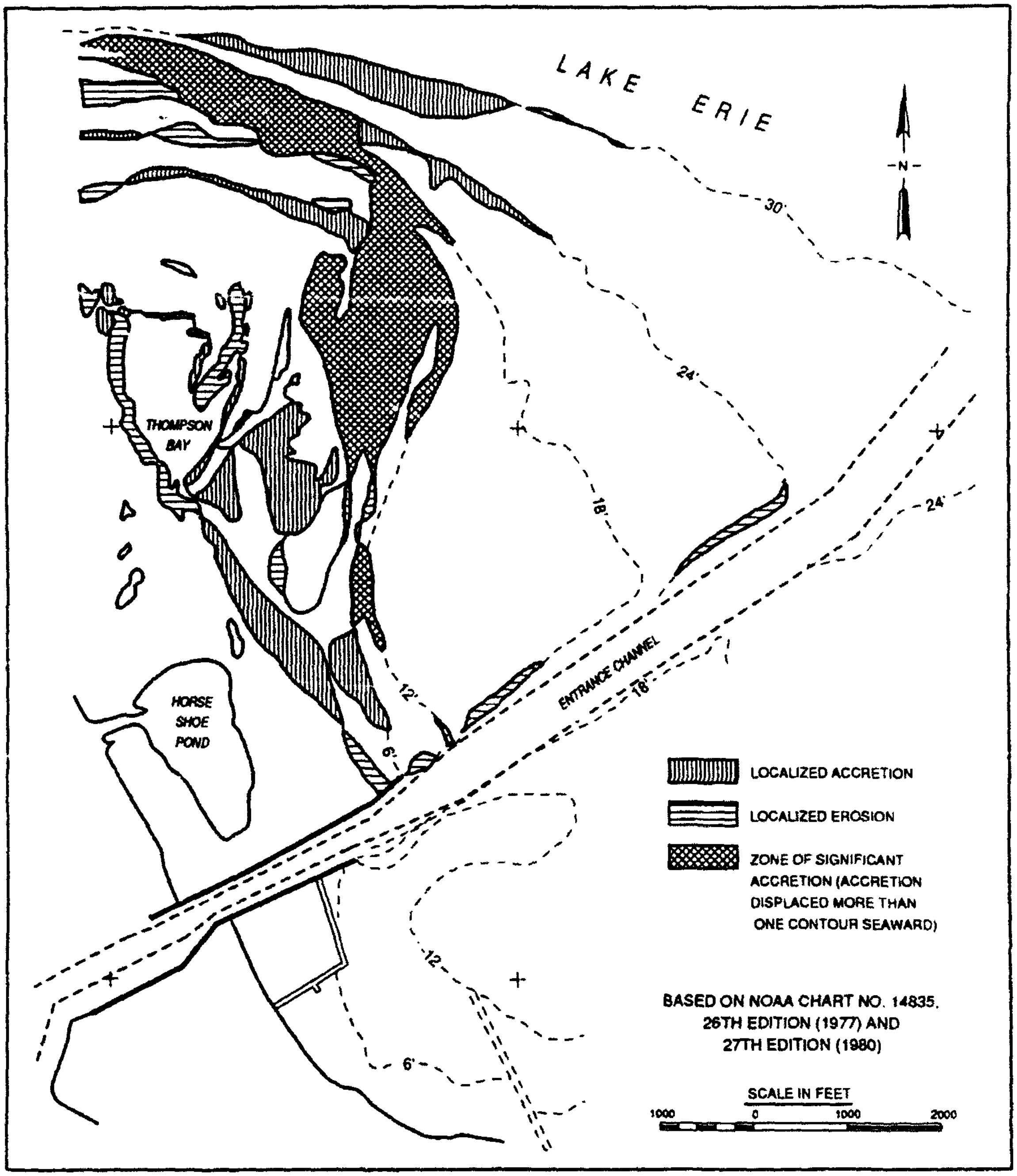


Figure 18. Growth of Gull Point from 1977 to 1980 (modified from USAED, Buffalo (1986))

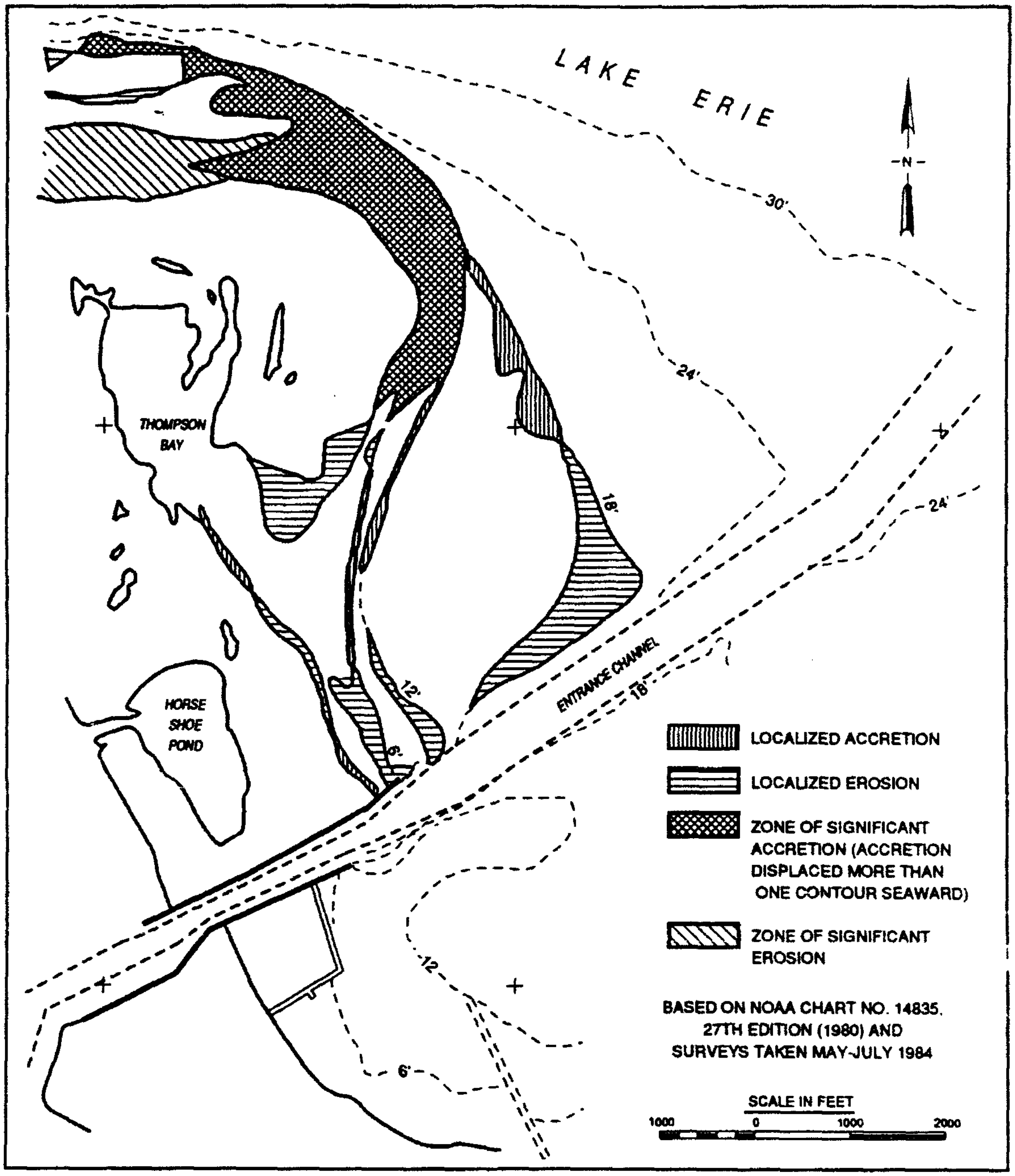


Figure 19. Growth of Gull Point from 1980 to 1984 (modified from USAED, Buffalo (1986))

4 Engineering History of Presque Isle

The Problem

The geological forces that have created Presque Isle (French for "almost an island") are also gradually destroying it. The natural processes of erosion and deposition continue as Presque Isle continues to migrate. Destructive natural processes, although necessary in a migrating coastal feature, are in conflict with the public use and investment in Presque Isle. Erosion of the lakeshore beaches and breaching of the neck have been counteracted by public and private efforts for over 160 years. The history of human efforts to retard erosion of Presque Isle is lengthy and complex.

When the Federal harbor at Erie, PA was first authorized in the early 1800's, the project included work at the entrance and protection of the shore at the neck of the peninsula of Presque Isle, which by its position, forms the natural harbor. Preservation of the peninsula is of vital importance to Erie Harbor and the city of Erie, PA. It was for the purpose of preserving the harbor that protection of the long, narrow neck at the western end of the peninsula was originally deemed necessary. Protective works to date have been constructed to prevent breaching through the narrow neck during severe storms from the west. Such breaches compromise the effectiveness of the harbor. A literature survey of the Chief of Engineers Reports (1867-1978) was undertaken, and the following paragraphs present documentation on protective works which have been implemented for the preservation of Presque Isle Peninsula.

History of Shore Protection

1823-1898

The attention of the United States Government was directed to Erie Harbor at the close of the War of 1812, since it was in Erie that Commodore Perry anchored his fleet after the Battle of Lake Erie. In 1823, the Board of Engineers presented an elaborate report with a plan for the improvement of the entrance to Erie Harbor. Subsequently, the River and Harbor Act of 26 May 1824 authorized improvement of Erie Harbor and protection of Presque Isle Peninsula.

The first breach recorded appears to have taken place during the winter of 1828-1829. Its location and extent were not reported, but the entire appropriation of $7,390.25 provided by the River and Harbor Act of 3 March 1829 was used in closing it. During the winter of 1832-1833, another breach occurred. Nothing was done to close it, and in 1835 it was reported to be nearly 1 mile wide. Plans were developed which provided for partially closing the breach with cribwork and making a 400-ft-wide western entrance to the bay. In 1836 work commenced, and 420 ft of cribwork breakwater was completed, strengthened by piling, and partially filled with stone. This cribwork breakwater was extended 1,920 ft in 1837, for an aggregate length of 2,340 ft. It was reported that the progress in partially closing the breach was very satisfactory, and in 1838, an additional 1,035 ft of cribwork was built. Work continued in 1839 when 990 ft of cribwork was built.

There were no appropriations or work done during the years 1840 through 1843. In 1844, the breach was reported to be about 3,000 ft wide, and the erosion was such that 470 ft of cribwork was built to protect the barracks built for workmen in 1836. Nothing further was done, and in 1852 the breach was reported as still existing, and the cribwork protection built in previous years almost destroyed. In 1853 efforts were made to prevent further erosion by armoring the shore with brush weighted with stone. The results were very satisfactory,and this mode of closing the breach continued in 1854 through 1856. Work was suspended in 1857 due to lack of funds, and no further work was done until 1864. In 1864 it was reported that the breach at the west end of the harbor was entirely closed, although about 500 ft of the peninsula was so low that waves would break clear across during high water and heavy gales. This low portion of the peninsula was strengthened in 1865 by placing old tree trunks, brush, saplings, etc., parallel to the shore, making a layer 30 ft wide.

During the years 1871 and 1872, 51,300 young trees, roots, and slips of silver poplar, American poplar, and willow were planted as an experiment on the west side of the peninsula for protection of the neck. Also, the beach at two exposed points was further protected by anchoring and picketing brush laid in rows and weighted with heavy stone. The fall and winter gales of 1873-1874 made alarming attacks on the shore of the peninsula, and in November 1874, the peninsula was once more breached. The breach was closed in 1875 with 400 ft of 6-ft-high, pile-and-plank fence riprapped on both sides with stone. The protection proved to be successful, and an additional 1,080 ft of pile-and-plank fence was built at other weak points on the peninsula in 1875. This pile and plank fence was extended 3,056 ft in 1876; another 1,461 ft in 1877; and 550 ft in 1878, making a total length of

6,547 ft. In 1879,the protection fence was badly damaged at various points with the stone washed away, piles broken off, and planks destroyed.

In 1880, eight jetties 200 ft apart were built by driving lines of close piling out to a depth of 6 ft in the lake. A ninth jetty was built about 2 miles from the neck of the peninsula. In addition, about 2,000 ft of brush and stone protection was built along the lakefront to repair the protective fences which had been destroyed during the previous winter. Violent gales during the winters of 1880-1881 and 1881-1882 destroyed several portions of the protective fencing built during the period from 1875 to 1878. In 1882, three additional piles were driven between every two old piles from the original protective fencing. About 1,000 ft of this type of protection was built to provide a nearly closed continuous row at a cost of nearly $2,500. This brought the total expenditures for work accomplished on Presque Isle during the period from 1829 through 1883 to approximately $220,000.

There was no work done for protection of Presque Isle Peninsula during the period from 1883 through 1887, and in 1887 it was reported that all the protection fences and pile jetties built in the previous years were so broken down and rotten that they were considered useless. The River and Harbor Act of 11 August 1888 authorized protection of the neck of the peninsula by construction of a 6,000-ft-long timber pile and sheet-pile breakwater located about 100 ft offshore. About 4,500 ft of breakwater was built by September 1889 at a cost of about $60,000, when a moderate storm badly wrecked all but 1,300 ft of the structure, and work was ordered stopped since it was evident that the protection constructed was not going to prove serviceable. The remaining sheet piling and walings were washed away during a severe storm in October 1892.

No further work was done on protection of the peninsula during the period of 1890 through 1895. Several severe storms occurred during this period where waves washed over the peninsula and into the bay causing severe erosion along the western portion of the peninsula. In 1896 another experimental tree planting project was undertaken. The neck of the peninsula was planted with 1,000 Carolina poplars, 200 Wisconsin willows, 200 yellow locusts, 200 Scotch pines, three bushels of blue grass, two bushels of orchard grass, one bushel of crimson clover, 300 willow cuttings, and about 60 native poplar trees at a cost of $360. The purpose of the plantings was to make a growth that would catch drifting sand and increase the height and width of the neck, thus increasing the resistance of the neck to erosion, and lessening the possibility of a breach from waves washing over the neck of the peninsula.

The experimental planting grew vigorously during 1896. Therefore, in 1897 about 2,400 yellow locust trees and two bushels of seeds of native shrubs were also planted on the neck of the peninsula at a cost of $376. The plantings were regarded as an important part of the harbor works and further plant growth was encouraged since those planted in previous years had thrived. An additional 2,000 honey-locust trees and 200 willow cuttings were planted in 1898 at a cost of $210.

1899-1952

The River and Harbor Act of 3 March 1899 authorized construction of four protection jetties along the outer edge of Presque Isle Peninsula. The first jetty was built in 1900 and located 5,200 ft west of the Presque Isle Light. The structure cost about $5,390 and was of timber crib construction filled with stone and had a "T" across the outer end. The cribbing was 12 ft wide, 11-1/2 ft deep, and 290 ft long; the "T" was 10 ft wide, 11-1/2 ft deep, and 32 ft long. The second protection jetty was built in 1903 at a cost of $8,560 and located 7,800 ft west of the Presque Isle Light. In 1906 it was determined that the jetties built in 1900 and 1903 were not correcting the beach erosion along the peninsula and, therefore, the remaining two jetties authorized by the River and Harbor Act of 1899 were never constructed.

There was no work done for protection of Presque Isle Peninsula during the period from 1904 through 1915. However, in 1916 about $316 was expended for planting 5,000 poplar trees and 2,725 linear ft of willow hedge on the neck of the peninsula to reinforce the existing growth. These trees and hedge grew well during the year, and in 1917 an additional 2,310 poplar trees and 2,280 willow cuttings were planted to reinforce the existing growth at a cost of $195.

A severe storm occurred late in October 1917 causing waves to break over the neck of the peninsula and creating a breach about 150 ft wide. Work on closing the breach with a 300-ft timber bulkhead was initiated in mid-November and continued until early December with 270 ft being completed at a cost of $7,000 when another severe storm occurred, uprooting large trees, washing out small growth, destroying the completed portion of the timber bulkhead, and widening the breach to 479 ft. There were no further attempts made to close the breach during 1918, and storms during the winter of 1918-1919 increased the width of the breach to 1,160 ft. Closure of the breach with sandfill protection was begun in the fall of 1919 when a 500-ft section of fill protection at the east end of the breach was placed before operations were halted for the winter. When operations resumed in April 1920, the breach was 1,470 ft wide. During 1920 about 3,000 ft of sandfill protection and 1,700 ft of rubble-mound protection were placed, and 4,800 small poplar trees were planted on the sandfill protection. In addition, 310 ft of riprap wall was placed on the lake side of the sandfill protection. The sandfill protection was completed during 1921, with 1,500 ft being placed, and the riprap wall on the lake side of the sandfill protection being extended 1,465 ft. During the period from October 1920 through November 1921, about 22,700 small poplar and 1,900 small willow trees were planted and 49 bushels of rye and six bushels of cowpeas were sown to protect the sandfill. In 1922 the riprap stone wall on the lake side of the sandfill protection was reinforced and extended 1,160 ft, thus completing the work in closing the breach. Approximately $282,000 was expended on work to close the breach.

The River and Harbor Act of 28 November 1922 reconveyed Presque Isle Peninsula to the Commonwealth of Pennsylvania for park purposes, and its care and protection were no longer to be considered by the United States as part of the project for improvement of Erie Harbor. The Commonwealth of Pennsylvania built six sand traps in 1927; a series of seven steel sheet-pile groins during 1928 and 1929; and about 5,300 ft of steel sheet-pile bulkhead in 1929 on the lake side of the peninsula at various locations from the neck to the lighthouse.

The United States Government again became involved with Presque Isle Peninsula for the protection of Erie Harbor in 1930 and 1931 when 5,646 ft of steel sheet-pile bulkhead (including shore returns) with 5,052 ft of stone facing was constructed along the neck of the peninsula at a cost of about $165,400. The Commonwealth of Pennsylvania extended this protection along the neck of the peninsula an additional 1,230 ft in 1931 and also built a steel sheet-pile groin. In 1932 the state built two more steel sheet-pile groins and extended the steel sheet-pile bulkhead, which they built in 1929, an additional 1,500 ft. This bulkhead was again extended 850 ft by the Commonwealth in 1937.

In 1943 and 1944, the United States Government repaired shore protection works constructed in previous years and further protected the steel sheet-pile bulkheads by construction of a rubble-mound facing on the lake side. In addition, 2,750 ft of rubble-mound protection was constructed at the root of the peninsula, and two experimental 300-ft-long rubble-mound groins were built. The work undertaken in 1943 and 1944 was accomplished at a cost of about $1,041,700. Further repairs to the protection works along Presque Isle Peninsula were undertaken by the United States Government during the period from 1947 through 1952 at a total cost of $443,100. During the period from 1924 through 1948, it was estimated that the Commonwealth of Pennsylvania had spent approximately $3,500,000 on maintenance of the peninsula.

Recent Efforts - The Cooperative Beach Protection Project

Severe storms during the early 1950's led to the establishment of the Cooperative Beach Protection Program between the Federal Government and the Commonwealth of Pennsylvania as authorized by the River and Harbor Act of 3 September 1954. Work commenced in the fall of 1955 and was completed in the summer of 1956, during which time 4,150,000 cu yd of sand were pumped on the beaches, 10 new steel sheet-pile groins were constructed, two existing groins were altered, and a badly damaged bulkhead section near the lighthouse groin was removed. The total cost of the cooperative project was $2,451,270, of which $817,090 was the Federal share and $1,634,180 was the non-Federal share. The total cost includes a 3,000-ft-long stone seawall built in 1952 on the neck of the peninsula.

Emergency sand replenishment was accomplished by the Commonwealth of Pennsylvania in the winter of 1959-1960 at a cost of about $24,000. The Cooperative Beach Protection Program was modified by the River and Harbor Act of 14 July 1960 to include participation in periodic nourishment for a period of 10 years following the first major replenishment operation.

Emergency protection in 1959-1960 prevented further damage to the project up to the time of the first major replenishment authorized by the 1960 River and Harbor Act. The first major replenishment was undertaken in 1960-1961 during which approximately 681,500 cu yd of sand were pumped onto the beaches at a cost of $500,000. In 1963-1964 the commonwealth of Pennsylvania repaired two groins which were built in 1956 by placing heavy stone at a cost of $54,000. A second major replenishment authorized by the 1960 River and Harbors Act was required in 1964-1965, at which time approximately 402,300 cu yd of sand were pumped on the beaches at a cost of $355,000. In 1965-1966, a third replenishment was undertaken where 45,000 tons of coarse-grained sandfill were placed, and six of the groins built in 1956 were modified by addition of a stone facing. The total cost for accomplishing the work undertaken in the third replenishment was about $166,000. A fourth major beach replenishment was undertaken in 1968-1969, with 102,700 tons of coarse sandfill being placed on the beaches at a cost of $348,000. The fifth and final beach replenishment operation authorized by the 1960 River and Harbor Act was accomplished in 1971 when a 1,200-ft-long barrier consisting of nylon bags filled with sand and grout was built at Beach No. 6; and 152,500 tons of sand were placed on the beaches at a total cost of $535,000. Under the authority of the 1960 River and Harbor Act, approximately 1,926,000 tons of sand were placed on the beaches at a total cost of $2,177,730 of which $1,328,470 was the Federal share and $849,260 was the non-Federal share.

In 1973, emergency sand replenishment was undertaken by the Federal Government, and 100,000 tons of sand were placed along the neck of the peninsula at a cost of about $240,000. Due to the severe erosion problem which still existed, the cooperative beach protection program between the Federal Government and the Commonwealth of Pennsylvania was again modified.

The Water Resources Development Act of 1974 reinstated and extended Federal participation in the cost for sand nourishment at Presque Isle Peninsula for a period of 5 years and at a cost not to exceed $3,500,000. Sand nourishment operations authorized by the 1974 Act were undertaken in 1975, 1976, 1977, 1978, and 1979 during which more than 961,000 tons of sand were placed on the beaches and three detached rubble-mound breakwaters were constructed at Beach No. 10. The total cost for the work accomplished under the 1974 Act was $5,000,000, of which $3,500,000 was the Federal share and $1,500,000 was the non-Federal share.

The Water Resources Development Act of 1976 modified the cooperative beach erosion control project by extending Federal participation in the cost for sand nourishment at the expiration of the authorization provided by the Water Resources Development Act of 1974. This extension allows Federal participation in sand nourishment during the pre-construction period for a project which is designed to provide long-term protection to Presque Isle Peninsula. Thirteen years of sand nourishment (1979 through 1991) as authorized by the 1976 Act have been completed, during which nearly 2,792,000 tons of sand were placed on the beaches. The total cost for these 13 years of beach nourishment was $16,143,450, of which $11,232,967 was the Federal share and $4,910,483 was the non-Federal share.

The project designed to provide a long-term solution to the erosion problem at Presque Isle was authorized for construction by the Water Resources Development Act of 1986 and was initiated in the Fall of 1989 with completion in 1992. Therefore, the beach nourishment undertaken in 1991 was the last year under the authority of the 1976 Act, in order to restore the eroded beaches in areas where structures were not built. Table 2 summarizes the shore protection efforts undertaken under the authorities of the 1974 and 1976 Water Resources Development Acts.

In summary, since 1955, $25,772,450 (of which $16,978,527 was the Federal share and $8,893,923 was the non-Federal share) has been spent under various authorities for the cooperative project to control erosion and maintain the recreational beaches at Presque Isle Peninsula. These protection and maintenance features include placement of approximately 11,904,000 tons of sand on the beaches through 1991. Table 3 summarizes the Federal and non-Federal expenditures incurred under the authorities of the cooperative beach erosion control project at Presque Isle Peninsula.

Table 2
Summary of Shore Protection Efforts Accomplished Under the 1974 and 1976 Water Resources Development Acts

Year	Work Accomplished	Funds Expended
1975	187,000 tons of sand placed from offshore borrow area	$1,097,000
1976	183,000 tons of sand placed from offshore borrow area	$1,109,500
1977	287,000 tons of sand placed from upland sand sources	$1,077,000
1978	173,000 tons of sand placed from upland sand sources and three prototype breakwaters constructed at Beach No. 10	$1,073,400
1979	216,000 tons of sand placed from upland sand sources	$1,060,500
1980	216,000 tons of sand placed from upland sand sources	$1,082,100
1981	236,000 tons of sand placed from upland sand sources	$1,213,300
1982	284,000 tons of sand placed from upland sand sources	$1,424,400
1983	194,000 tons of sand placed from upland sand sources	$1,049,000
1984 & 1985	505,000 tons of sand placed from upland sand sources and 30,000 tons of gravel placed on test beach at Beach No. 5	$3,007,000
1986	258,000 tons of sand placed from upland sand sources	$1,631,400
1987	173,000 tons of sand placed from upland sand sources and 45,000 tons of coarse sand and 10,000 tons of fine sand placed from offshore borrow area	$1,671,500
1988	211,000 tons of sand placed from upland sand sources and 27,000 tons of fine sand placed from offshore borrow area	$1,529,200
1989	234,000 tons of sand placed from upland sand sources and 35,000 tons of fine sand placed from offshore borrow area	$1,599,900
1990	150,000 tons of sand placed from upland sand sources and 20,000 tons of fine sand placed from offshore borrow area	$993,200
1991	56,000 tons of sand placed from upland sand sources and 23,000 tons of fine sand placed from offshore borrow area	$524,900

Table 3
Summary of Expenditures Incurred Under Authorities of Cooperative Beach Erosion Control Project

Authorization	Federal Cost	Non-Federal Cost	Total Cost
1954 R&H Act	$817,090	$1,634,180	$2,451,270
1960 R& H Act	$1,328,470	$849,260	$2,177,730
1974 WRD Act	$3,500,000	$1,500,000	$5,000,000
1976 WRD Act	$11,232,967	$4,810,483	$16,143,450
TOTAL	$16,978,527	$8,893,923	$25,772,450

5 Prototype Breakwaters

Purpose and Plan

The erosion of and possible remedial measures for Presque Isle were discussed by the civilian members of the Coastal Engineering Research Board during the 22-23 March 1976 meeting at the U.S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center. In view of the need for more information on this problem, it was recommended by the subcommittee that a visit be made to Presque Isle. That visit and inspection of the peninsula took place on 6-7 October 1976. Use of segmented offshore breakwaters which will serve as wave attenuators and beach builders was an alternative that was to be given serious consideration during the Phase I GDM stage. Therefore, the subcommittee members recommended that an experimental program be undertaken to construct three concrete grout-filled nylon bag breakwaters at the 3- to 4-ft water depth near Beach No. 10, since existing structures of this type at Presque Isle have withstood the local wave climate for several years. Beach No. 10 (Figure 20) was selected as the site for the experimental program because it was the nodal point between which erosion and accretion were occurring.

In order to actually test the effectiveness of breakwaters at Presque Isle, the Corps of Engineers obtained the necessary authority to construct three rubble-mound breakwaters at Beach No. 10. Rubble-mound construction was selected in lieu of the concrete grout-filled nylon bags because if it were determined in the Phase I study that offshore breakwaters were the best alternative, the permanent project would probably be designed using stone construction. Therefore, any information that could be obtained on the effectiveness of rubble-mound breakwaters would be beneficial in assessing the breakwater alternative.

Three rubble-mound breakwaters were constructed in June 1978, and 70,000 tons of sand were spread along the shoreline behind the breakwaters. Each breakwater, aligned parallel to the peninsula shoreline, is 125 ft long, 6 ft high, and separated by gaps of 300 ft and 200 ft. The two spacings between the prototype breakwaters were selected to provide additional information on determining an optimum gap to allow swimming between the

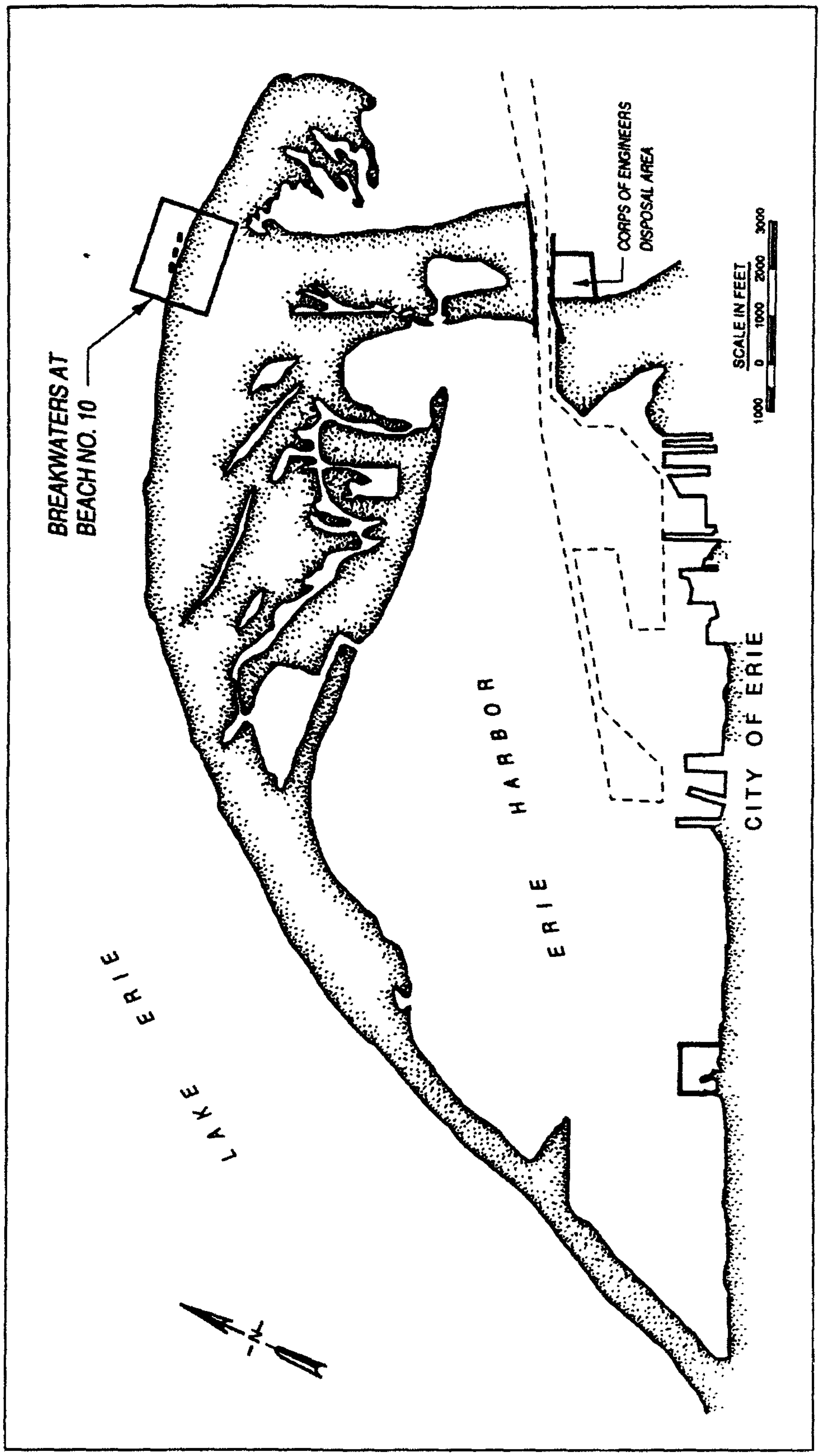


Figure 20. Location of Beach No. 10, Presque Isle (modified from Gorecki (1985))

breakwaters while being effective in holding a beach. Figure 21 shows the project after construction.

Monitoring Program

In order to monitor the effectiveness of the prototype breakwaters as wave attenuators and beach builders and to obtain information and data for use in analyzing the segmented offshore breakwater alternative, a monitoring program was established. The monitoring program consisted of obtaining post-construction vertical aerial photography of the Beach No. 10 area in spring, summer, and fall. In addition, topographic and bathymetric surveys of the Beach No. 10 area were obtained each spring and fall to quantify beach changes. Sediment samples were obtained during the fall survey, and gradation analyses were performed to determine the particle size distribution in the vicinity of the breakwaters in order that an optimum sand gradation could be determined for future nourishment operations. The monitoring program was initiated in the spring of 1978 and continued through the spring of 1984.

Aerial photography

Figures 22 through 35 depict the beach changes in the lee of the prototype breakwaters from May 1978 through May 1984. Figure 22, dated 19 May 1978, shows the Beach No. 10 area prior to construction of the prototype project. Figure 23 shows the Beach No. 10 area immediately after construction of the prototype project in July 1978.

The following observations were made from aerial photography of the Beach No. 10 area:

a. By November 1978 (Figure 24), distinct salients were present behind the western and center breakwaters.

b. On 6 April 1979, the project was subjected to a severe storm which may have exceeded the design event (design lake stage = 575.3 ft IGLD or +6.7 ft LWD and design wave = 7.0 ft) when winds gusting to 62 knots caused waves estimated by state park personnel to be 8 to 10 ft. A field inspection after the storm showed that there had been major changes along other portions of the peninsula shoreline; however, the breakwaters performed as designed with only slight movement of the stones, and salients still existed behind each structure as shown in Figure 25.

c. In November 1979 (Figure 26), tombolos existed behind the western and center breakwaters and one had almost formed behind the eastern structure.

Figure 21. Prototype breakwater project after construction

Figure 22. Beach No. 10 prototype breakwater site prior to construction, 19 May 1978

Figure 23. Beach No. 10 immediately after construction of prototype project, 12 July 1978

Figure 24. Beach No. 10, 9 November 1978

Figure 25. Beach No. 10, 18 April 1979

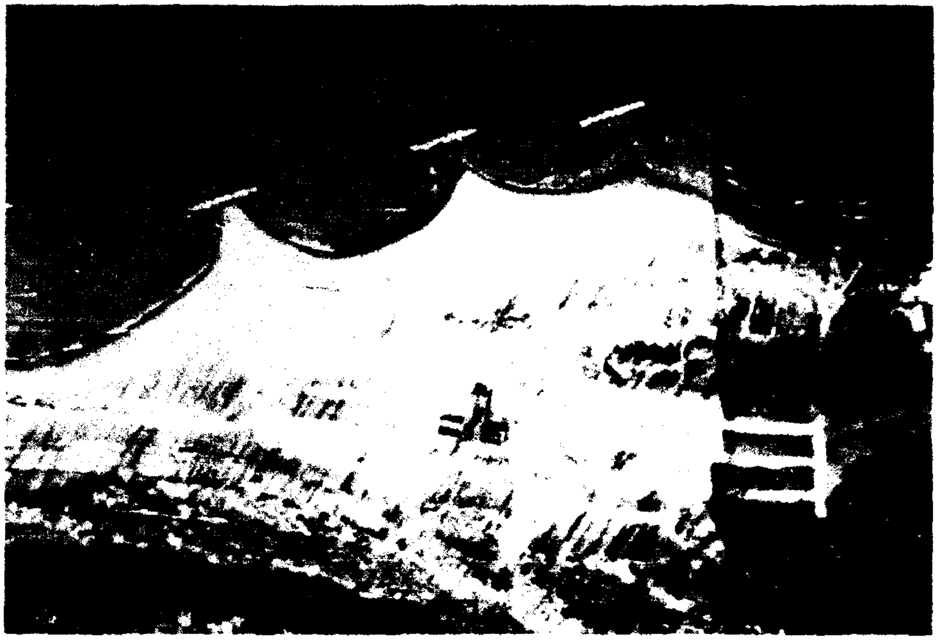


Figure 26. Beach No. 10, 16 November 1979

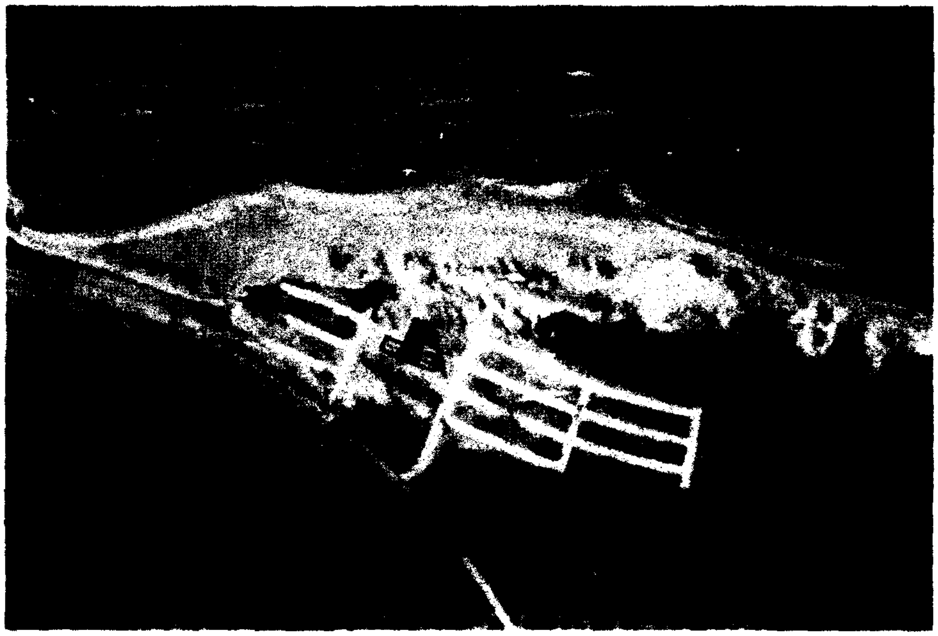


Figure 27. Beach No. 10, 17 April 1980

Figure 28. Beach No. 10, 12 September 1980

Figure 29. Beach No. 10, 10 April 1981

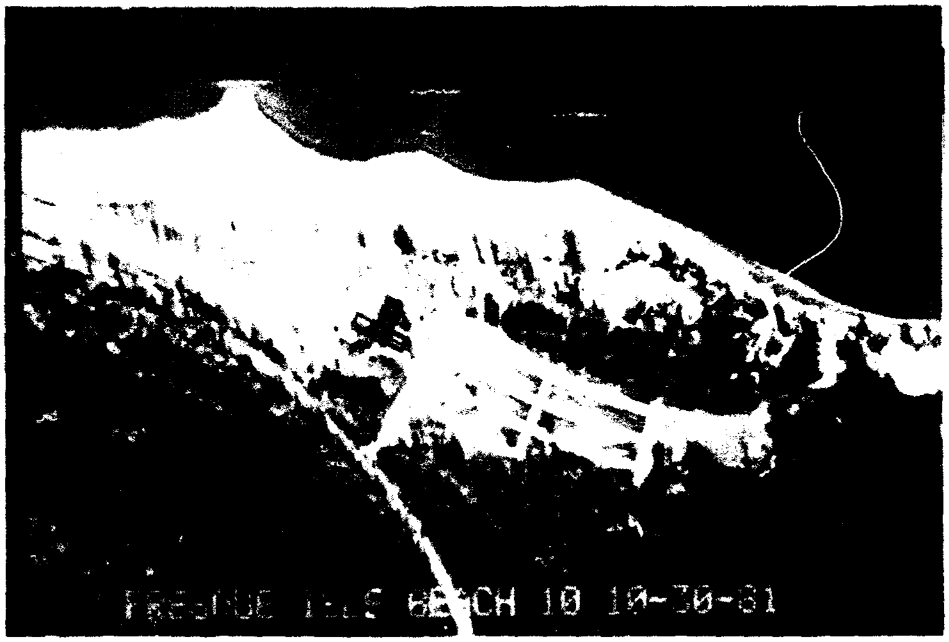


Figure 30. Beach No. 10, 30 October 1981

Figure 31. Beach No. 10, 2 June 1982

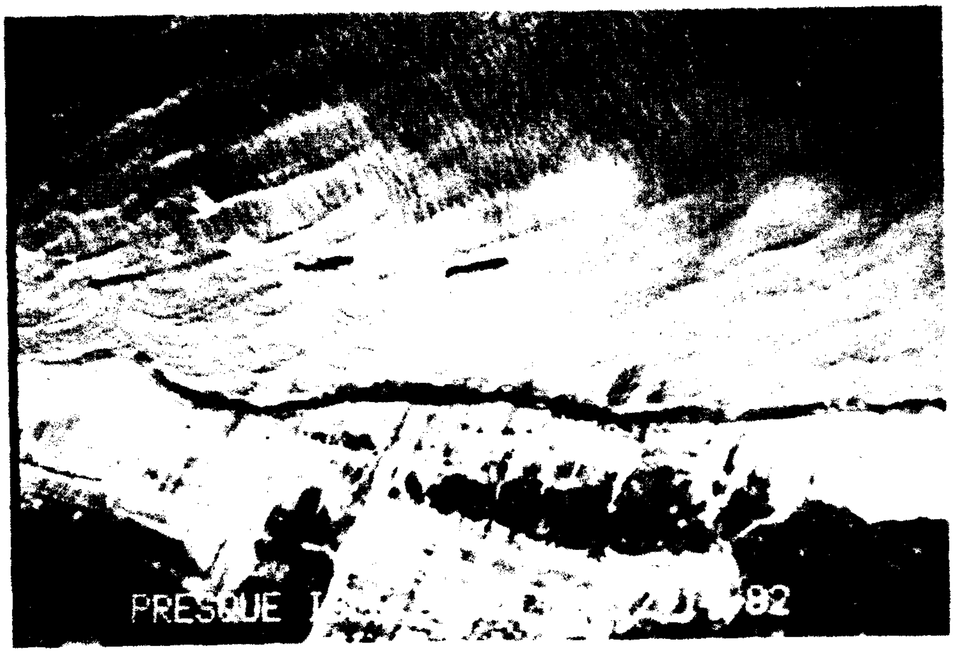


Figure 32. Beach No. 10, 14 December 1982

Figure 33. Beach No. 10, 26 April 1983

Figure 34. Beach No. 10, 31 October 1983

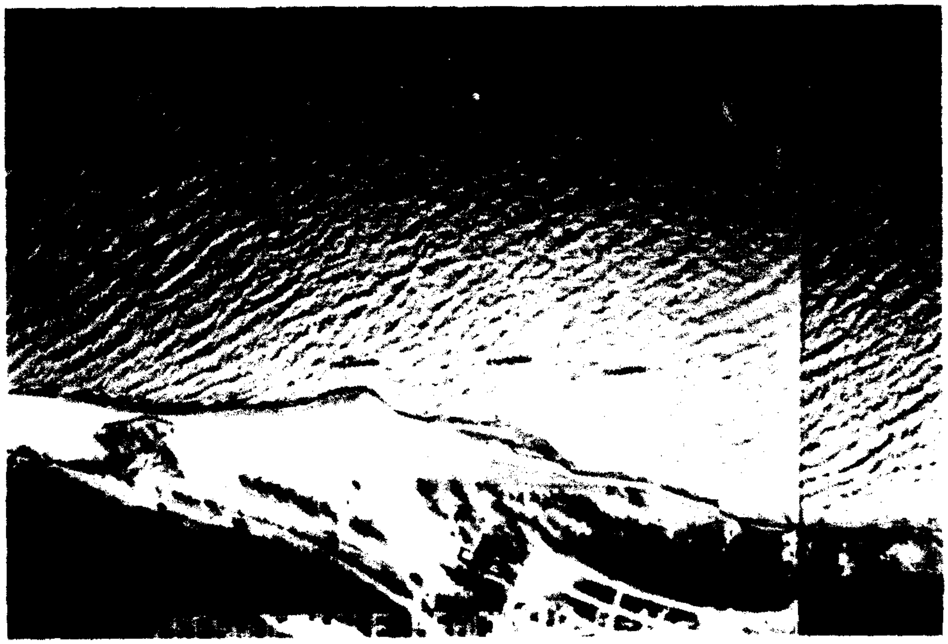


Figure 35. Beach No. 10, 16 May 1984

d. Salients were still present in April 1980 (Figure 27). The 1980 fall photography (Figure 28) showed that there was not much change in the beach since the spring.

e. By the spring of 1981 (Figure 29), a complete tombolo formed behind the western breakwater and distinct salients were evident behind the two other breakwaters.

f. In the fall of 1981, the tombolo still existed behind the western breakwater; however, the salients were cut back considerably behind the two other breakwaters as shown in Figure 30.

g. By June 1982 (Figure 31), the tombolo was cut back behind the western breakwater, and the salients were further flattened behind the two other breakwaters.

h. In December 1982 (Figure 32), the tombolo behind the western breakwater was cut back even further, and the beach behind the two other breakwaters experienced considerable losses.

i. Normally, Lake Erie freezes over during the winter months, and the ice cover protects Presque Isle from severe winter and spring storms. The winter of 1982-1983 was mild, and Lake Erie did not freeze. The lack of an ice cover and the numerous storms that occurred during the winter and spring further aggravated the erosion at the Beach No. 10 area as shown in Figure 33. Subsequently, the contract for the 1983 beach nourishment program was modified to place about 32,000 tons of sand beach fill in the lee of the middle and eastern breakwaters. This was the first time that sand was placed at Beach No. 10 since the initial construction in 1978.

j. By the fall of 1983 (Figure 34), there was a complete tombolo again behind the westernmost breakwater. The sand berm placed in the lee of the two other breakwaters had been reduced.

k. In the spring of 1984 (Figure 35), the tombolo behind the western breakwater was cut back, but the beach built up considerably behind the middle breakwater. The contract for the 1984 beach nourishment program required placement of 25,000 tons of sand fill at Beach No. 10 to re-establish the protective sand berms.

Bathymetric and topographic surveys

A survey plan (Figure 36) consisting of 16 profile lines was established between Stations 97+00 and 121+00. Each profile line extended from the top of the parking lot or dune through the beach area and offshore to a depth of 20 ft below LWD. A total of 13 surveys were completed. The data for each profile line from the current survey was plotted for comparison with the

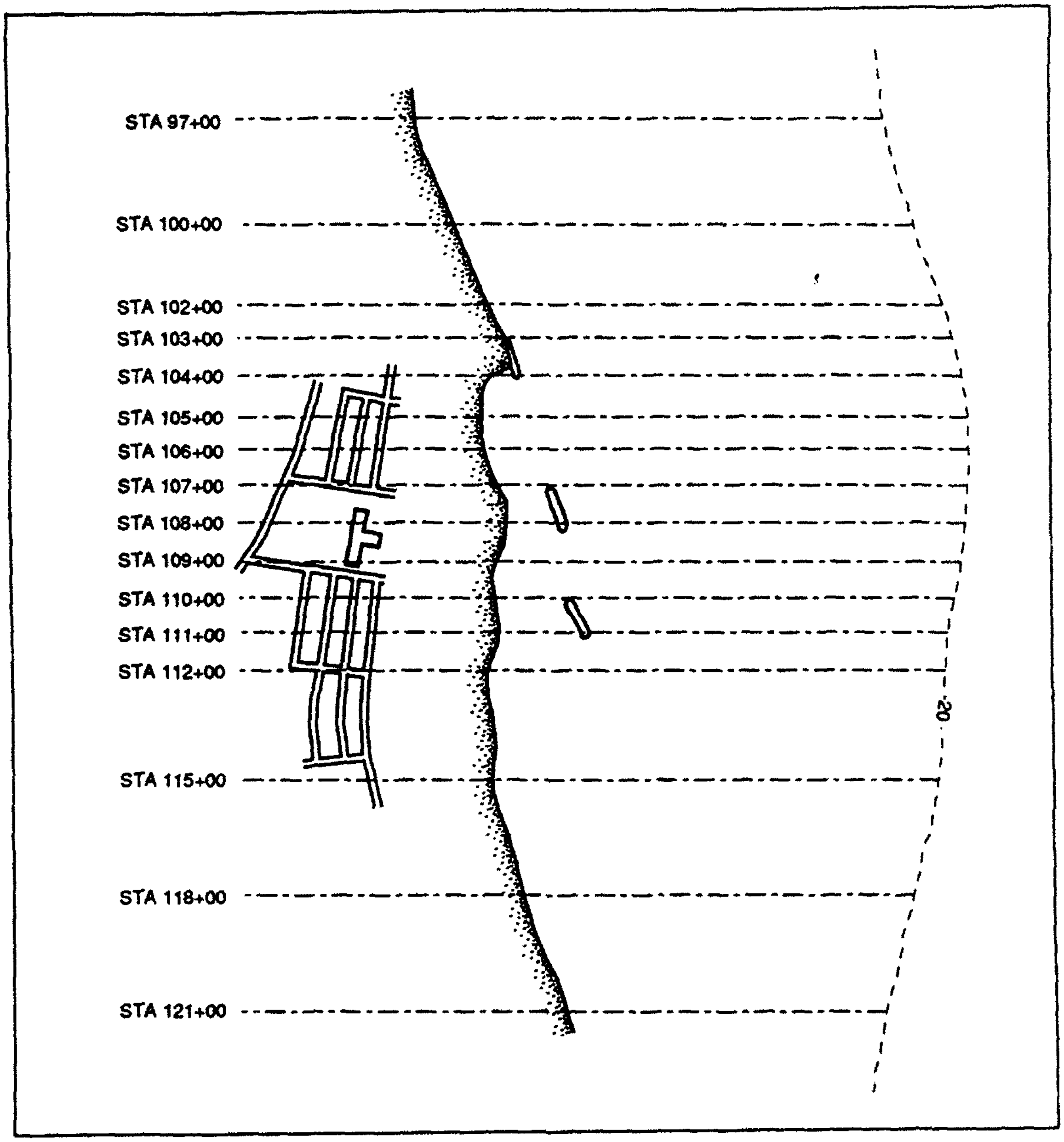


Figure 36. Survey lines established for Beach No. 10 monitoring program (modified from Gorecki (1985))

data from the previous survey. In order to quantify beach versus offshore volume changes, the survey area was divided into two zones. Area "A" is in the lee of the breakwaters and is bounded between Stations 102+00 and 112+00. Area "B" extends offshore from the breakwaters to the 20-ft depth contour and was bounded between Stations 97+00 and 118+00. Data for each profile line were input into the Interactive Survey Reduction Program (Birkemeier 1984) to compute the volume changes in Areas "A" and "B."

The net results, as shown in Tables A1 and A2, indicated that during the period from July 1978 through October 1981 there were extensive losses in the offshore zones in Area "B," while there was a tendency towards accretion in the lee of the breakwaters (Area "A"). During the period from October 1981 through October 1983, a reversal was observed and accretion occurred in the offshore zones of Area "B" and losses occurred in the lee of the breakwaters in Area "A." These variations are illustrated in Figure 37.

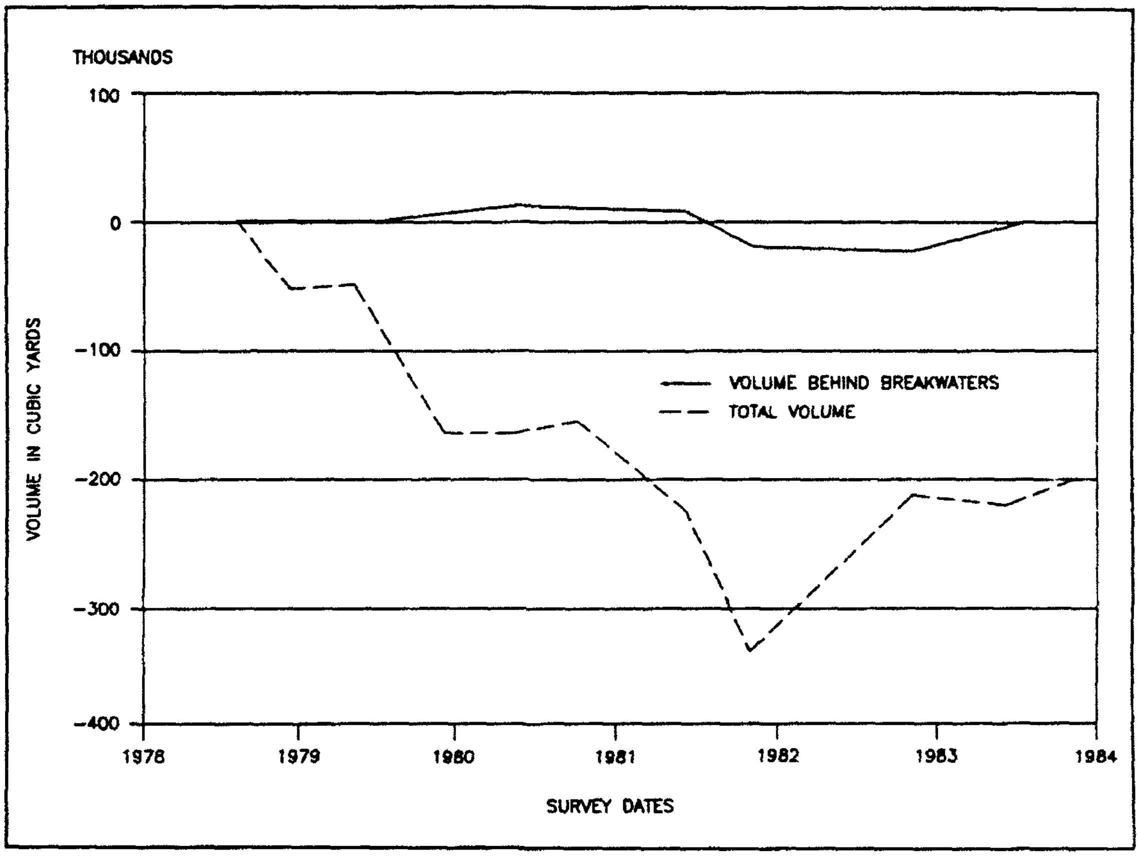


Figure 37. Volume changes measured at Beach No. 10, 1978 through 1984 (modified from Gorecki (1985))

Tracer studies of sediment movement in the bar system at Presque Isle were conducted by Nummedal and Sonnenfeld (1983). These studies identified a permanent outer bar and transient inner bar system where the majority of longshore sediment movement occurs. Nummedal and Sonnenfeld concluded that there is a net lakeward movement of sand on both the outer and inner bars and that sand is carried alongshore in the bar system. Since the breakwaters at Beach No. 10 were constructed landward of the outer bar and trough system, the sand which is being carried alongshore on the outer bar bypasses the breakwaters.

Sediment sampling program

A sediment sample was collected at each of 41 locations during each of the six fall surveys (Figure 38). A gradation analysis was performed on each sample, and the results are presented in Tables B1 through B8. The results of the gradation analyses were evaluated to determine the grain size distribution in the vicinity of the breakwaters. Generally, the sampling has shown the usual progression from coarse sand near the water's edge to fine sand at the 20-ft depth. Coarser material collected lakeward of the middle and east breakwaters during the initial sampling is thought to have occurred because of dredging operations for the breakwater foundations. As documented through successive samplings, the coarse pocket was gradually reduced in area and by November 1981 had entirely disappeared. Hence, fine gravel to coarse sand was found between the water's edge and the breakwaters, and fine sand was found lakeward of the breakwaters.

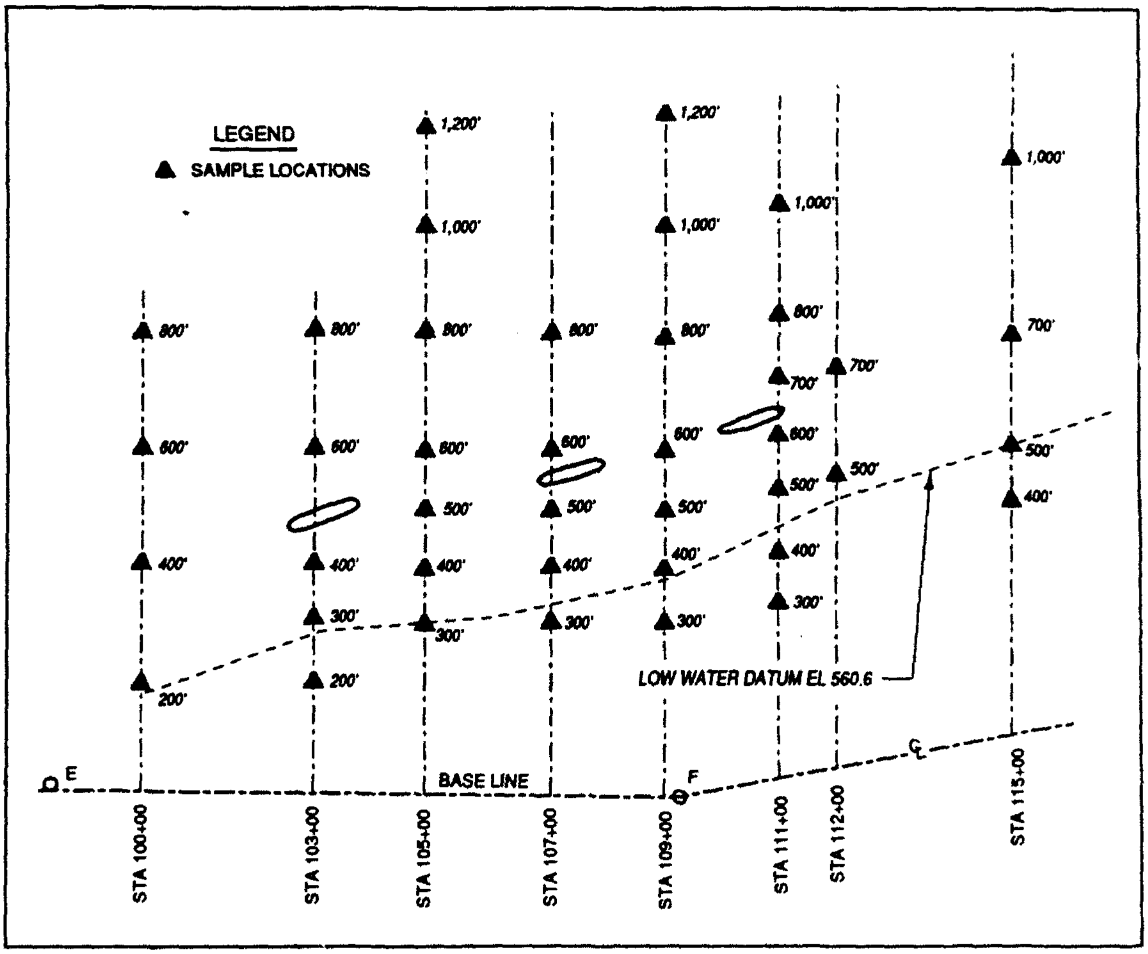


Figure 38. Sediment sampling plan established for Beach No. 10 monitoring program (modified from Gorecki (1985))

6 The Present Authorized Project

The periodic beach nourishment program authorized by the 1960 River and Harbor Act was not a complete system approach to the erosion problem. Nourishment quantities were far greater than those originally predicted for the 1955 project. In March 1967, the Commonwealth of Pennsylvania requested that sand replenishment as a method of protection against beach erosion at Presque Isle be reevaluated to determine if a more effective method of protection could be developed. In April 1968, the Commonwealth of Pennsylvania requested that their representatives to the U.S. Congress introduce resolutions to authorize a complete restudy of the Presque Isle cooperative beach erosion control project in order to develop a more effective and more permanent solution to the erosion problems. In addition, residents of the city of Erie were concerned over the high nourishment costs and the recurring threat to established facilities on Presque Isle, including bathhouses, parking areas, highways, and especially the bathing beaches. Erie residents have repeatedly requested a "permanent" solution to the erosion problems of the peninsula, thus implying a low-maintenance solution by stabilizing the beaches.

An extensive evaluation of the Presque Isle erosion problem and various beach erosion control alternatives was conducted from 1968 to 1985. Numerous methods of shore protection were considered (USAED, Buffalo 1973), evaluated for economic feasibility (USAED, Buffalo 1980), and studied in a physical model (Seabergh 1983). Several alternatives were reevaluated based on funding limitations (USAED, Buffalo 1983, 1984, 1985). The 58-breakwater plan with staged construction was ultimately identified as the most cost-effective plan presenting the least risk and uncertainty in obtaining the desired degree of shore protection.

Section 501(a) of the Water Resources Development Act of 1986 (Public Law 99-662), which was signed into law on November 17, 1986, authorized construction of the project for shoreline protection at Presque Isle Peninsula, Erie, PA, in accordance with the Report of the Chief of Engineers dated October 2, 1981. The project authorized for construction provides for:

a. Placement of an estimated 560,000 tons of sandfill to provide a beach berm with an average 75-ft width and a crest elevation 10.0 ft above LWD.

b. Construction of 58 offshore rubble-mound breakwater segments aligned parallel to the shoreline and positioned in a trough between the first and second offshore sandbars.

c. An annual nourishment of approximately 38,000 cu yd of sand fill, in order to maintain the protective sand berms at the minimum design 60-ft crest width and a crest elevation 10 ft above LWD.

The total project cost presented in the authorization was $34,800,000, with an estimated first Federal cost of $18,900,000 and an estimated first non-Federal cost of $15,900,000.

7 Summary and Conclusions

Summary

Presque Isle Peninsula provides natural protection to Erie Harbor, and it was for the purpose of preserving the harbor that shore protection works at Presque Isle were originally constructed. The structures built for preservation of Presque Isle Peninsula during the 1800's and early 1900's were mainly of timber construction. These structures had a useful life of only a few years. The 1922 River and Harbor Act reconveyed Presque Isle Peninsula to the State of Pennsylvania for park purposes and its care and protection shifted to preserving a unique natural and environmentally sensitive area which offers a wide variety of recreational and educational opportunities. During the period from 1920 through 1978, rubble-mound and steel sheet-pile construction methods were implemented. These types of construction are more durable and longer lasting. Structures built of these types of construction made up the majority of the protective structures in existence along the peninsula prior to construction of the breakwaters. The locations of these protective structures along Presque Isle Peninsula, the type of construction utilized, the date the structures were built, and who built them are presented in Figure 39.

In 1956, the Federal Government, in cooperation with the Commonwealth of Pennsylvania, completed an erosion control project consisting of a seawall, bulkhead, and groin system along the neck of the peninsula, and restoration of the beaches by placement of sand fill. Since 1956, the project has proved to be inadequate, and sand nourishment measures were required periodically through the 1960's and early 1970's, and annually from 1975 to 1991, to protect the shore protection and erosion control structures and park facilities throughout the peninsula. Sand fill is placed each year to provide sand berms with crest elevations of 10.0 to 12.0 ft above LWD and crest widths of 60 to 75 ft at selected locations as stopgap measures. These sand nourishment measures do not represent a complete solution to the erosion problem because they fail to maintain a continuous sand berm of sufficient width and elevation to provide protection for the backshore dunes and park facilities. The annual sand nourishment costs are escalating, making the continuation of annual nourishment an increasingly expensive means of controlling beach erosion. With the completion of the breakwater project in November 1992, future annual nourishment requirements will be reduced significantly.

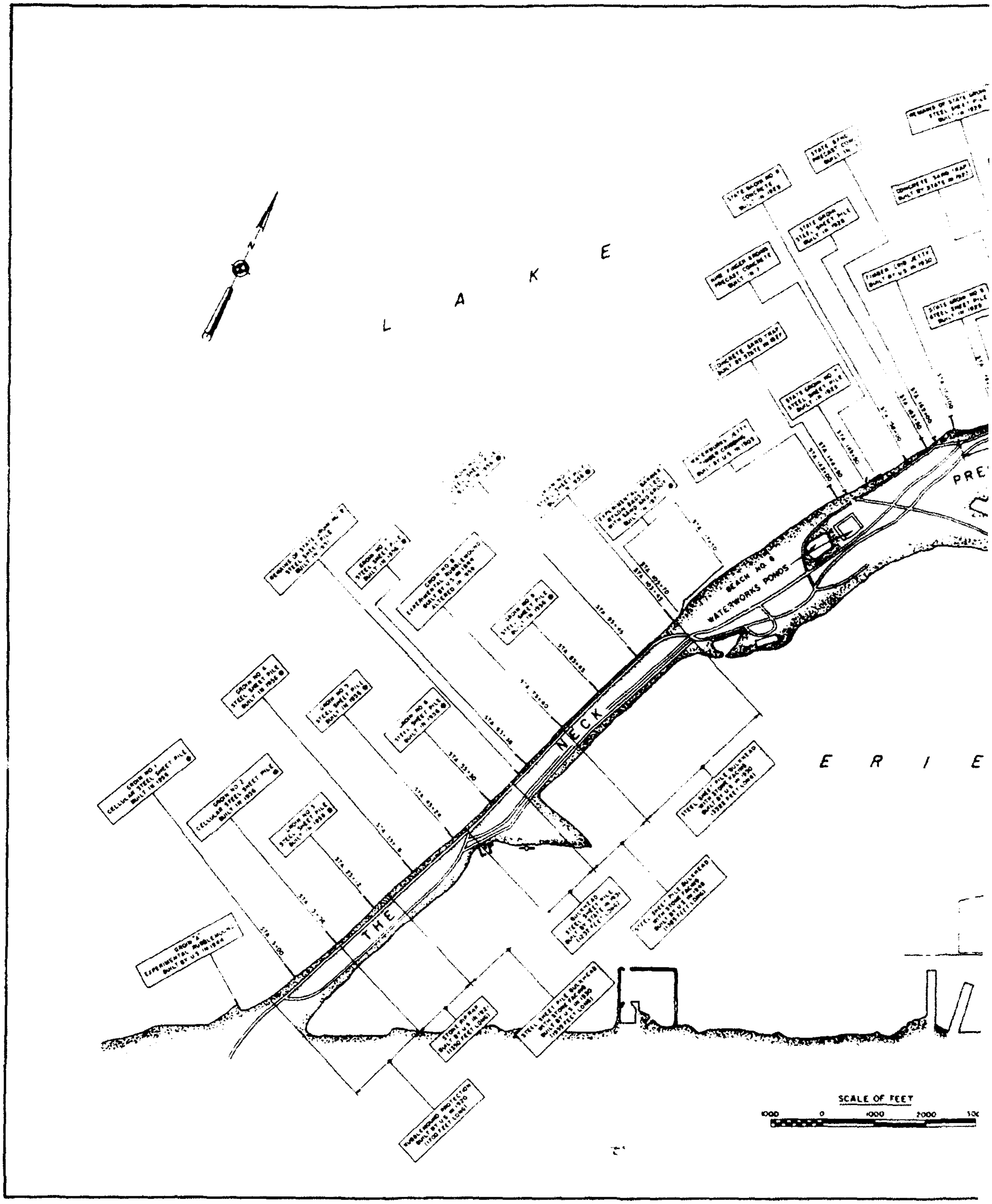
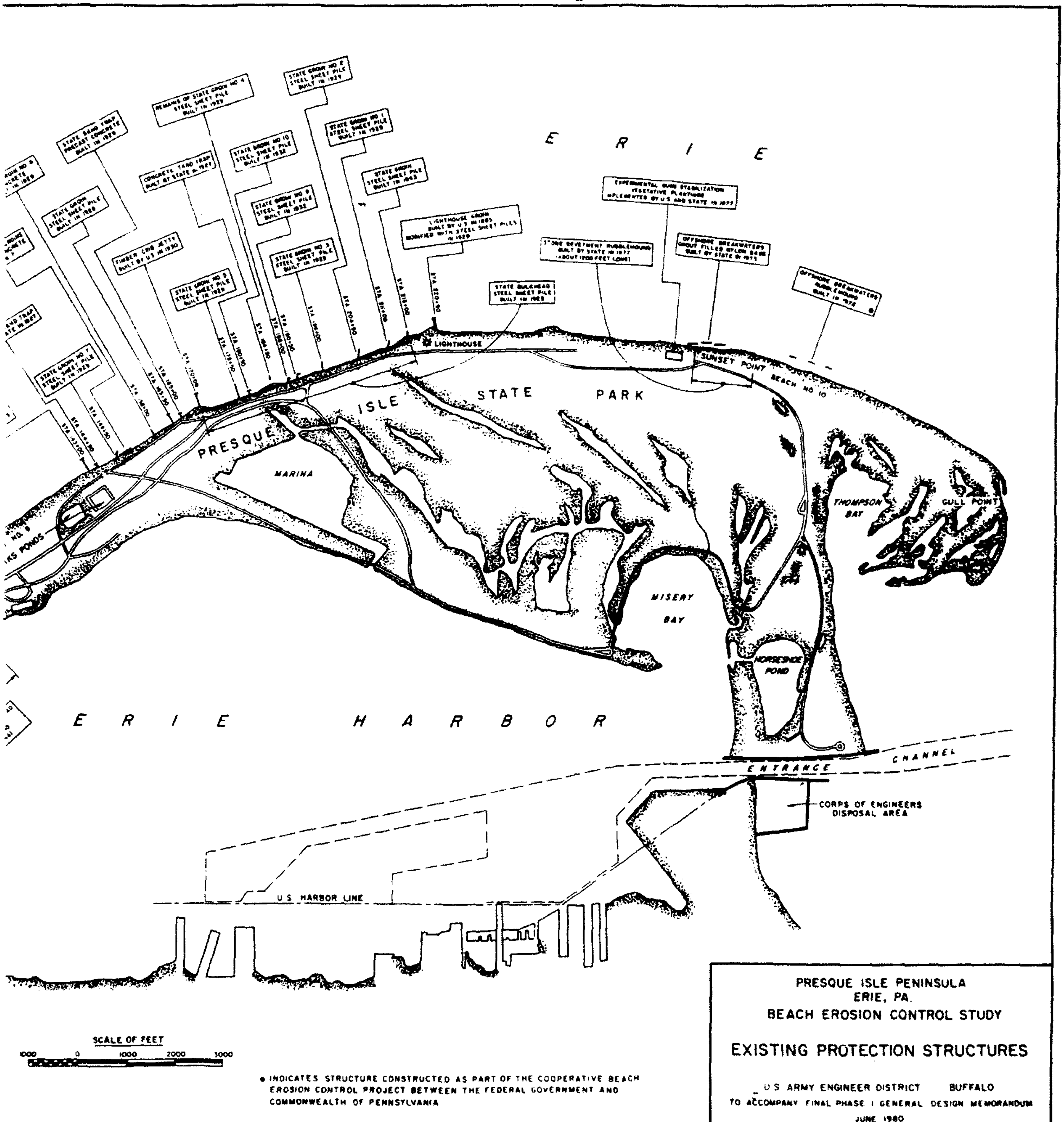


Figure 39. Shore protection structures existing at Presque Isle prior to breakwater construction (USAED, Buffalo 1980)



PRESQUE ISLE PENINSULA
ERIE, PA.
BEACH EROSION CONTROL STUDY

EXISTING PROTECTION STRUCTURES

U S ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY FINAL PHASE I GENERAL DESIGN MEMORANDUM
JUNE 1980

● INDICATES STRUCTURE CONSTRUCTED AS PART OF THE COOPERATIVE BEACH EROSION CONTROL PROJECT BETWEEN THE FEDERAL GOVERNMENT AND COMMONWEALTH OF PENNSYLVANIA

PLATE 5

2

Prototype breakwaters constructed in 1978 have proven to be very effective in attenuating waves and stabilizing the beach. To further analyze the effectiveness of offshore breakwaters at Presque Isle, a model study of the proposed structures for the permanent project was conducted (Seabergh 1983). The basin philosophy for the model study was based on the three prototype detached breakwaters constructed at Beach No. 10 and the reproduction in the model of the documented (from monitoring program) beach evolution shoreward of these breakwaters. An examination of the beach containing the three prototype breakwaters was made with a moveable-bed model (Figure 40) to determine suitable modeling materials and techniques to be used in the model study for the breakwater project (Figure 41).

Model testing indicated that the crown elevation of the breakwater relative to water level was a critical factor in determining whether a salient or tombolo formed. Tombolo formation occurred under the lower wave and water level test conditions. Under severe wave and high water level test conditions, the tombolo was eroded, leaving a salient. Since tombolo development was not desired at Presque Isle, the crest elevation of the breakwaters was reduced from +10.2 ft above LWD as proposed in the Phase I GDM to +8.0 ft above LWD (USAED, Buffalo 1986).

Present Status

The Phase II GDM (USAED, Buffalo 1986) was approved by the North Central Division on July 27, 1988. The report presents the detailed final design of the Presque Isle Shoreline Erosion Control Project. This project is a modification to the existing cooperative beach erosion control project at Presque Isle Peninsula that was authorized by the 1954 River and Harbor Act and constructed in 1955 and 1956. The project generally follows the selected plan proposed in the Phase I GDM (USAED, Buffalo 1980).

The plan of improvement recommended in the Phase II GDM is shown in Figure 42 and consists of constructing structures for wave attenuation and beach restoration along 5-1/2 miles of shoreline on the lakeward side of Presque Isle Peninsula. The recommended plan was designed to protect and maintain the environmentally unique Presque Isle Peninsula and to satisfy the projected recreational beach demand from the surrounding area. The plan of improvement requires the placement of an estimated 560,000 tons of sand fill to provide a protective berm with a minimum 75-ft width and a crest elevation 10.0 ft above LWD; construction of an estimated 58 offshore rubble-mound breakwater segments aligned parallel to the shoreline; and an annual nourishment requirement of approximately 38,000 cu yd of sand fill in order to maintain the protective sand berms at the minimum design 75-ft crest width and a crest elevation 10 ft above LWD. Section 501(a) of the Water Resources

Figure 40. Moveable-bed model of Beach No. 10 (Seabergh 1983)

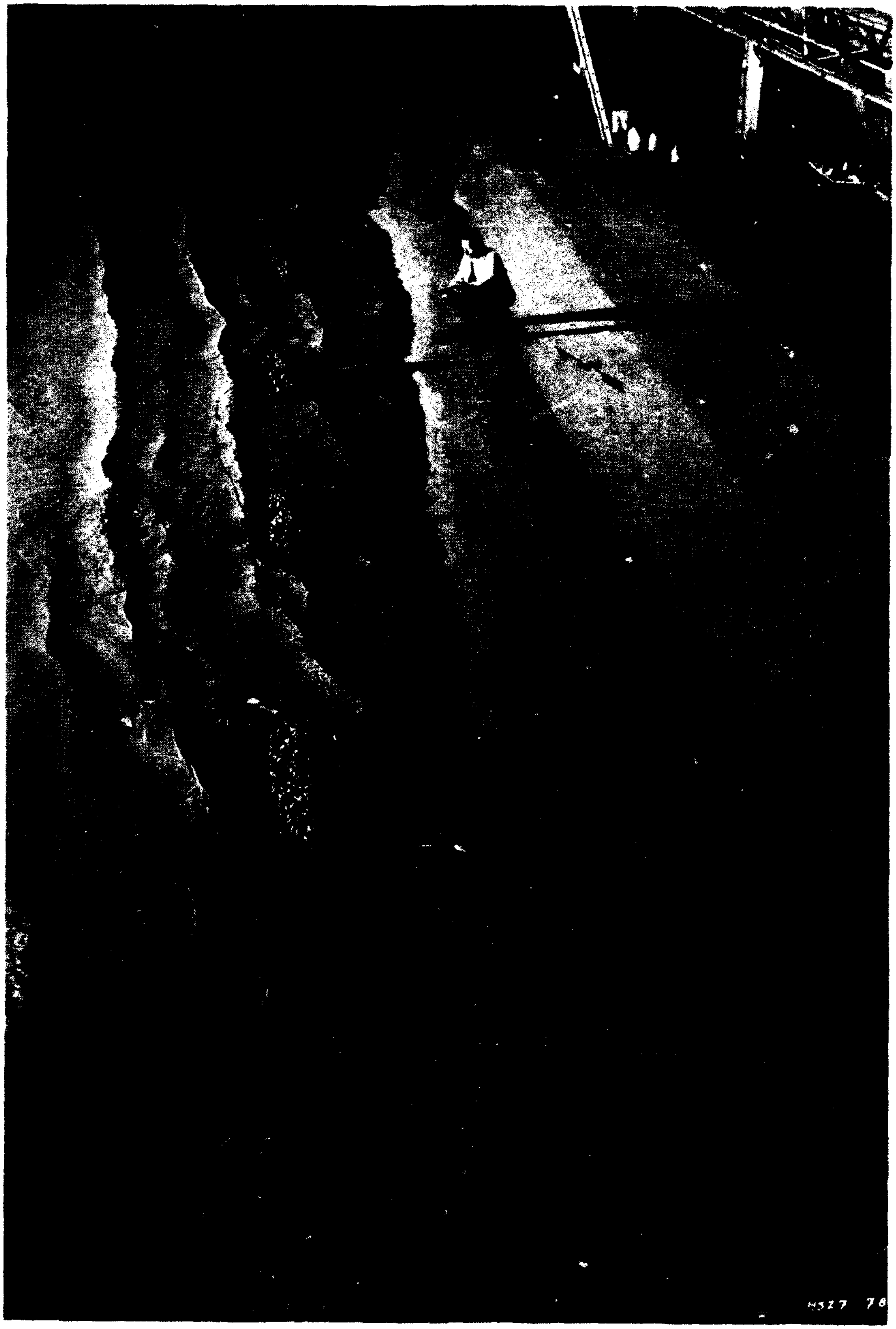


Figure 41. Present authorized plan in physical model (Seabergh 1983)

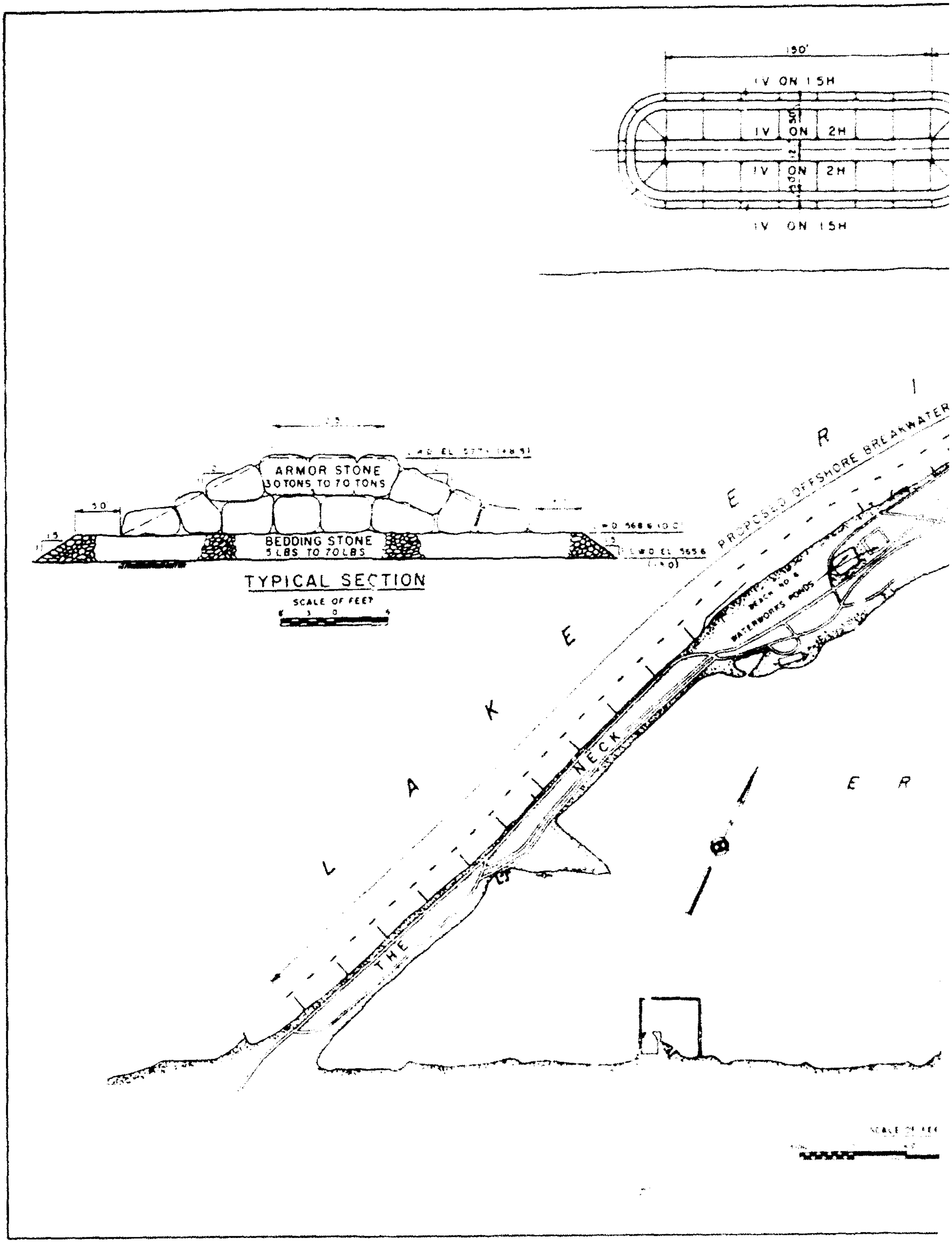
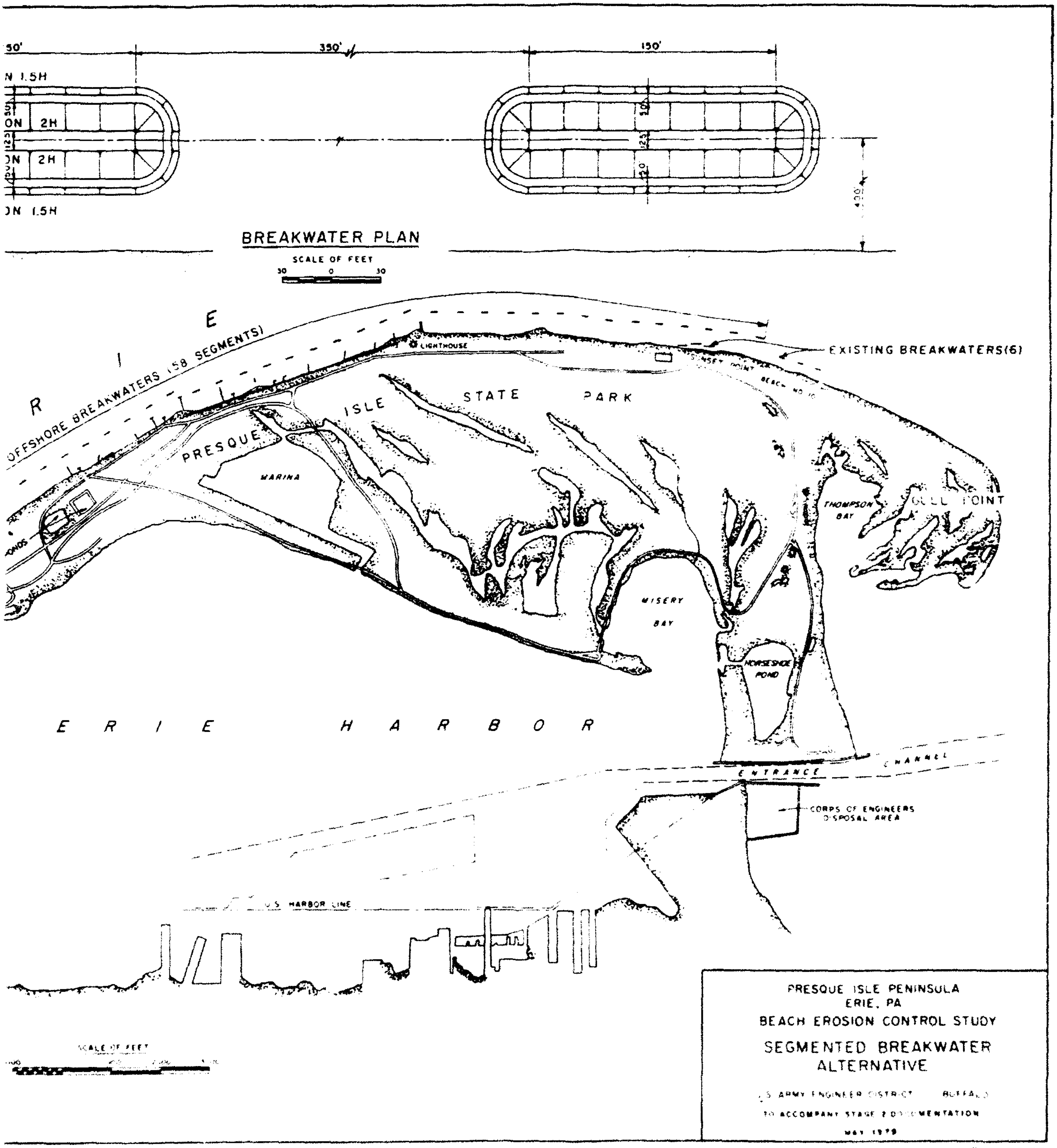


Figure 42. Present authorized plan of erosion control structures at Presque Isle (modified from USAED, Buffalo (1986))



PRESQUE ISLE PENINSULA
ERIE, PA
BEACH EROSION CONTROL STUDY

SEGMENTED BREAKWATER ALTERNATIVE

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STAGE 2 DOCUMENTATION
MAY 1979

PLATE 10

Development Act of 1986 (Public Law 99-662), which was signed into law on November 17, 1986, authorized construction of the project for shoreline protection at Presque Isle Peninsula, Erie, PA, in accordance with the Report of the Chief of Engineers dated October 2, 1981.

Contract plans and specifications for construction of the project for shoreline protection at Presque Isle Peninsula, Erie, PA were prepared in June 1988 and approved on August 3, 1988. Edward Kraemer and Sons, Inc. and Durocher Dock and Dredge, Inc., a joint venture, were awarded the contract based on their low bid of $18,428,700. Construction began in October 1989 and was completed in November 1992. Fifty-five of the fifty-eight authorized breakwaters were constructed initially. Numerical modeling of the shoreline conducted during the construction using the generalized model for shoreline change, GENESIS, augmented the conclusion that the construction of Breakwaters 1, 2, and 3 should be deferred until an unspecified future date (USAED, Buffalo 1992). Historic observations of the beach at this location coupled with the model results, indicated that the shoreline in this area is and will be relatively stable without the breakwaters. The total estimated cost for the project is $133,500,000, of which $27,500,000 is for initial construction and $106,000,000 is the fully inflated cost for 50 years of annual nourishment after initial project construction. The cost for the project will be shared equally (50/50) between the Federal Government and the Commonwealth of Pennsylvania. Figure 43 is a photograph showing the completed breakwater project.

Conclusions

Presque Isle Peninsula is a very dynamic geologic feature that has a long history of engineering designed to retard its migration and erosion. The formation of Presque Isle was dependent upon a sand supply which no longer exists. As Presque Isle migrates, it diminishes in size and threatens the integrity of Erie Harbor. Each engineering activity of the past designed to preserve Presque Isle provided only short-term, local shore protection benefits. The present authorized breakwater project is designed to reduce the net combined Presque Isle beach and Erie Harbor annual costs as an interactive coastal system. The project is intended to preserve the peninsula and its recreational facilities with the least amount of destruction to the environmental and geological growth of the area. The project will also restore the eroded beaches and provide long-term protection to the peninsula and, hence, Erie Harbor.

Figure 43. Completed breakwater project at Presque Isle, PA, Fall 1992

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Appendix A
Volume Change Data at Beach No. 10

Table A1
Volume Changes in Area "A" (Cu Yd)

Date of Survey	Stations										
	102+00	103+00	104+00	105+00	106+00	107+00	108+00	109+00	110+00	111+00	112+00	Total
78 07												
	-1,265	-472	786	130	-274	283	2,222	148	-1,000	563	639	1,760
78 11												
	-1,872	-1,299	-1,749	-67	2,287	1,611	-1,076	818	671	164	1,232	720
79 04												
	-2,444	-3,546	400	176	-1,210	179	1,673	1,169	2,103	640	533	-327
79 11												
	2,387	3,137	212	424	283	-968	-1,454	768	-129	778	690	6,128
80 04												
	1,571	2,236	977	-967	-254	-273	558	-688	405	161	580	4,306
80 09												
	2,152	2,120	285	224	-310	-208	316	-1,256	-1,745	-675	-1,363	-460
81 05												
	788	726	376	-139	-563	-200	-1,293	-1,104	-1,059	-197	-279	-2,944
81 10												
	-3,334	-2,864	-1,099	-1,759	-2,974	-3,864	-2,928	-2,040	-1,353	-2,060	-2,138	-26,413
82 04												
	739	-500	-177	-287	-36	231	-2	-299	-736	-421	-246	-1,734
82 10												
	2,036	1,313	-352	1,414	965	302	58	-1,471	-1,358	-1,890	-1,432	-415
83 05												
	1,240	2,170	1,481	659	1,342	2,849	1,467	2,415	1,438	1,411	1,013	17,485*
83 10												
Total	1,998	3,021	1,140	-192	-744	-58	-459	-1,540	-2,763	-1,526	-771	-1,894

* Includes 32,000 tons of sand beachfill placed in June 1983.

Table A2
Volume Changes in Area "B" (Cu Yd)

Date of Survey	Stations								
	97+00	100+00	103+00	106+00	109+00	112+00	113+00	118+00	Total
78 07									
	-15,500	-11,100	-8,200	-4,700	7,300	-5,100	-5,400	-10,100	-52,800
78 11									
	8,900	-21,000	-5,500	25,100	-14,200	5,600	10,000	-4,300	4,600
79 04									
	-28,900	-14,000	-23,500	-19,900	-6,200	-8,[illegible]00	-6,200	-13,2[illegible]	-120,000
79 11									
	21,000	22,300	5,000	-12,600	2,500	-24,700	-4,000	-9,600	-100
80 04									
	*	8,600	10,800	-5,200	-2,700	13,000	-17,000	4,800	12,100
80 09									
	*	6,000	18,000	-6,400	-24,000	-23,100	-9,600	-34,100	-73,200
81 05									
	-20,000	-10,900	-20,600	-10,300	-11,800	-9,000	-14,200	-16,100	-112,900
81 10									
	34,800	17,100	17,200	8,500	-600	-3,300	-11,600	*	62,100
82 04									
	11,100	19,600	5,600	8,900	3,500	8,300	5,400	1,800	64,200
82 10									
	5,900	5,200	6,200	9,800	500	-20,800	5,200	-19,900	-7,900
83 05									
	5,100	-1,800	7,000	1,300	6,700	3,700	100	*	22,100
83 10									
Total	22,400	20,000	12,000	-5,500	-39,000	-63,500	-47,500	-100,700	-201,800

* Survey data unavailable at this profile line at these dates.

Appendix B
Sediment Sample Distributions at Beach No. 10

Table B1
Beach No. 10 Station 100+00 (Particle Size Distribution in Percent)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 200 ft					
Jul 1978	0.80	32.50	22.70	17.00	27.00
Nov 1978	0.30	78.70	8.70	0.20	12.10
Nov 1979	0.10	95.60	4.30	0.00	0.00
Nov 1980	0.10	17.80	41.20	33.70	7.20
Nov 1981	0.80	60.90	37.90	0.40	0.00
Oct 1982	0.10	68.60	30.70	0.50	0.10
Nov 1983	0.20	66.10	26.60	3.40	3.70
Offset @ 400 ft					
Jul 1978	0.10	98.10	1.40	0.20	0.20
Nov 1978	0.10	2.30	5.30	1.90	90.40
Nov 1979	0.40	89.20	9.90	0.50	0.00
Nov 1980	0.40	75.80	18.70	3.20	1.90
Nov 1981	2.30	91.90	5.50	0.30	0.00
Oct 1982	0.20	98.70	1.00	0.10	0.00
Nov 1983	0.10	98.20	1.50	0.10	0.10
Offset @ 600 ft					
Jul 1978	0.70	99.00	0.30	0.00	0.00
Nov 1978	0.10	98.60	1.00	0.30	0.00
Nov 1979	0.80	96.10	3.00	0.10	0.00
Nov 1980	0.50	98.20	1.30	0.00	0.00
Nov 1981	1.40	98.30	0.30	0.00	0.00
Oct 1982	0.10	98.70	1.10	0.10	0.00
Nov 1983	0.10	83.80	15.50	0.40	0.20
Offset @ 800 ft					
Jul 1978	1.90	97.60	0.40	0.10	0.00
Nov 1978	4.90	91.50	3.40	0.20	0.00
Nov 1979	14.90	83.50	1.20	0.40	0.00
Nov 1980	3.60	95.90	0.50	0.00	0.00
Nov 1981	3.00	96.30	0.70	0.00	0.00
Oct 1982	0.30	99.40	0.20	0.10	0.00
Nov 1983	0.30	98.00	1.60	0.10	0.00

Table B2
Beach No. 10 Station 103+00 (Particle Size Distribution in Percent)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 200 ft					
Jul 1978	12.90	21.90	39.60	14.20	11.40
Nov 1978	11.50	17.80	44.30	18.30	8.10
Nov 1979	11.60	23.00	42.80	17.70	4.90
Nov 1980	4.70	37.50	44.90	8.80	4.10
Nov 1981	1.50	29.30	67.50	1.70	0.00
Oct 1982	10.90	27.10	41.10	15.10	5.70
Nov 1983	0.40	61.00	37.40	1.10	0.10
Offset @ 300 ft					
July 1978	5.30	21.60	50.10	19.20	3.80
Nov 1978	3.10	30.90	53.50	10.60	1.90
Nov 1979	0.60	0.60	58.30	33.10	7.40
Nov 1980	[illegible]	16.00	82.70	1.20	0.00
Nov 1981	0.60	62.80	35.60	1.00	0.00
Oct 1982	1.50	92.80	5.60	0.10	0.00
Nov 1983	0.10	82.40	17.00	0.40	0.00
Offset @ 400 ft					
Jul 1978	1.80	55.10	12.80	0.80	29.50
Nov 1978	0.80	88.70	8.20	1.90	0.40
Nov 1979	0.80	96.60	2.10	0.50	0.00
Nov 1980	0.10	76.00	18.20	4.10	1.60
Nov 1981	0.40	9.30	76.50	13.80	0.00
Oct 1982	0.50	76.90	7.60	6.10	8.90
Nov 1983	0.10	69.30	10.40	10.30	8.40
Offset @ 600 ft					
Jul 1978	0.30	99.50	0.20	0.00	0.00
Nov 1978	0.70	98.60	0.60	0.10	0.00
Nov 1979	0.20	61.00	21.60	3.20	14.00
Nov 1980	0.20	99.40	0.40	0.00	0.00
Nov 1981	0.30	99.10	0.60	0.00	0.00
Oct 1982	0.20	98.70	1.00	0.10	0.00
Nov 1983	0.10	99.10	0.70	0.10	0.00

(Continued)

Table B2 (Concluded)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 800 ft					
Jul 1978	1.60	97.60	0.70	0.10	0.00
Nov 1978	2.60	96.80	0.60	0.00	0.00
Nov 1979	0.20	88.20	11.40	0.20	0.00
Nov 1980	1.90	96.10	1.80	0.20	0.00
Nov 1981	1.50	97.30	0.90	0.30	0.00
Oct 1982	0.70	98.30	0.90	0.10	0.00
Nov 1983	0.80	98.20	0.90	0.10	0.00

Table B3
Beach No. 10 Station 105+00 (Particle Size Distribution in Percent)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 300 ft					
Jul 1978	14.60	19.60	45.10	16.10	4.60
Nov 1978	9.30	20.30	43.20	17.30	9.90
Nov 1979	7.60	25.70	42.40	12.70	11.60
Nov 1980	7.10	33.10	36.40	15.30	8.10
Nov 1981	8.80	26.80	39.20	15.20	10.00
Oct 1982	0.70	69.20	26.70	2.30	1.10
Nov 1983	7.10	18.60	47.70	13.90	12.40
Offset @ 400 ft					
Jul 1978	1.80	20.00	61.60	11.30	5.30
Nov 1978	1.50	72.50	12.30	6.10	7.60
Nov 1979	0.10	68.40	19.10	0.30	12.10
Nov 1980	0.40	74.10	20.30	3.90	1.30
Nov 1981	0.40	0.40	64.00	32.30	2.90
Oct 1982	0.10	94.80	3.60	1.00	0.50
Nov 1983	0.10	94.00	4.30	1.20	0.40
Offset @ 500 ft					
Jul 1978	0.30	95.40	3.50	0.50	0.30
Nov 1978	3.60	43.00	41.60	8.90	2.90
Nov 1979	0.30	96.50	2.90	0.30	0.00
Nov 1980	0.10	82.90	13.20	2.90	0.90
Nov 1981	2.00	95.80	2.10	0.10	0.00
Oct 1982	*	*	*	*	*
Nov 1983	0.20	82.10	7.80	8.70	1.20
Offset @ 600 ft					
Jul 1978	0.80	97.90	1.20	0.10	0.00
Nov 1978	0.20	98.90	0.70	0.20	0.00
Nov 1979	0.20	94.70	3.50	0.90	0.70
Nov 1980	0.60	86.00	13.10	0.30	0.00
Nov 1981	2.70	89.00	5.90	2.40	0.00
Oct 1982	0.30	10.10	43.00	30.70	15.90
Nov 1983	0.00	99.20	0.70	0.10	0.00

(Continued)

* No sample collected.

Table B3 (Concluded)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 800 ft					
Jul 1978	15.90	81.60	2.10	0.40	0.00
Nov 1978	0.10	0.60	77.50	16.80	5.00
Nov 1979	1.90	96.10	1.90	0.10	0.00
Nov 1980	1.10	98.60	0.30	0.00	0.00
Nov 1981	2.20	96.00	1.80	0.00	0.00
Oct 1982	2.10	97.30	0.50	0.10	0.00
Nov 1983	0.90	97.70	1.10	0.10	0.00
Offset @ 1,000 ft					
Jul 1978	1.20	10.50	59.80	18.20	10.30
Nov 1978	1.40	90.90	7.70	0.00	0.00
Nov 1979	2.60	96.00	1.40	0.00	0.00
Nov 1980	32.00	67.40	0.60	0.00	0.00
Nov 1981	15.90	83.20	0.90	0.00	0.00
Oct 1982	1.70	97.90	0.30	0.00	0.00
Nov 1983	1.00	98.60	0.20	0.10	0.00
Offset @ 1,200 ft					
Jul 1978	0.30	96.00	3.40	0.30	0.00
Nov 1978	2.60	97.10	0.30	0.00	0.00
Nov 1979	0.60	6.80	60.90	27.90	3.80
Nov 1980	0.50	25.00	64.40	8.40	1.70
Nov 1981	4.60	92.80	2.20	0.40	0.00
Oct 1982	3.80	95.80	0.30	0.00	0.00
Nov 1983	3.00	95.50	1.40	0.10	0.00

Table B4
Beach No. 10 Station 107+00 (Particle Size Distribution in Percent)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 300 ft					
Jul 1978	14.30	18.00	41.00	19.20	7.50
Nov 1978	11.80	15.90	41.40	19.30	11.60
Nov 1979	9.90	20.30	44.30	17.70	7.80
Nov 1980	5.60	43.00	32.60	11.20	7.60
Nov 1981	4.90	45.30	32.10	11.00	6.70
Oct 1982	4.30	67.70	20.70	3.90	4.00
Nov 1983	9.00	19.80	41.90	15.70	12.70
Offset @ 400 ft					
Jul 1978	0.90	25.70	55.50	15.80	2.10
Nov 1978	0.10	98.90	0.90	0.10	0.00
Nov 1979	0.10	96.00	3.90	0.00	0.00
Nov 1980	0.00	5.70	1.20	0.30	54.40
Nov 1981	0.50	31.60	65.00	2.90	0.00
Oct 1982	0.10	98.50	1.30	0.00	0.10
Nov 1983	0.10	36.00	59.20	3.90	0.70
Offset @ 500 ft					
Jul 1978	22.70	70.00	6.60	0.70	0.00
Nov 1978	1.10	73.30	21.00	3.10	1.50
Nov 1979	1.20	10.60	53.40	23.90	10.90
Nov 1980	0.10	95.20	2.70	1.40	0.60
Nov 1981	1.90	89.10	7.20	1.80	0.00
Oct 1982	0.40	97.40	1.60	0.50	0.10
Nov 1983	0.10	95.80	3.70	0.20	0.20
Offset @ 600 ft					
Jul 1978	0.50	94.30	4.10	0.90	0.20
Nov 1978	0.30	98.00	1.50	0.20	0.00
Nov 1979	0.10	65.60	24.00	7.00	3.30
Nov 1980	0.30	95.10	4.30	0.30	0.00
Nov 1981	*	*	*	*	*
Oct 1982	*	*	*	*	*
Nov 1983	*	*	*	*	*

(Continued)

* No sample collected.

Table B4 (Concluded)					
Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 800 ft					
Jul 1978	1.70	37.00	56.90	4.40	0.00
Nov 1978	0.50	97.90	1.60	0.00	0.00
Nov 1979	0.10	76.90	21.70	1.30	0.00
Nov 1980	0.80	97.90	1.20	0.10	0.00
Nov 1981	2.70	95.80	1.50	0.00	0.00
Oct 1982	0.80	97.00	2.10	0.00	0.10
Nov 1983	0.30	99.40	0.20	0.10	0.00

Table B5
Beach No. 10 Station 109+00 (Particle Size Distribution in Percent)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 300 ft					
Jul 1978	7.20	21.50	44.50	19.10	7.70
Nov 1978	12.40	17.70	42.00	18.20	9.70
Nov 1979	0.70	75.80	14.80	5.10	3.60
Nov 1980	0.30	97.80	1.90	0.00	0.00
Nov 1981	13.40	27.10	32.30	16.00	11.20
Oct 1982	2.30	74.60	17.50	3.20	2.20
Nov 1983	2.80	71.10	17.40	5.60	3.00
Offset @ 400 ft					
Jul 1978	6.90	28.40	44.70	16.40	3.60
Nov 1978	6.00	18.20	49.20	19.40	7.20
Nov 1979	3.40	19.60	51.40	21.40	4.20
Nov 1980	7.80	24.00	41.00	18.40	8.80
Nov 1981	0.40	68.40	17.20	3.10	10.90
Oct 1982	0.20	75.40	24.10	0.20	0.10
Nov 1983	0.00	35.20	44.10	8.80	11.90
Offset @ 500 ft					
Jul 1978	0.30	55.00	41.40	2.30	1.00
Nov 1978	0.30	98.60	1.10	0.00	0.00
Nov 1979	0.20	65.00	8.40	5.90	20.50
Nov 1980	0.20	76.60	8.80	0.40	14.00
Nov 1981	0.30	82.20	13.00	4.50	0.00
Oct 1982	0.30	95.50	3.80	0.30	0.10
Nov 1983	0.20	98.80	0.90	0.10	0.00
Offset @ 600 ft					
Jul 1978	0.60	61.50	27.60	2.40	7.90
Nov 1978	0.40	91.80	7.80	0.00	0.00
Nov 1979	0.10	51.40	25.80	12.10	10.60
Nov 1980	0.00	77.50	20.40	1.60	0.20
Nov 1981	0.40	94.30	4.60	0.70	0.00
Oct 1982	0.30	99.10	0.50	0.10	0.00
Nov 1983	0.10	98.30	1.50	0.10	0.00

(Continued)

Table B5 (Concluded)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 800 ft					
Jul 1978	0.50	4.70	48.90	18.00	27.90
Nov 1978	0.10	16.30	35.30	18.10	30.20
Nov 1979	0.60	83.40	13.90	1.20	0.90
Nov 1980	0.20	99.40	0.40	0.00	0.00
Nov 1981	1.60	98.00	0.40	0.00	0.00
Oct 1982	0.40	97.90	1.60	0.10	0.00
Nov 1983	0.10	98.80	1.00	0.10	0.00
Offset @ 1,000 ft					
Jul 1978	0.70	50.00	42.10	4.50	2.70
Nov 1978	1.00	35.20	48.20	8.10	7.50
Nov 1979	0.10	10.50	85.70	3.40	0.30
Nov 1980	0.40	7.80	74.40	10.60	6.80
Nov 1981	3.10	94.30	2.00	0.60	0.00
Oct 1982	3.90	95.00	0.80	0.30	0.00
Nov 1983	2.10	97.40	0.40	0.10	0.00
Offset @ 1,200 ft					
Jul 1978	1.30	98.20	0.50	0.00	0.00
Nov 1978	2.10	44.90	47.90	3.90	1.20
Nov 1979	0.10	4.10	43.00	24.30	28.50
Nov 1980	0.10	13.10	52.20	16.40	18.20
Nov 1981	0.60	14.50	81.10	2.80	1.00
Oct 1982	8.80	90.80	0.30	0.00	0.10
Nov 1983	3.30	96.10	0.50	0.10	0.00

Table B6
Beach No. 10 Station 111+00 (Particle Size Distribution in Percent)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 300 ft					
Jul 1978	0.50	97.40	2.10	0.00	0.00
Nov 1978	0.10	98.80	1.10	0.00	0.00
Nov 1979	0.10	97.20	2.70	0.00	0.00
Nov 1980	0.30	70.90	28.80	0.00	0.00
Nov 1981	0.40	91.90	7.00	0.70	0.00
Oct 1982	0.70	93.60	5.60	0.00	0.10
Nov 1983	0.20	96.60	3.10	0.00	0.10
Offset @ 400 ft					
Jul 1978	4.20	24.60	48.90	16.90	5.40
Nov 1978	6.00	20.60	48.30	19.00	6.10
Nov 1979	0.10	28.50	57.20	13.30	0.90
Nov 1980	0.20	80.40	6.90	0.00	12.50
Nov 1981	0.40	83.40	15.00	1.20	0.00
Oct 1982	2.70	23.30	49.90	13.60	8.90
Nov 1983	0.30	34.60	44.50	13.40	7.20
Offset @ 500 ft					
Jul 1978	2.30	96.40	1.20	0.10	0.00
Nov 1978	0.10	84.60	10.60	2.90	1.80
Nov 1979	0.10	57.10	26.90	8.80	7.10
Nov 1980	0.50	63.50	33.50	2.00	0.50
Nov 1981	0.00	3.40	0.10	0.90	89.50
Oct 1982	0.30	96.00	3.00	0.50	0.20
Nov 1983	0.00	83.80	8.20	4.40	3.50
Offset @ 600 ft					
Jul 1978	0.60	93.20	5.00	0.90	0.30
Nov 1978	1.40	89.30	8.40	0.90	0.00
Nov 1979	0.20	97.90	1.60	0.30	0.00
Nov 1980	*	*	*	*	*
Nov 1981	0.50	97.60	1.50	0.40	0.00
Oct 1982	0.30	95.20	4.20	0.20	0.10
Nov 1983	*	*	*	*	*

(Continued)

* No sample collected.

Table B6 (Concluded)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 700 ft					
Jul 1978	0.40	57.90	28.20	10.60	2.90
Nov 1978	2.30	96.90	0.80	0.00	0.00
Nov 1979	0.30	81.20	16.60	1.50	0.40
Nov 1980	0.40	37.00	43.60	13.90	5.10
Nov 1981	1.50	12.00	79.60	6.90	0.00
Oct 1982	1.50	62.10	23.60	7.70	5.10
Nov 1983	*	*	*	*	*
Offset @ 800 ft					
Jul 1978	0.30	10.10	64.20	21.20	4.20
Nov 1978	0.60	22.30	61.90	14.50	0.70
Nov 1979	0.10	97.10	2.80	0.00	0.00
Nov 1980	0.70	63.50	31.90	2.80	0.10
Nov 1981	1.40	97.70	0.90	0.00	0.00
Oct 1982	0.30	98.20	1.40	0.10	0.00
Nov 1983	0.40	96.50	3.00	0.00	0.10
Offset @ 1,000 ft					
Jul 1978	1.50	74.00	21.50	2.40	0.60
Nov 1978	0.40	96.50	3.10	0.00	0.00
Nov 1979	0.60	97.90	1.50	0.00	0.00
Nov 1980	19.70	21.00	52.70	6.00	0.60
Nov 1981	5.20	94.50	0.30	0.00	0.00
Oct 1982	2.40	96.60	0.70	0.30	0.00
Nov 1983	2.00	97.10	0.80	0.00	0.10

Table B7
Beach No. 10 Station 112+00 (Particle Size Distribution in Percent)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 500 ft					
Jul 1978	2.10	96.50	1.30	0.10	0.00
Nov 1978	0.50	19.50	44.20	29.60	6.20
Nov 1979	0.10	81.70	14.00	2.30	1.90
Nov 1980	0.30	95.70	3.90	0.10	0.00
Nov 1981	0.40	90.40	3.20	6.00	0.00
Oct 1982	0.30	98.70	0.90	0.00	0.10
Nov 1983	0.00	89.20	9.90	0.70	0.20
Offset @ 700 ft					
Jul 1978	0.30	71.90	18.40	3.80	5.60
Nov 1978	0.40	83.40	11.80	2.20	2.20
Nov 1979	0.10	97.60	1.80	0.30	0.20
Nov 1980	0.30	98.60	1.10	0.00	0.00
Nov 1981	0.80	98.90	0.30	0.00	0.00
Oct 1982	0.10	98.80	1.00	0.10	0.00
Nov 1983	0.10	97.40	2.40	0.10	0.00

Table B8
Beach No. 10 Station 115+00 (Particle Size Distribution in Percent)

Date Sampled	Silt & Clay	Fine Sand	Med. Sand	Coarse Sand	Gravel
Offset @ 400 ft					
Jul 1978	0.70	97.10	2.10	0.10	0.00
Nov 1978	0.20	31.90	56.20	8.90	2.80
Nov 1979	0.10	96.30	3.60	0.00	0.00
Nov 1980	0.00	15.50	10.50	8.80	65.20
Nov 1981	0.20	94.00	2.90	2.90	0.00
Oct 1982	0.20	99.30	0.40	0.10	0.00
Nov 1983	0.10	87.90	4.60	3.90	3.50
Offset @ 500 ft					
Jul 1978	0.30	29.50	3.60	2.20	64.40
Nov 1978	1.30	92.20	5.70	0.80	0.00
Nov 1979	0.60	96.90	2.50	0.00	0.00
Nov 1980	0.30	76.10	15.10	4.80	3.70
Nov 1981	0.10	96.90	2.50	0.50	0.00
Oct 1982	0.10	23.10	1.50	0.10	75.20
Nov 1983	0.00	99.80	0.10	0.00	0.10
Offset @ 700 ft					
Jul 1978	0.50	95.20	4.10	0.20	0.00
Nov 1978	1.80	96.10	1.90	0.20	0.00
Nov 1979	0.70	98.60	0.70	0.00	0.00
Nov 1980	0.30	91.20	6.80	1.40	0.30
Nov 1981	0.20	96.40	2.70	0.70	0.00
Oct 1982	0.10	98.70	0.90	0.30	0.00
Nov 1983	0.40	99.40	0.10	0.10	0.00
Offset @ 1,000 ft					
Jul 1978	0.10	95.90	3.90	0.10	0.00
Nov 1978	1.50	94.70	3.70	0.10	0.00
Nov 1979	0.10	1.90	65.10	20.00	12.90
Nov 1980	1.00	31.60	52.80	10.60	4.00
Nov 1981	1.60	94.40	3.90	0.10	0.00
Oct 1982	21.20	76.20	2.50	0.00	0.10
Nov 1983	0.50	99.10	0.30	0.10	0.00

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13. ABSTRACT *(Maximum 200 words)*

Presque Isle is a unique and significant coastal feature on the south shore of Lake Erie at Erie, Pennsylvania. It is a compound, recurved sandspit that arches lakeward about two and one-half miles from an otherwise straight shore. The peninsula has a lake shoreline of about six and one-quarter miles from its narrow connection with the mainland to its distal end where it turns sharply shoreward. It is the only major positive depositional feature along the generally sand-starved south shore of Lake Erie. Presque Isle Peninsula is an old-age geomorphic feature which is migrating eastward into deeper water, thereby resulting in a net annual loss to the sand body. The processes responsible for the geological evolution of this feature will also be responsible for its eventual destruction unless attempts are undertaken to slow its migration. The history of coastal engineering measures for shore protection on the peninsula has been extensive and dates back to the early 1800's. The peninsula is truly a rare ecological laboratory that allows the process of primary plant and animal succession to be studied in habitat diversity ranging from pioneer vegetation on newly formed shore zones to climax woodland communities on old beach ridges, all within a distance of about three miles. The peninsula is developed as a state park and is a popular recreational area.

(Continued)

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In the interest of brevity, many of the complex geologic, environmental, engineering, and socioeconomic issues could not be presented herein. The purpose of this paper is purely academic and is designed to enlighten the reader by providing an understanding of the geologic evolution of Presque Isle Peninsula and the history of man's attempts at stabilization.