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U.S. ARMY CORPS OF ENGINEERS

NORTH CENTRAL DIVISION

GENERAL INFORMATION PAMPHLET

GREAT LAKES SHORELINE DAMAGE

CAUSES AND PROTECTIVE MEASURES

MAY 1972

Army Corps of Engineers

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ACKNOWLEDGEMENTS

The Division Engineer of the North Central Division, Corps of Engineers wishes to acknowledge the assistance of the Chicago District offices in the preparation of this pamphlet. Further, the comments provided by Detroit and St. Paul District offices, the Coastal Engineering Research Center and Lake Survey Center, NOAA, Department of Commerce are greatly appreciated.

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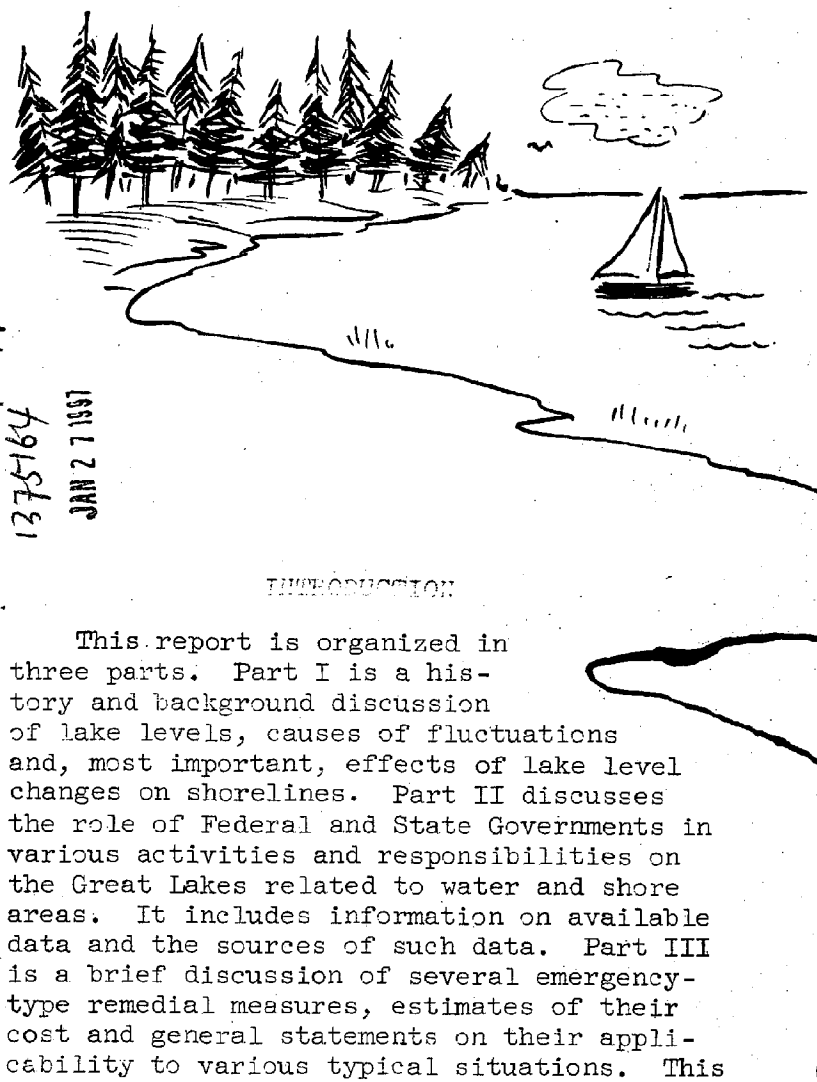

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FOREWORD

The problem of adequate control of erosion on the shores of the Great Lakes has seriously concerned engineers and riparian owners since the early 1800's. The existence of the present above-average levels on the Great Lakes emphasizes the effects of the fluctuating lake levels upon shore properties and other uses of these waters. This pamphlet has been prepared to provide interested parties information which will be useful in the consideration of remedial measures for problems resulting from erosion and/or inundation of the shoreline. Primarily, it is a compilation of data and facts related to Great Lakes water levels and to shore erosion and inundation problems along the Great Lakes shores.

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INTRODUCTION

This report is organized in three parts. Part I is a history and background discussion of lake levels, causes of fluctuations and, most important, effects of lake level changes on shorelines. Part II discusses the role of Federal and State Governments in various activities and responsibilities on the Great Lakes related to water and shore areas. It includes information on available data and the sources of such data. Part III is a brief discussion of several emergency-type remedial measures, estimates of their cost and general statements on their applicability to various typical situations. This section is not intended to be used for design of permanent protective works without the advice and guidance of qualified engineering consultants.

U.S. DEPARTMENT OF COMMERCE NOAA
COASTAL SERVICES CENTER
2234 SOUTH HOBSON AVENUE
CHARLESTON, SC 29405-2413

PART I

LAKE LEVELS

Changes in Great Lakes levels have long been of concern in the affairs of those living along the lakes or dependent upon lake transportation. Records of lake levels have been kept by the U. S. Lake Survey, Corps of Engineers since 1860. This agency is now an office of the Department of Commerce, NOAA.

Levels of the Great Lakes fluctuate from year to year and also from month to month during each year depending upon the volume of water in the lakes. In addition, there are daily and even hourly fluctuations of levels resulting from unbalance or tilting of the lake surfaces caused by winds and barometric pressure differences. The source of Great Lakes water is the rain and snow which fall on the lakes themselves and on the land areas which drain to them.

Seasonal fluctuations, caused by the annual weather pattern, are superimposed upon the long-term variations resulting from extended periods of below or above normal precipitation. Unusual variations in the amount of water evaporated from the lakes can also significantly alter the net amount remaining in the lakes and thus the lake levels. Because of the size of the Great Lakes and the limited discharge capacities of their outflow rivers, extreme high or low levels and flows persist for considerable time after the factors which caused them have changed.

Where the outflows from the lakes are artificially controlled by regulatory works, as is the case with Lakes Superior and Ontario, the releases of water are made in accordance with the plan for the regulation of the lake's levels and outflows which maintains the lake within a range of water levels acceptable to all interests concerned. All regulation plans are approved by the Governments of the United States and Canada.

Several years ago the Great Lakes were in a period of low levels. In fact, Lakes Michigan and Huron levels were at an all-time record low level, starting in February 1964 and ending in January 1965. This was the result of unusually low precipitation during the period 1962-1964, which amounted to about 11.5 inches less than normal for the Lake Michigan basin and 7.2 inches less than normal for the Lake Huron basin. During this period, property owners on Lakes Michigan and Huron and to a lesser extent on the other lakes, became accustomed to these lower levels. Since this period of low levels, above-average amounts of precipitation have occurred in the Great Lakes basin. Lakes Michigan and Huron have risen again, returning to their average level in early 1969. The other lakes are above their long-term average levels. The bulletin of lake levels attached as inclosure 1 provides the recorded levels for the previous year and current year to date for each of the lakes, including Lake St. Clair. General information on Great Lakes levels is shown in the following table 1.

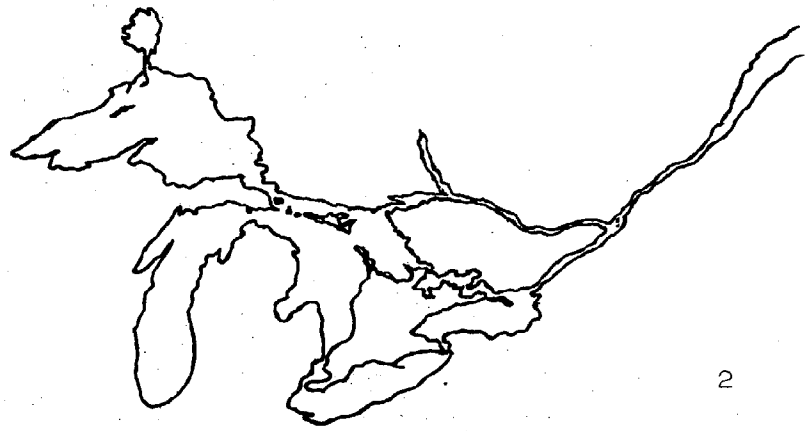


TABLE 1

GENERAL GREAT LAKES INFORMATION

DESCRIPTION	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ST. CLAIR	LAKE ERIE	LAKE ONTARIO
Outlet river or channel	St. Marys River	Str. of Mackinac	St. Clair River	Detroit River	Niagara River	St. Lawrence River
Length in miles	70	-	27	32	37	502
Average flow in CFS (1860-1971)	75,100	52,000	188,000	189,000	202,000	239,000
Monthly Elevations in feet[3] IGLD(1955)		[1]	[1]	[2]		
Average (1860-1971)	600.39	578.69	578.69	573.06	570.39	244.77
Maximum	602.06	581.94	581.94	575.70	572.76	248.06
Minimum	598.23	575.35	575.35	569.86	567.49	241.45
Average - winter low to summer high	1.1	1.1	1.1	1.6	1.5	1.8
Maximum - winter low to summer high	1.9	2.2	2.2	3.3	2.7	3.5
Minimum - winter low to summer high	0.4	0.1	0.1	0.9	0.5	0.7
Annual precipitation in inches (1900-1971)						
Average on basin (land & water)	30	31	31	-	34	34
Average on lake surface	30	30	31	-	33	33

1. The Straits of Mackinac between Lakes Michigan and Huron are so wide and deep that the difference in the monthly mean levels of these two lakes is not measureable.

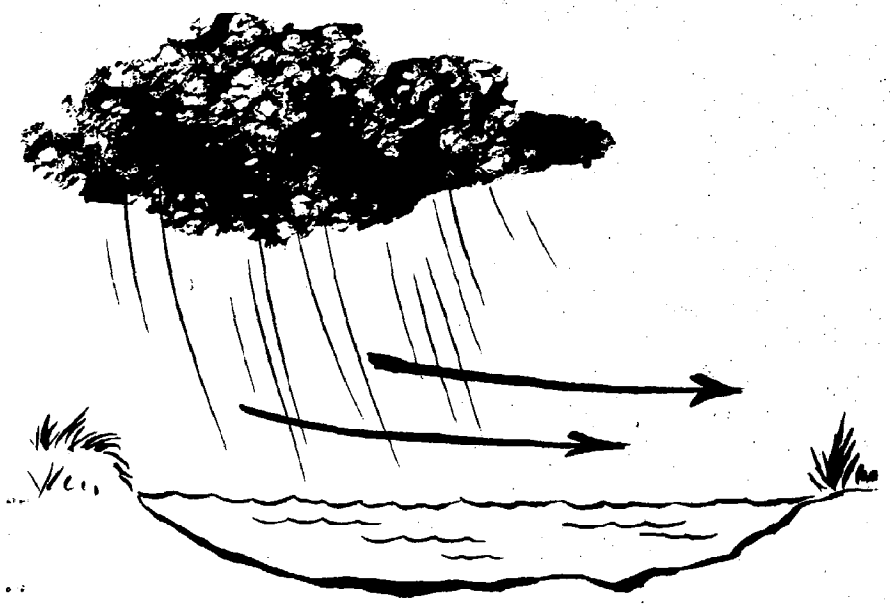
2. Lake St. Clair elevations are available only for the period 1898 to date.

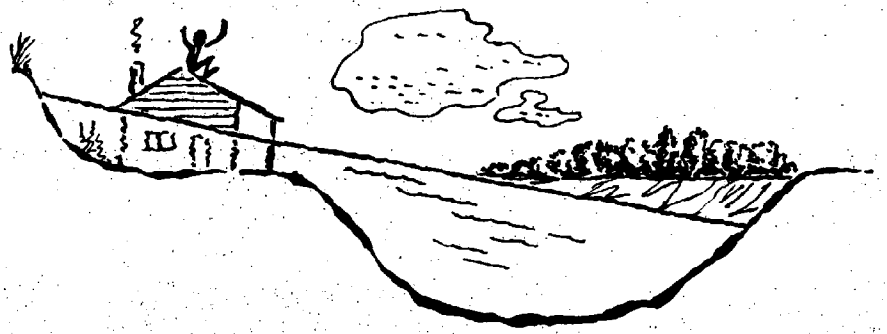
3. Lake elevations are as recorded at Marquette (L. Superior), Harbor Beach (L. Michigan-Huron), Grosse Pointe Shores (L. St. Clair), Cleveland (L. Erie) and Oswego (L. Ontario). Recorded elevations are affected by man-made changes such as: regulation of outflows from Lake Superior (1921) and Lake Ontario (1960); diversions of water from Hudson Bay basin into Lake Superior (1939) and from Lake Michigan basin into Mississippi basin at Chicago (before 1860); and regimen changes in the natural outlet channels from the lakes throughout the period of record.

TEMPORARY RISES IN LAKE LEVELS

Winds, particularly of storm velocity, and sharp gradients in barometric pressures over short distances have pronounced effects on lake levels and can cause a wide range of fluctuations. These short period fluctuations are superimposed on the prevailing levels and may cause unusually high levels during periods of above average levels.

High storm levels at one end of a lake are accompanied by lower levels at the opposite end. Pronounced fluctuations from these causes are experienced also in bays and other shallow portions of each lake such as in Green Bay on Lake Michigan, and in Saginaw Bay on Lake Huron and both ends of Lake Erie.





In terms of monthly average values, water levels in the various shoreline localities are substantially the same as for all other areas around the shores of each of the Lakes. However, the water level at a particular locality or any other shore area on a lake may be, and frequently is, temporarily higher or lower than the monthly average value, due to the effects of storms over the lake. The height of the temporary rises above the monthly average level varies for the different shore areas depending on a number of factors. For a severe storm, the temporary rise at a particular locality may be in the order of two or three feet above the monthly average lake level for the larger, deeper lakes such as Lake Superior. For shallow Lake Erie, temporary changes of greater extremes of 8 feet or more have been experienced. Table 2 shows short period fluctuations in lake levels at selected gage sites. Storms over the lake causing such temporary rises also generate high waves which beat against and erode the materials forming the shoreline, particularly where the shore is composed of sand, clay or other erodable materials.

TABLE 2

SHORT-PERIOD FLUCTUATIONS IN LAKE LEVELS

AT SELECTED GAGE SITES

Lake and Gage Location	Period of Gage Record	MAXIMUM RECORDED Rise In Feet	Rise for One-Year Recurrence Interval In Feet
SUPERIOR at Marquette	1903-1970	2.8	1.3
MICHIGAN at Calumet Harbor (Chicago)	1903-1970	3.5	1.8
HURON at Harbor Beach	1902-1970	2.5	0.9
ERIE at Buffalo	1900-1970	8.2	4.9
ERIE at Toledo	1940-1970	5.3	3.1
ONTARIO at Oswego	1933-1970	2.2	0.9

NOTE: Short period fluctuations are the differences between the monthly mean elevation and the maximum reading of the gage during each month. The "recurrence interval" is the average time interval within which an event of a given or greater magnitude will take place.

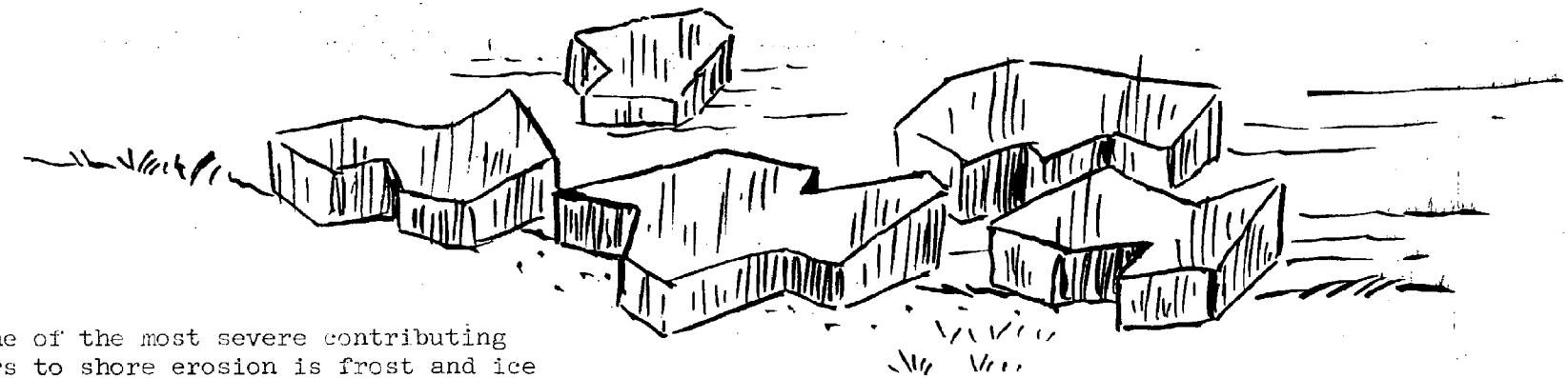
CAUSES OF EROSION

In the continuing natural processes which act on Great Lakes shorelines, erosion can and does occur at all stages of lake levels. During periods of high lake levels, however, the rate of erosion is accelerated and the extent greatly expanded.

The major causes of erosion of the shoreline are as follows: (1) wave action, (2) underground water seepage, (3) frost and ice action and (4) surface water runoff.

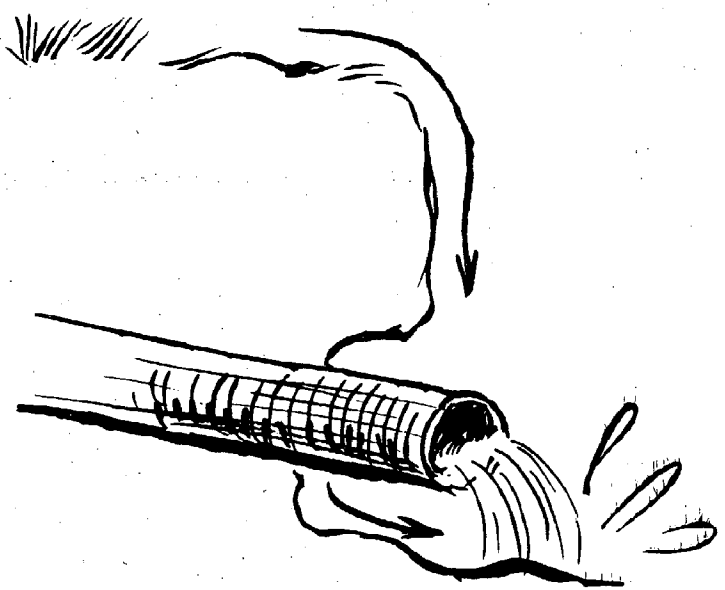
Wave action works directly on the beach or at the toe of the bank eroding away materials chiefly of clay, silt, sand and gravel. During periods when lake levels are above their average levels, erosion by wave action is accelerated, because the beaches are narrower or submerged and the waves are able to attack the unprotected toe of the banks or bluffs directly. The best natural protection that the upland shore could have from wave attack is wide beaches.

Where underground water seeps out of exposed bluffs of unstable material, it causes slumping and further weakening of the material, often resulting in large slides. Seepage often takes place through sandy layers in glacial till bluffs. Problems with underground water may sometimes be caused by man-made drainage works.



One of the most severe contributing factors to shore erosion is frost and ice action. In certain of the fine-grained silty types of soils along the lakes, the alternate freezing and thawing can cause soil weakening to the point where soil slides take place. Frost and ice formation in fissures in clays, glacial tills or shale bluffs may also contribute to their erosion. Shore ice is another source of damage, when broken up and driven onto the beaches by on-shore storms. Lake bottom material may be scoured out and damage to structures often occurs. However, shore ice also provides beneficial protection of the shore from erosion by winter storms.

Surface water runoff carries with it large amounts of erodable material, particularly where barren, steep sloped bluffs are present. Where surface water is carried off by man-made drainage works, inadequate protection of the sewer outfall may result in increased erosion at that point.



PART II

EXISTING FEDERAL LAWS ON BEACH EROSION CONTROL AND LAKE INUNDATION

The Federal Government's role in shore erosion control is defined in the provisions of Public Law 826, 84th Congress, approved July 28, 1956, as amended by the River and Harbor Act of 1962 (PL 87-874), approved October 23, 1962 and is further ammended by the River and Harbor Act of 1965 (PL 89-298), approved October 27, 1965. Under this statute the Corps of Engineers participates in the solution of shore erosion problems by making studies of such problems entirely at Federal expense for shores eligible under existing law for Federal participation in the cost of remedial action. The present policy for Federal participation in the cost of works for shore protection applies, generally, to publicly owned shores. Privately owned shores may be eligible for Federal assistance only if there are significant public benefits arising from public use or from protection of nearby public property, and provided further that any protective works are economically justified.

Privately owned shores qualify for Federal assistance only if public benefits along such shores will be considered to include those resulting from: (a) Public recreational use, opportunity for which will be assured for the economic life of the project (50 years) or (b) Prevention of damage to near shore publicly owned facilities such as highways, buildings, parks, etc. The protection of privately owned property that does not result in such public benefits will not qualify for Federal aid.

The Corps of Engineers also conducts beach erosion control surveys or reviews and updates previous reports on the basis of individual directives from the U.S. Congress. The directives are in the form of either a resolution of the Public Works Committee of the Senate or the House or a separate item in a public works authorization bill. The Soil Conservation Service, Department of Agriculture has broad authority to undertake studies for upland watershed protection. These reports deal primarily with means of reducing flood flows into the Great Lakes.

The provisions of Section 111 of the River and Harbor Act of 1968 authorizes the Corps of Engineers to investigate, study and construct projects for the prevention or mitigation of shore damages attributable to Federal navigation works. Investigation of the feasibility or desirability of work under this authority must be formally requested by a State, County or other properly constituted local authority.

Flooding or inundation damages on the Great Lakes shores are a direct consequence of building or placing improvements on the lake's flood plain. A possible solution to the problem on a long-term basis would involve studies to determine pertinent flood hazards, including the stability of the shoreline and definition of the rate of erosion which can be expected. This information could be furnished by the Corps of Engineers under its flood plain information program. This program was authorized by Section 206 of the 1960 Flood Control Act (Public Law 86-645 approved 14 July 1960) and was greatly expanded by amendment to this act in 1966 and HD 465, 89th Congress, 2nd Session entitled "Unified National Program for Managing Flood Losses". The Corps has a Flood Plain Management Services Program operating in North Central Division and each of its District offices. This program makes available to Federal, State and local governmental agencies information, guidance

and advice on the flood hazard which will permit them to proceed with such planning, engineering studies, construction and other action as may be necessary for wise use of flood plains. Requests for studies to determine flood hazards should be initiated by responsible local and state authorities concerned with the problem.

EMERGENCY FLOOD AND COASTAL STORM ACTIVITIES

The authority for Federal assistance in emergency flood and coastal storm activities is set forth in Public Law 99/84 (33 United States Code 701n) as amended by Section 206 of the Flood Control Act approved October 23, 1962; and in Section 9 of the Flood Control Act approved June 15, 1936 (33 U.S.C. 702 g-1). Preceding and during flood and coastal emergencies, the primary missions of the Corps of Engineers are preparation for and conduct of operations under statutory authorities assigned to the Chief of Engineers. Essentially the following responsibilities are authorized:

(1) Preserve Federally owned and maintained flood control works and other facilities operated by the Corps of Engineers.

(2) Furnish appropriate technical assistance to state and local authorities upon request, advising them in their efforts to maintain the integrity of flood control works and Federally authorized shore and hurricane protection projects under their jurisdiction.

(3) If responsible state or local authorities are unable to cope with the flood or coastal storms situation, direct Federal assistance may be provided either by supply of needed materials or equipment or by undertaking Federal flood fighting or emergency protection.

The Federal Disaster Act of 1950 (Public Law 875/81) authorizes Federal assistance to state and local governments in a major disaster. A major disaster is defined as any "flood, drought, fire, hurricane, earthquake, storm or other catastrophe which, in the determination of the President, is or threatens to be of sufficient severity and magnitude to warrant disaster assistance by the Federal Government to supplement the efforts and available resources of state and local governments in alleviating the damage, hardship, or suffering caused thereby".

Functions reserved to the President include the determination of a "major disaster declaration, the affected areas are then defined by the Director, Office of Emergency Preparedness.

The Corps of Engineers may be called upon to render assistance when specifically authorized by OEP as follows:

(1) Damage surveys and investigations.

(2) Performing assignments on public and private lands protections and other work essential for the preservation of life and property.

(3) Clearing debris and wreckage.

(4) Emergency repair or temporary replacement of public facilities.

(5) Provision of technical advice and engineering services.

Unless a major disaster has been declared, the only aid that can be provided to private land owners or public landowning agencies by the Corps of Engineers is Technical Assistance. The Corps of Engineers can provide technical assistance to local interests through consultations to acquaint them with erosion and inundation processes and potential on the Great Lakes, by making existing reports and other useful data available, and by making appropriate recommendations for suitable types of protection.

CORPS OF ENGINEERS
NAME AND ADDRESS OF DISTRICT OFFICES
DESCRIPTION OF SHORELINE COVERED

BUFFALO DISTRICT
District Engineer
U.S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, New York 14207

Lake Erie shoreline, Marblehead, Ohio to Buffalo, New York, including Pennsylvania shoreline, Niagara River shoreline

All of the Lake Ontario shoreline, St. Lawrence River shoreline to the Canadian Border

DETROIT DISTRICT
District Engineer
U.S. Army Engineer District, Detroit
P.O. Box 1027
Detroit, Michigan 48231

Lake Michigan from near Bridgman to Mackinaw City, Michigan, and from St. Ignace to the Peninsula Point, Michigan

Lake Superior shoreline from Au Train Point to Sault Ste. Marie, Michigan, and including the St. Marys River shore

All of the Lake Huron shoreline, St. Clair River shoreline, Lake St. Clair shoreline, Detroit River shoreline. Lake Erie shoreline to Marblehead, Ohio

CHICAGO DISTRICT
District Engineer
U.S. Army Engineer District, Chicago
219 South Dearborn Street
Chicago, Illinois 60604

Lake Michigan from Bridgman, Michigan including Indiana, Illinois and Wisconsin shoreline to Peninsula Point, Michigan

ST. PAUL DISTRICT
District Engineer
U.S. Army Engineer District, St. Paul
1210 U.S. Post Office and Customhouse
St. Paul, Minnesota 55101

Lake Superior from the Minnesota-Canadian Border, including the Wisconsin shoreline to Au Train Point, Michigan

NAME AND ADDRESS OF DIVISION OFFICE

NORTH CENTRAL DIVISION
Division Engineer
U.S. Army Engineer Division, North Central
536 South Clark Street
Chicago, Illinois 60605

OTHER FEDERAL AGENCIES

LAKE SURVEY CENTER
Director
Lake Survey Center, NOAA
U. S. Department of Commerce
630 Federal Building and U. S. Courthouse
Detroit, Michigan 48226

Levels of all the Great Lakes are recorded and published by the Lake Survey Center. A hydrograph showing the levels of the various lakes during the period of record 1860 to date is available from this office. The Water Level Bulletin similar to inclosure 1 is published monthly and copies are available to interested individuals upon request.

AVAILABLE CORPS OF ENGINEERS DATA AND REPORTS

The Corps of Engineers has completed a number of erosion control studies and several flood control studies for various reaches of the Great Lakes shores. In general, the reports on these studies discuss the erosion or flooding problems of a given shore segment, recommend desirable plans of protection, and provide the supporting technical information and data on which the recommended plans were developed. Copies of the reports on these studies along the localities listed below are available for inspection by the public at the Corps of Engineers' District Office under which the report is listed. Copies of the reports may also be available in local public libraries located in the general vicinity of the study area.

BUFFALO DISTRICT CORPS OF ENGINEERS

	Report Identification House Document No./Congress/Session
Lake Ontario	
Niagara County, N.Y.	271/78/1
Selkirk Shores State Park, N.Y.	343/83/2
Fair Haven State Park, N.Y.	134/84/1
Hamlin Beach State Park, N.Y.	138/84/1
Fort Niagara State Park, N.Y.	319/91/2
Lake Erie	
Sandusky Bay, Ohio	126/83/1
Sandusky O. - Vermilion, Ohio	32/83/1
Vicinity of Huron, Ohio	220/79/1
Vermilion, O.-Sheffield Lake Vil.	229/83/1
Sheffield Lake Vil., O.-Rocky Riv.	127/83/1
Cleveland and Lakewood, Ohio	502/81/2
Euclid, O.-Chagrin R., Ohio	324/83/2
Chagrin R., O.-Fairport, Ohio	596/81/2
Fairport, O-Ashtabula, Ohio	351/82/2
Ashtabula, O.-Penn. State Line	350/82/2
Sheffield Lake Com. Pk., Ohio	414/87/2
Presque Isle Penn., Erie, Pa.	231/83/1 and 397/86/2

DETROIT DISTRICT CORPS OF ENGINEERS

Lake Erie	
Michigan-Ohio State Line to Marblehead, Ohio	63/87/1
*Reno Beach, Lucas County, Ohio	554/80/2
*Water Levels of the Great Lakes - Local Flood Protection Project - Point Place, Lakewood-Luna Pier and Detroit Beach, Michigan	424/83/2
Lake Michigan	
Berrien County, Michigan	336/85/2

CHICAGO DISTRICT CORPS OF ENGINEERS

Lake Michigan	
Illinois Shore	28/83/1
City of Evanston, Illinois	159/89/1
City of Kenosha, Wisconsin	273/84/2
Racine County, Wisconsin	88/83/1
Milwaukee County, Wisconsin	526/79/2
Two Rivers to Manitowoc, Wis.	348/84/2

* Denotes Flood-Control (inundation) Report

NATIONAL SHORELINE STUDY

In 1968, the 90th Congress authorized the Corps of Engineers to accomplish a National appraisal of shore erosion and shore protection needs. This National Shoreline Study and the existing Federal shore protection programs recognize beach and shore erosion as problems for all levels of government and all citizens. To satisfy the purposes of the authorizing legislation, a number of related reports were published in August 1971. All are available to concerned individuals.

GREAT LAKES REGION, INVENTORY REPORTS. (Report covering one of the 9 major drainage areas of the United States) assess the nature and extent of erosion; develop conceptual plans for needed shore protection; develop general order-of-magnitude estimates of cost for the selected shore protection; and identify shore owners.

A report entitled "SHORE PROTECTION GUIDELINES" describes typical erosion control measures and present examples of shore protection facilities, and present criteria for planning shore protection programs.

A report entitled "SHORE MANAGEMENT GUIDELINES" provides information to assist decision makers to develop and implement shore management programs.

A report entitled "REPORT ON THE NATIONAL SHORELINE STUDY," addressed to the Congress, summarizes the findings of the study and recommends priorities among serious problem areas for action to stop erosion.

OTHER REPORTS

SHORE PROTECTION PROGRAM - Department of the Army, Office, Chief of Engineers: Revised June 1971. This report provides information on assistance by the Corps of Engineers in shore protection. Copies are available from the North Central Division office or the Office, Chief of Engineers, Washington, D. C.

PERMIT REQUIREMENTS

Federal and state permits are required prior to the construction of any work in, under, across, or on the banks of navigable waters of the United States. In general, both Federal and state permits are required prior to the initiation of construction of shore protection structures along the shores of the Great Lakes lakeward of the highwater mark. Federal permits are issued by the Corps of Engineers, usually only after a state permit has been obtained. A pamphlet entitled "Permits for Work in Navigable Waters", describing the procedures for applying for a Federal permit, may be obtained free of charge from any Corps of Engineers district office.

Information regarding the procedures for applying for a state permit should be obtained from the following state agencies.

Illinois:
Chief Engineer
State of Illinois
Division of Waterways
201 West Monroe Street
Springfield, Illinois 62706

Indiana:
Chief, Division of Water
Indiana Dept. of Natural Resources
605 State Office Building
Indianapolis, Indiana 46325

Michigan:
Michigan Water Resources Commission
Department of Natural Resources
Stevens T. Mason Building
Station A
Lansing, Michigan 48926

Minnesota:
Minnesota Dept. of Conservation
Div. of Water, Soils & Minerals
Centennial Building
St. Paul, Minnesota 55101

New York:
Central Permit Agent
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12201

Ohio:
Staff Coordinator
Ohio Dept. of Natural Resources
Ohio Dept. Building, Room 815
65 South Front Street
Columbus, Ohio 43215

Pennsylvania:
Chief Engineer
Pennsylvania Department of Environmental Resources
P. O. Box 1467
Harrisburg, Pennsylvania 17120

Wisconsin:
Director, Bureau of Water and Shoreland Management
Division of Environmental Protection
Wisconsin Dept. of Natural Resources
Box 450
Madison, Wisconsin 53702

PART III

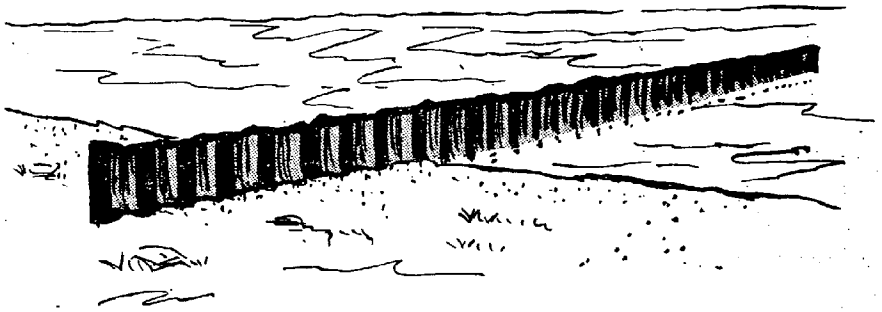
SHORE PROTECTION METHODS

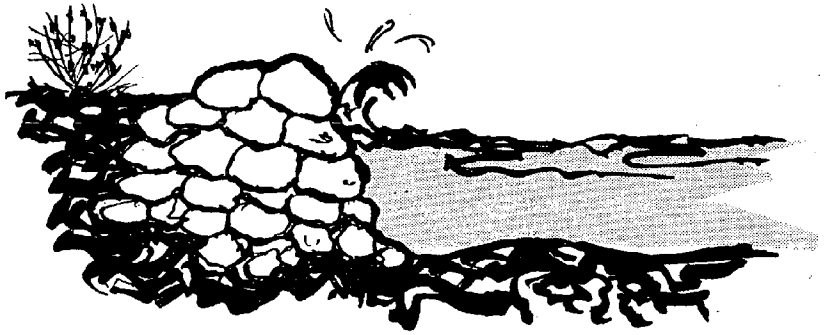
Protective measures are generally built for the purpose of preventing recurrence of damages to shore property, including measures to prevent damage from erosion and wave action, and measures to prevent damage from inundation.

Shore protection methods may be divided into three basic types, (1) those that provide protection by means of a higher beach, (2) those that shield vulnerable portions of the shores from the forces of waves and (3) those that reduce or prevent flooding of lower adjacent lands behind such protective structures.

In planning shore protective measures, it should be borne in mind that the high levels which occur at one time on a lake will probably recur in the future. Also, when lake levels are above their long-term average the possibility exists that such levels may continue during the fall and spring seasons. The greatest shore property damages are more likely to occur in the fall and spring seasons when the most severe storms occur on the Great Lakes.

When permanent protection is being planned for a locality, consideration must be given to the range of high and low levels which have occurred in that region over the period of record.





ADVANTAGES, DISADVANTAGES AND LIMITATIONS OF SHORE PROTECTION STRUCTURES

Each of the different types of shore protective structures has its own inherent advantages, disadvantages and limitations. These attributes generally dictate the method and degree of protection to be employed and in some instances provide an indicator as to what not to do, as well as what should be done.

Bulkheads, seawalls and revetments differ only in their primary function. By definition, a bulkhead is a structure separating land and water areas, primarily designed to resist earth pressures. Also, by definition, a seawall is a structure separating land and water areas, primarily designed to prevent damage to an upland area while retaining its seawall limit in a fixed position. A seawall may also be designed to resist earth pressure. A revetment is a facing, generally of stone, built to protect an otherwise stable embankment against erosion from wave action. The principal advantages attributable to bulkheads, seawalls and revetments are: (1) they provide positive protection and generally permit more intensive use of the adjacent upland; (2) they maintain the upland area on a fixed alignment; and (3) they are adaptable to providing protection to an area with a minimum of incidental damage to adjacent areas. Disadvantages of bulkheads, seawalls and revetments are: (1) they are not effective in maintaining a beach; (2) they provide no protection to adjacent areas which will continue to erode and eventually expose the flanks of the protected property.

Groins provide upland protection by intercepting part of the granular material that is moved along shore by wave generated currents. Their principal advantages are: (1) the resulting beach provides protection to upland areas as well as a potential recreation area; (2) their effect may spread over considerable lengths of shore; and (3) at those locations where groins would be effective, protection can generally be provided at lower initial cost by their use. Disadvantages in the use of groins include: (1) they are not as positive as a seawall for continuous upland protection; (2) they may be outflanked; (3) they are ineffective in areas of low littoral drift unless granular beach fill is artificially added and (4) the area immediately downdrift of the groin may be subject to increased scour.

Offshore breakwaters provide protection to upland property by reducing the wave energy impinging on the shoreline. Submerged breakwaters are a type of offshore breakwater and have the same general effect depending on depth of submergence. These may also be used to reduce beach slopes artificially, and thus prevent loss of material. The principal advantages are that: (1) they provide protection without impairing the usefulness of the beach; and (2) they may provide sheltered waters for boating. Disadvantages are that: (1) the relatively high cost of construction; (2) they protect only the shore behind them and for a short distance updrift; and (3) they may cause downdrift erosion.

A beach fill protects the upland by interposing a width of beach between the upland and the lake to absorb wave energy. The advantages of protection by beach fills are its pleasing appearance and possible recreational value. The principal disadvantages are that they require an adequate supply of beach material economically located and continuous maintenance must be provided.

There are a number of publications which have been prepared by various Federal and

State Agencies providing technical information on shore protection measures. The most complete and comprehensive publication is Technical Report No. 4 entitled "Shore Protection Planning and Design". This is a compilation of available knowledge on coastal engineering which has been prepared by the Coastal Engineering Research Center, Corps of Engineers. The latest edition may be purchased at a cost of $3.00 from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

Other sources of technical assistance are as follows:

1. SHORE EROSION IN OHIO, State of Ohio, Department of Natural Resources, Division of Shore Erosion, February, 1959.

2. LOW COST SHORE PROTECTION FOR THE GREAT LAKES, Research Publication No. 3, University of Michigan Lake Hydraulics Laboratory in cooperation with Michigan Water Resources Commission, reprinted October, 1959.

3. SHORELAND AND FLOOD PLAIN ZONING ALONG WISCONSIN SHORE OF LAKE MICHIGAN, A. R. Striegl, State of Wisconsin, Department of Natural Resources, Division of Resource Development.

4. GREAT LAKES SHORE EROSION IN MICHIGAN-STATUS REPORT, State of Michigan, Department of Natural Resources, Water Resources Commission, June 1969.

5. SHORELINE EROSION STUDY, Lake Erie Shoreline, Lake County, Ohio, State of Ohio, Department of Natural Resources, August 1969.

6. FLOOD PLAIN INFORMATION, Ontonagon River, Ontonagon, Michigan and Lake Superior Shoreline, Ontonagon County, Michigan, Department of the Army, St. Paul District, Corps of Engineers, September 1970.

This pamphlet provides only brief descriptions on the methods of shore protection. Reference to the above mentioned literature as well as the retaining of a qualified Engineering Consultant experienced in coastal engineering work is highly recommended. It should be pointed out, as indicated in another section of this pamphlet, that each State along with the Federal Government requires issuance of a permit prior to construction of shore protections on the banks of navigable waters. The Corps of Engineers issues the Federal permit.

ADEQUATE HEIGHT OF PROTECTIVE STRUCTURES

In addition to short period fluctuations in lake levels that might occur in a locality (table 2) the upper elevation limit of wave action must be known in order to properly design necessary protective structures.

One of the principal natural conditions that determine how high wave action will reach on the shorelines (wave runup) is the beach area condition between the upper limit of wave action and the existing still water lake level and the near-shore underwater zone between the water's edge and the lakeward zone where the waves break. The slopes of the beach areas and near-shore underwater areas vary widely throughout the Great Lakes shores. With a wide variation of bottom and beach slopes a change in the lake level of one or two feet might make a difference of only a dozen feet or perhaps 100 feet or more in distance from the shore at which waves break and also a change in the height of wave runup may result.

The vertical height to which water from a breaking wave will runup on a given protective structure will determine the top elevation to which the structure must be built to prevent wave overtopping and resultant flooding on the landward side, and to prevent possible damage by erosion. The proper elevation for the most economical groin system is required in order to provide the height and width of protective beach necessary for the locality. This runup, also called uprush, depends upon many factors such as the composition of the structure, its shape, its slope, its roughness, the depth of the water, the wind velocity and duration, etc. There is not an exact formula to determine the value of the runup, however, studies based on detailed information can lead to a very close approximation. It is noted that suggested design criteria for providing plans of protection for a particular location might be obtained from one of the completed Corps of Engineers' erosion or flood control studies for the general lake locality listed on page 11 or one of the technical references listed on page 16.

PLANS OF EMERGENCY PROTECTION

There are various methods for providing emergency protection rapidly at low cost which have been utilized on Great Lakes shores. These methods include: (1) placement of a granular fill. As an example the least amount of fill material that would provide a degree of protection will vary depending on the slope of the beach involved; (2) a temporary seawall at the base of the bluffs constructed of sand bags filled with sand and cement; and (3) combination of brush or timbers with sand bags. However, these plans may result in only partial or perhaps short-term protection for the shoreline.

Generally speaking emergency protection may provide a reasonable degree of protection through the first storm with the degree of protection diminishing as additional storms occur. Maintenance usually is necessary after each storm. It is estimated that the annual cost of maintenance of emergency protection could well be twice the initial construction costs.

It is difficult to make accurate comparisons of the effectiveness of the different methods which have been utilized in various sites on the Great Lakes shores since in no two installations will there be exact similarity of such factors as shore topography, beach compositions, wave conditions, etc. The emergency protections briefly mentioned above are considered "low-cost" measures and are not types that will withstand the severe conditions which occur on the shorelines of the Great Lakes.

RECENTLY DEVELOPED MATERIALS FOR SHORE PROTECTION

There are several medium cost protective methods that have merit which are classified as intermediate protective measures both in cost and durability.

In recent years several new commercial products have become available which appear to have merit in providing medium priced shore protection. It should be noted unless otherwise stated that no degree of performance or length of life is known by the Corps of Engineers.

The providing of information on these commercial products is in no way intended to imply that the North Central Division, Corps of Engineers or any of its District offices indorses the use of these specific commercial products as Great Lakes shoreline protective measures. This information is provided to advise property owners of the availability of these products for use as shore protection. The North Central Division office intends to provide similar information on other products which merit the same type application when such other items become known. The known sources of these products may be obtained from the North Central Division office or its District offices.

GABIONS

Gabions are steel wire mesh boxes or baskets (hexagonal triple twist mesh openings 3"x4") made of a complete and continuous metal fabric that can be filled with pieces of ballast such as stone, boulders, bricks or broken concrete to produce a heavy, wave resistant protective unit. Gabions are available in units about 3' deep with several heights and lengths available. The capacities vary from 1-5 cubic yards with the unit costs for the basket ranging from $10.00 to $29.00 plus shipping cost. Gabions may be used in various types of revetments to protect slopes or provide a retaining wall. Figure 1 is a sketch showing a 3'x6'x1½' gabion unit assembled and figure 2 shows an example of a typical shore protective use of this product. The permanence of this protection depends upon the life of the wire baskets as well as the proper design and preparation of its foundation which should include a filter.

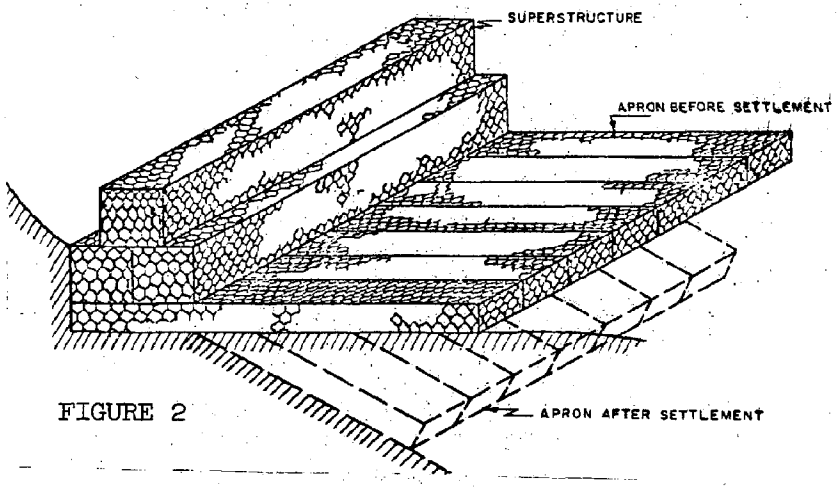


FIGURE 2

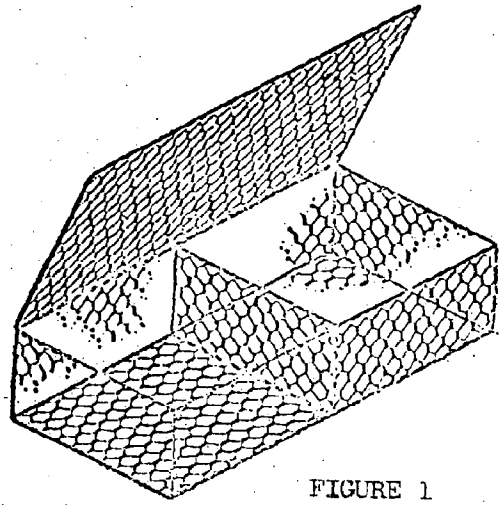


FIGURE 1

One of the main features as shown in figure 2 is the thin gabion apron (12 inches high) that projects out beyond the superstructure about twice the depth of the anticipated settlement. The apron with its flexibility can then conform to the changing contours of the shoreline and protect the structure against scourring.

For estimating purposes the use of an arrangement as shown in figure 2 would cost about $30.00 per foot of shoreline frontage (materials only - labor involved would be additional). Ballast material included in this estimate was based on costing $6.00 per ton delivered to the site with approximately 1-3/4 tons required to fill each cubic yard capacity of gabion units.

The use of gabions appears to be a satisfactory "do-it-yourself" construction project. Gabions have been used for shore protection measures at numerous localities throughout the Great Lakes.

FILTER MATERIAL

It should be noted that one common deficiency of most "do-it-yourself" revetments is that there is a complete lack of a filter material between the heavy cover material and the fine, easily erodible bluff or beach material.

A commercial product of a woven sheet of polypropylene yarns can be obtained and used beneath blocks, rubble or gabions to prevent the sand from working out through the blocks or rubble thus weakening the revetment or wall and causing settling. The woven material permits water from wave action or seepage to pass through it slowly but prevents the fine particles from being washed away. Costs of a suitable filter material in amounts between 300 square feet and 10,000 square feet, including anchor pins, is something in the order of $0.12 to $0.15 per square foot. Assuming that a standard 18-foot wide strip might be used as a filter under material to protect the toe and slope of a bluff, it would cost from $2.16 to $2.70 per linear foot of frontage for this item.

In many cases, existing stone or blocks could be reinstalled on the filter material to provide a much more effective protection requiring less future maintenance.

Figure 4 is a sketch showing the use of the filter material in a typical stone rubble revetment on a sloped shoreline. The need for a filter layer beneath the rubble is a definite necessity as the voids between the pieces of rubble are large and the constant wave action will draw the sand or backfill foundation out through the rubble and cause it to settle and eventually collapse. Figure 5 is a sketch of a rubble mound groin showing similar use of the filter material.

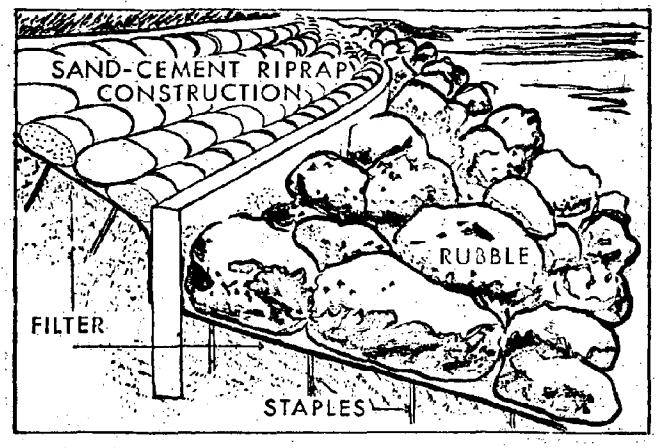


FIGURE 4

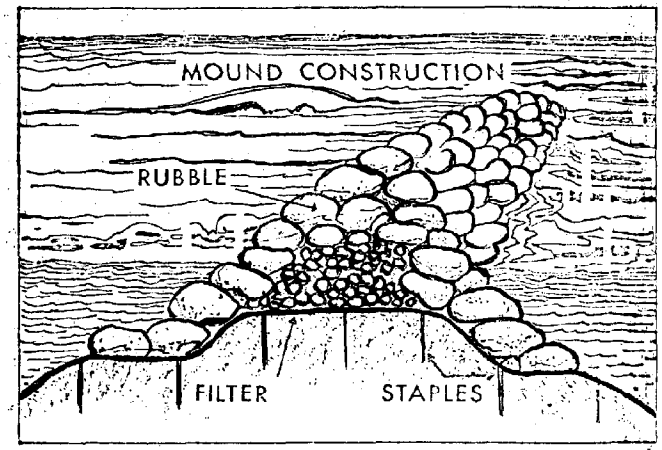


FIGURE 5

PRECAST CONCRETE SHAPES

A number of precast concrete shapes intended for use either as shore revetment or in lieu of heavy coverstone are available. Generally these are patented products controlled by a single supplier who collects a royalty for the use of his patent. Some have been tested in a limited number of prototype installations; others have been tested only in scale models. One of these shapes is illustrated in Figure 6. The installed cost of such a single interlocking line varies between $50 to $60 per linear foot for a basic 2-ton unit. Properly designed structures using similar products would provide long lasting protection but the costs are relatively high. Precast concrete shapes would be competitive in cost where suitable sizes and quality of stone are not readily available. Actual installations have been in coastal areas but at least one supplier plans to have an installation on the Great Lakes in late 1971.

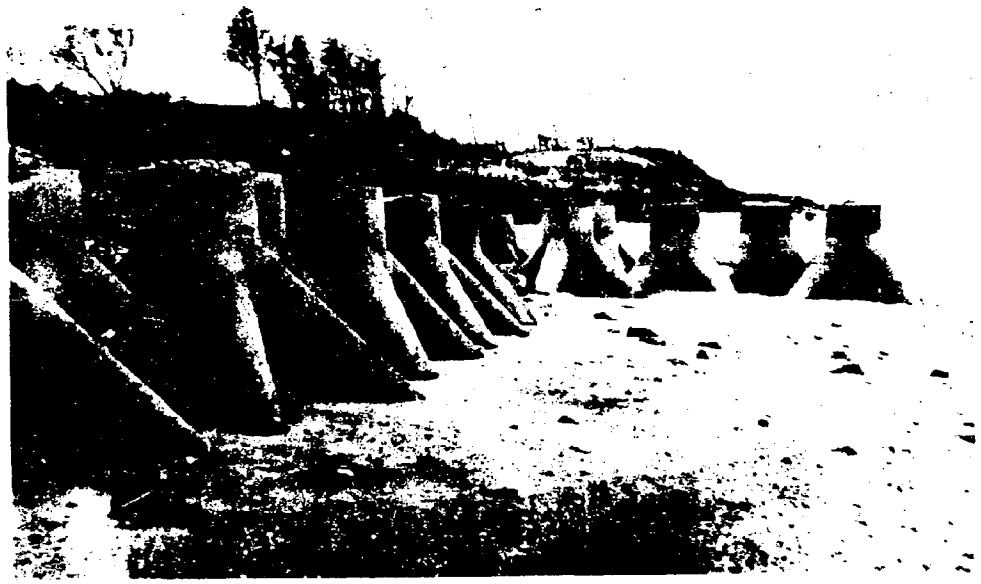


FIGURE 6

TWO TON INTERLOCKING CONCRETE SHAPES

MISCELLANEOUS INFORMATION

Property owners who are in danger of sustaining extensive damages should consult their local office of the Internal Revenue Service for information relative to "disaster losses" which might be claimed as deductions on Federal Income Tax filing. It is believed that definite proof of such losses must be documented for each storm occurrence. Concerned owners should contact the Internal Revenue Service office for exact information or determination on individual situations.

SOME CONCLUSIONS

Under present laws and authorities the Corps of Engineers cannot aid shore property owners threatened by losses in construction of protective measures. It is the burden of the property owners to provide adequate protection for their threatened properties, otherwise damages will result. As has taken place at many localities, it is a very wise procedure for neighboring property owners to work together in a cooperative effort to provide well planned and properly placed measures of protection at the locality threatened.

It is most important that expert advice be obtained from competent Engineering Consultants in the proper planning and determination of the specific design of shore protection. Property owners are advised to consult their local or state agencies responsible for shoreline protective programs. It is believed that these agencies will have direct knowledge of qualified Engineer Consulting and Contracting Firms knowledgable and experienced in providing shore protective measures in their locality.

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