A SHORE EROSION POLICY FOR MARYLAND

Report of the Governor's Special Committee to Study Shore Erosion

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The Honorable J. Millard Tawes
Governor of the State of Maryland
State House
Annapolis, Maryland

Dear Governor Tawes:

The report of your Committee to Study Shore Erosion is submitted herewith. Your committeemen express their appreciation for having been given this opportunity to become fully acquainted with the problem.

Members of the committee, both individually and as a group, have observed many examples of shore erosion. We saw some successful efforts to prevent or retard shore erosion but many more that were only partially effective or completely ineffective in preventing damage. The individuals on your committee have studied carefully a mass of pertinent information. Personnel of State and Federal Agencies known to be concerned were invited and have attended meetings of the committee to discuss the problem from their viewpoint and to explain the details of their actual, as well as their assigned, roles in the control of shore erosion.

Our report is submitted with the hope that the information contained therein will contribute to a clear recognition of the importance of the problem of shore erosion and the recent marked acceleration of the economic losses that our State is experiencing from this cause.

Proven engineering techniques and skills that will insure protection, if applied to physiographic units of shore line, are now available. However, new legislation is needed to permit private citizens who own eroding land to join with local, state, and federal agencies to control the destructive and obstructive effects of the action of wind and wave on Maryland's tidal shores.

Sincerely yours,

William K. Connor	William R. Kahl
Stanley E. Day	Clarence Z. Keller
T. Walter Denny	Milton M. Malkus
Ralph L. Dodge	Bernard L. Nicholson
George W. Dorsey, Sr.	Jack W. Rayner
Joseph G. Harrison	John E. Stafford
Walter C. Hopkins	Upshur C. Stevenson

Robert L. Green, Chairman

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ACKNOWLEDGEMENTS

The work of the Committee to Study Shore Erosion has been made possible through the cooperation and assistance of many people representing state and federal agencies. The committee expresses its appreciation to all who have aided in its work and especially to the individuals noted below:

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SUMMARY

Shore erosion is the result of the combined forces of wind, waves, and tides acting against exposed reaches of shore line. The most obvious damage is the direct damage to the affected property, but losses also affect adjacent property owners, the counties and the state. In some instances the deposition of eroded material may block navigable channels necessitating abandonment or expenditure of large sums for channel maintenance. In some other instances erosion of shore lines adds to the sediment load of adjacent waters and is harmful to marine biological life. Erosion along one reach of shore line may be beneficial to another reach in that soil lost at the first may be transported by littoral drift and deposited at the second reach to form a protective beach. However, the harmful effects of shore erosion are most readily recognized and generally this aspect is implied when the "shore erosion problem" is discussed.

Shore Erosion in Tidewater Maryland, Bulletin 6 of the Department of Geology, Mines and Water Resources, vividly portrays the extent of shore erosion losses from about 1850 to 1942. In this excellent reference work, published in 1948, Dr. J. T. Singewald, Jr., and Mr. T. H. Slaughter point out that 1,939 of Maryland's 3,190 miles of shore line have an erosion problem with an average net loss of 0.14 acre per mile per year. This average covers a wide range from virtually no loss to linear recession of 500 to 700 feet during the period of study. Recession and accretion of some points far exceed these; for example in Anne Arundel County a hooded spit built out linearly 1900 feet northwest of the mouth of Jack Creek reducing its width to 150 feet; from Carr's Creek to Parker Creek there was linear recession of 700 feet; however, the neck known as Parker Island had receded 2,600 feet. These examples represent the extreme but were selected to minimize the possible tendency for one to be complacent towards the problem when averages only are considered.

The State Roads Commission has effectively protected the highway at Ocean City by means of groins which have caused deposition of a protective beach. The jetty, north of the Ocean City Inlet constructed and maintained by Corps of Engineers, U. S.

Army, has contributed to the protective beach, has prevented deposition in the inlet and simultaneously has starved the northern end of Assateague Island by interfering with normal littoral drift.

Several sub-divisions in Anne Arundel and a smaller number in Calvert and St. Mary's Counties have formed Erosion Districts under the powers of County Commissioners. These Districts have generally had effective structural control programs because, as subdivisions, they could effectively defend a complete physiographic unit of shore line. The Districts have also made it possible to spread the costs over longer periods of time than is possible for individual property owners.

With the exceptions noted above, shore erosion control has been piecemeal and generally ineffective. In fact, there are many examples where private, piecemeal construction of defensive works appears to have accelerated erosion on adjacent areas which in turn ultimately contributed to the failure of the defensive works.

Shore erosion control measures must protect an entire physiographic unit of shore line for maximum effectiveness. Treatment of a complete unit of shore line will increase the initial cost and will increase the number of landowners concerned and, therefore, the problems of coordination and cooperation, but it will result in greater effectiveness and will reduce maintenance costs.

The population increase in the area is drastically increasing the demand for both public and private development of waterfront property for recreational and other uses. The population explosion predicted for the area makes it desirable to establish effective shore erosion control at the earliest possible time. An adequate educational program may also reduce the incidence of waterfront owners being rudely awakened to their ownership of an erosion hazard they cannot effectively cope with alone, even if they are financially able to construct protective works on their individual tracts of land.

In recognition of the importance of shore erosion, sixteen other states and Puerto Rico have adopted various programs. Six states, California, Connecticut, New Jersey, New York, Massachusetts and Ohio, match funds with local governments for shore erosion control studies and construction. Six states, Delaware, Hawaii, Louisiana, New Hampshire, Rhode Island and South Carolina, have paid all costs for specific projects. Florida, Illinois, North Carolina and

Puerto Rico have contributed to the cost of studies. In addition to these, Virginia has contributed funds to Virginia Beach but has no general policy at this time.

The consensus of the committee is that shore erosion in Maryland is of increasing importance. The physical problem in itself has changed little over the years; however, the demands on the land of an increasing population make shore erosion of greater concern to more people than ever before. The science of shore erosion control has markedly advanced in recent years through research by the Beach Erosion Board, Corps of Engineers, United States Army and other agencies and through the increased knowledge available from reports of accomplishments throughout the world in publications, such as Shore and Beach of the American Shore and Beach Preservation Association.

In view of these conditions the committee believes Maryland should centralize and expand its efforts for the control of shore erosion and respectfully submits the recommendations which follow in a sincere belief that their adoption will effect a material reduction of our continuing irreversible losses of increasingly valuable bay shore and ocean shore land.

RECOMMENDATIONS

I. The committee recommends that an independent agency be established and charged solely with conduct of an expanded educational and operational program on shore erosion and its control. Assignment of this responsibility to an independent agency will necessitate passage of legislation relieving the Department of Geology, Mines and Water Resources of certain of its present responsibilities.

A. The agency should promptly start an educational program that will tell the citizens of Maryland about:

1. How shore erosion takes place.
2. Where it is serious in Maryland.
3. How to stop it.
4. Where and how to get help.

B. The agency should actively cooperate with:

1. The State Roads Commission for shore erosion control where essential to protection of municipal, county and state highways.
2. The Corps of Engineers, United States Army for the conduct of shore erosion studies.
3. The Soil Conservation Service, United States Department of Agriculture in evaluation and application of vegetative measures for shore erosion control.
4. The Water Pollution Commission in the reduction of pollution originating from shore erosion.
5. The Department of Geology, Mines and Water Resources in the conduct of overall geological studies of shore erosion.
6. The Department of Forests and Parks in shore erosion control aspects of recreational area management.

C. An agency program should be promptly undertaken which will:

1. Provide technical assistance to individual landowners, municipalities and counties having specific shore erosion problems.

2. Design, or cause to be designed, shore erosion control structures (including vegetative cover).
3. Enter into agreements with individuals, municipalities or counties for construction of shore erosion structures.
4. Supervise, or secure supervision, of the erection of shore protective devices.
5. Prepare and prosecute requests for appropriation of funds necessary to pay the state's share of the costs of such shore protective devices.

II. The committee recommends that an engineer qualified in shore erosion control be appointed operational head of the independent agency and that he be provided with essential staff to perform the above functions. It is further recommended that the operational head of this agency be an ex-officio member of the State Board of Natural Resources.

III. The committee recommends that an Advisory Commission be appointed with responsibility for establishing operational policy and work priorities for the shore erosion control agency.

IV. The committee recommends that the state match county and local, private or public, funds that may be made available for shore erosion control studies to be carried out by the Corps of the Engineers, United States Army.

V. The committee recommends that the state contribute 25% of the construction costs of projects approved by the new agency for protecting complete physiographic units of shore line on land owned by individuals, municipalities or counties. The value of engineering services provided by the shore erosion control agency in the planning and design of such works shall be considered a part of the state contribution. The agency shall actively seek cooperation and cost sharing from federal sources for all eligible projects. After project designs and cost estimates are complete and there is adequate assurance that 75% of estimated project costs will be available from funds contributed by individuals, municipalities, counties or federal sources, the agency will submit a request supported by an itemized list of such specific projects for appropriations to complete the state's 25% share. Construction and appropriations, therefore, may be scheduled during a period of time of one or more years.

VI. The committee recommends that existing powers of the County Commissioners as set forth and defined in Article 25, Annotated Code of Maryland, 1957 Edition, Sections 161 through 167, be amended:

A. To permit formation of an Erosion District encompassing a complete physiographic unit of shore line when requested by 75% of the landowners or by owners of 75% of the property, whether or not all or any part of such shore line be within a recognized sub-division, as is presently required. (See Appendix F).

B. To require the shore erosion control agency to submit a report on project plans and feasibility to the county commissioners within whose jurisdiction any part of the project falls, prior to the county commissioners' approval of the formation of an Erosion District.

C. To permit county and/or town commissioners to finance 25% of the cost of construction for shore erosion control works, to accept contributions from private, state or federal sources for all or any part of the remaining 75% as is now permitted under the alternative method of financing Erosion Districts, and to finance any remainder through a town or county tax on protected property in proportion to identifiable benefits thereto.

VII. The committee recommends that town and county Planning and Zoning Commissions be authorized to require adequate provisions for erosion control as a precedent condition for approval of a sub-division plat.

Appendix

INTRODUCTION

The Maryland shore line extends for 3,190 miles along the Atlantic Ocean, the Chesapeake Bay and other bays and tidal estuaries. The United States Coast and Geodetic Survey Serial 22, revised in 1939-40, shows 31 miles of general coast line, 452 miles of general shore line and 3,190 miles total detailed shore line. The latter figure includes shore lines of bays, sounds and other bodies of water to the head of tidewater or to a point where such waters narrow to a width of one hundred feet and includes the shore line of the islands within the bays.

In 1949 the Maryland Department of Geology, Mines and Water Resources published Bulletin 6, Shore Erosion in Tidewater Maryland. In this report, Dr. Joseph T. Singewald, Jr., Director, and Mr. Turbit H. Slaughter, Geologist, report a comparison of the Maryland shore line from the earliest available maps, 1848-1849, to the latest available maps which were published in 1942. In a summary of measurements the detailed comparison shows 1,939 miles of shore line subject to an average net loss of 0.14 acres per mile per year. The range of losses varied from 0.04 acres per mile per year in Prince Georges County to 0.22 acres per mile per year in Dorchester County. The total loss was 29,371 acres and the net loss, in excess of deposition, was 24,712 acres or 320 acres gross loss, and 265 acres net loss per year which verifies to some degree an anonymous observation that shore lines are an exhaustible resource.

Shore erosion will continue to be a serious problem in Maryland. However, increased knowledge of how to control shore erosion from the Beach Erosion Board, Corps of Engineers, United States Army, and other sources makes our present study timely. The direct property losses, the retarding effect of unstable shore lines on development, the influence on marine biological life, the channel dredging costs, and other results, especially when considered in light of increasing population pressures in the area, indicate some responsible group should give careful consideration to the needs and responsibilities of the citizens, municipalities, counties, and state.

Appendix A

THE GOVERNOR'S COMMITTEE

In September, 1959, the citizens of Queen Anne County, through their Soil Conservation District and with support of the State Soil Conservation Committee, sponsored a meeting and tour on Kent Island to focus attention upon the shore erosion problem in Maryland. Approximately two hundred, including Governor Tawes and interested citizens from throughout Tidewater Maryland and representatives of state and federal agencies, attended. Subsequently, Supervisors of the Queen Anne Soil Conservation District requested the State Soil Conservation Committee to take appropriate action in view of the extent and seriousness of the problem within the state.

After consideration and an informal exchange of information with Dr. Joseph T. Singewald, Jr., Director of the State Department of Geology, Mines and Water Resources, the State Soil Conservation Committee made a recommendation to the State Board of Agriculture which was approved and forwarded to Governor J. Millard Tawes. The substance of the recommendation was that a committee be appointed to study the shore erosion problem and to make recommendations for future policy of the state.

As a result of this series of recommendations Governor Tawes, in August 1960, appointed a committee with representation from Tidewater Maryland. (See page 6 of report for roster). After its organizational meeting the committee recognized a need for deliberate study to gain knowledge on which to base recommendations. The committee needed information in three general areas:

1. The extent of shore erosion as a serious problem in the state.
2. Methods of controlling shore erosion.
3. Activities of individual, municipal, county, state and federal agencies in shore erosion control together with laws, policies and regulations pertaining thereto.

Committee members have made a careful study of pertinent literature. Corporate membership in the American Shore and Beach

Preservation Association made available publications and unpublished reports which may not have otherwise been available. Five committee members attended the annual meeting of the Association in Ocean City. These five members made contact with professional specialists in shore and beach preservation and had the opportunity of an inspection trip on Assateague Island where extensive shore erosion is currently taking place.

Field meetings of the committee have been held at Smith Island, Ocean City, Kent Island and Annapolis. The first and last of these meetings included shore line inspection from patrol boats of the Department of Tidewater Fisheries. Representatives of the Beach Erosion Board and the Office of the District Engineer, Corps of Engineers, United States Army, attended most of the above field meetings to assist in explaining technical details of shore erosion processes and control techniques observed.

The staff of the Beach Erosion Board was host for one day at the facilities of the Board in Washington, D. C. The staff members discussed fundamentals of shore erosion processes and demonstrated facilities and techniques used for research.

At one meeting, representatives of all state and federal agencies concerned with shore erosion discussed activities, policies and laws of their respective agencies. The Department of Geology, Mines and Water Resources, the State Roads Commission, the Department of Forests and Parks, and the Agricultural Extension Service were the state agencies represented. The Soil Conservation Service, the District United States Army Engineer's office and Beach Erosion Board were the federal agencies represented. A past-president and the executive secretary of the American Shore and Beach Preservation Association were also present to discuss the work of the Association.

In addition the committee has held six other meetings for discussions leading to the format and contents of this report with the better part of three meetings developing the recommendations.

It is the consensus of the committee that far more time than has been available would be required for one to become a qualified specialist in the science of shore erosion control. On the other hand, it is felt that the committee has acquired sufficient background knowledge from which to draw its conclusions and on which to base its recommendations.

Appendix B

AREA AFFECTED

The United States Coast and Geodetic Survey has compiled and published tables of coastline measurements. These coastline measurements were first issued in November, 1915 as Serial No. 22. In 1939-40, an extensive project to coordinate existing data and remeasure much of the shoreline resulted in a complete revision of the information contained in Serial No. 22.

These new 1939-40 measurements were scaled from the largest scale maps or charts then available of the coastal regions of the United States. For the Atlantic Coast, Coast and Geodetic Survey large-scale topographic and planimetric maps compiled from aerial photography were used to the extent of their coverage. The next priority coverage comprised the largest scale Coast and Geodetic Survey nautical charts available. Beyond the limits of this detailed coverage the Geological Survey and Corps of Engineers quadrangles were used.

The general coastline measurements as defined below were measured on charts and maps of relatively small scale in 1946. A permanent record of the actual measurements by locality is in the file of the United States Coast and Geodetic Survey. Mileage of Maryland's coast and shore lines, tabulated below, has been characterized by the three types of measurement selected for publication by the United States Coast and Geodetic Survey and are explained as follows:

1. **General Coastline.** The mileage under this heading is the length of the general outline of the seacoast. The measurements were made with a unit measure of 30 minutes of latitude or charts as near the scale of 1:1,200,000 as possible. The shoreline of bays and sounds is included to a point where such waters narrow to the width of the unit measure, and the distance across at such point is included.

2. **Tidal Shoreline, General.** Measurements under this heading were made with a unit measure of 3 statute miles on charts of

1:200,000 and 1:400,000 scale when available. The shoreline of bays, sounds, and other bodies of water is included to a point where such waters narrow to a width of 3 statute miles, and the distance across at such point is included.

3. **Tidal Shoreline, Detailed.** Mileage under this heading was obtained in 1939-40 with a recording measure on the largest scale maps and charts then available. Shoreline of bays, sounds, and other bodies of water is included to the head of tidewater or to a point where such waters narrow to a width of 100 feet.

	Length in statute miles		
Locality	General coastline	Total shoreline, general	Total shoreline, detailed
Maryland	31	452	3,190

4. **Ocean Shoreline.** The earliest known authentic map of a portion of Maryland's coastal shoreline is indicated on a drawing prepared by a survey of the United States Coast and Geodetic Survey in 1849. This survey embraces an area of the Atlantic Coast and the Sinepuxent Bay area from approximately 5 miles south of South Point on State Route 611 for a distance of several miles north of Ocean City, which lies approximately 9 miles south of the Maryland-Delaware line. The survey shows the shoreline very uniform in direction, without any indication of an existing inlet, although on Assateague Island opposite South Point there appeared on the chart the wording "OLD SINEPUXENT INLET."

Successive coastal surveys and maps made by this agency revealed a similar condition to their 1849 survey and maps, except for notations relative to several small inlets south of Ocean City.

In a survey of August 1877, the United States Coast and Geodetic Survey issued information showing the approximate determination of main buildings in Ocean City. The Atlantic Hotel and Ocean House, together with about a half dozen other buildings, are shown on this chart. Also recorded is the Eastern Shore Railroad line which crossed Sinepuxent Bay with a bridge containing a draw span.

Appendix C

EXTENT OF SHORE EROSION

Shore erosion long has been recognized as a serious problem in Tidewater Maryland. In the introduction of the Shore Erosion Problem (Bulletin 6, Maryland Department of Geology, Mines and Water Resources) Dr. Joseph T. Singewald, Jr., wrote that the first measurements of the amount of shore erosion and rate of shore erosion were made by G. F. Hunter in 1914. Hunter's studies, sponsored by the Maryland Geological Survey, found Sharps Island reduced from 438 acres in 1848 to 53 acres in 1910; James Island was reduced from 976 acres to 490 acres and Tilghman Island from 2015 acres to 1686 acres in the same period. By 1946 erosion had further reduced Sharps Island to 6 acres and today it is only a bar in the Chesapeake Bay.

The number of striking examples of the extent of shore erosion and its serious effect upon property, areas and communities is limited only by time to seek out details. The committee visited Smith Island in September, 1960 to observe conditions which may necessitate future abandonment unless effective protective measures can be justified. In 1959 the tides and waves of a severe storm broke through a barrier marsh on the western side of the island leaving Rhodes Point exposed to future westerly storms. At Tylerton, protective measures established approximately twenty-five years ago have passed their useful life and extreme high tides wash over a section of this village.

In Anne Arundel County the community projects established under the erosion district law are fine examples of successful protection for complete physiographic units of shore line. Across the Bay on Kent Island are a number of gross disappointments for individuals attempting shore erosion control for individual tracts, some tracts with "protective" bulkheads for one hundred foot lot fronts and others for several hundred yards. The only difference, when protection is applied to incomplete physiographic units, between treatment of a few feet or a long reach is time that will elapse before erosion at ends of bulkheads cause failure.

One owner wrote the committee to say he bought a lot 100′ x 125′ in 1958 and now it was about 100′ x 105′. Another owner wrote that he could afford no more protective works and would have to salvage as much of his investment as possible by disposing of his bayfront cottage. While *caveat emptor* is the rule, there is an indication of need for required protection by developers for the good of the communities and counties.

In tables 17-20 in that part of the previously cited Bulletin 6 devoted to the Shore Erosion Measurements, Slaughter effectively summarized quantitative data of shore erosion. These data depict clearly long range trends and averages and it was considered unnecessary by the committee to attempt to update these data even if necessary personnel had been available. These tables are reproduced here without modification as a summary. Persons having need for additional details are referred to the original text.

TABLE 17.—*Mainland Shore Erosion Statistics of Maryland Tidewater Counties*

County	Time Interval	Miles Measured	Erosion	Deposition	Net Loss	Rate of Loss	Annual Rate of Loss
	years		*acres*	*acres*	*acres*	*acres*	*acres*
Anne Arundel	89	135.1	1902	290	1612	11.1	.12
Baltimore	89	59.9	698	80	618	10.3	.11
Calvert	90	67.0	890	232	658	9.8	.10
Charles	61	88.3	361	193	168	1.9	.03
Harford	94	66.8	834	117	717	10.7	.11
Prince George's	81	21.3	107	35	72	3.3	.04
St. Mary's	82	115.1	1600	218	1382	12.0	.14
Western Shore Totals	84	553.5	6,392	1,165	5,227	9.4	.11
Caroline	93	13.1	128	3	125	9.3	.10
Cecil	94	77.5	843	171	672	8.6	.09
Dorchester	94	224.5	4673	283	4390	19.5	.20
Kent	96	81.2	1013	99	914	11.2	.11
Queen Anne's	96	122.6	1874	243	1631	13.3	.13
Somerset	93	113.1	1630	121	1509	13.3	.14
Talbot	90	162.9	1792	162	1630	10.0	.11
Wicomico	93	35.0	552	9	543	15.5	.16
Worcester	92	178.3	2206	1738	468	2.5	.02
Eastern Shore Totals	93	1,008.2	14,711	2,829	11,882	10.7	.11
MAINLAND TOTALS	89	1,561.7	21,103	3,994	17,109	10.9	.11

TABLE 18.—*Island Shore Erosion Statistics of Maryland Tidewater Counties*

County	Time Interval	Miles Measured	Erosion	Deposition	Net Loss	Annual Loss
	years		*acres*	*acres*	*acres*	*acres*
Anne Arundel	89	3.0	29	5	24	.26
Baltimore	88	7.2	195	2	193	2.19
Calvert	94	1.7	3	0	3	.03
Charles	75	4.0	54	5	49	.65
Harford	95	13.8	267	14	253	2.66
Prince George's St. Mary's	77	12.2	201	49	152	1.97
Western Shore Totals	86	41.9	749	75	674	7.83
Caroline						
Cecil						
Dorchester	94	108.7	2646	150	2496	26.5
Kent	96	19.0	289	23	266	2.77
Queen Anne's	96	6.8	152	4	148	1.54
Somerset	93	119.9	1925	130	1795	19.3
Talbot	93	26.1	1643	51	1595	17.1
Wicomico Worcester	92	55.3	864	232	632	6.76
Eastern Shore Totals	94	335.8	7,519	590	6,929	73.7
ISLAND TOTALS	90	377.2	8,268	665	7,603	84.4

TABLE 19.—*Shore Erosion Statistics of Chesapeake Bay Mainland Shore*

County	Time Interval	Miles Measured	Erosion	Deposition	Net Loss	Rate of Loss	Annual Rate of Loss
	years		*acres*	*acres*	*acres*	*acres*	*acres*
Anne Arundel	91	40.3	1155	114	1041	25.8	.28
Baltimore	90	9.3	178	14	164	17.6	.19
Calvert	96	31.3	645	115	530	16.9	.17
Charles Harford	92	24.0	405	22	383	15.9	.16
Prince George's St. Mary's	94	22.5	672	72	600	26.6	.28
Western Shore Totals	92	127.4	3,055	337	2,718	21.3	.23
Caroline Cecil	94	15.6	209	14	195	12.5	.13
Dorchester	94	29.5	1874	65	1809	61.0	.64
Kent	97	36.9	611	33	578	15.6	.16
Queen Anne's	97	17.6	688	96	592	33.0	.34
Somerset Talbot	90	11.3	301	15	286	25.3	.28
Wicomico							
Worcester							
Eastern Shore Totals	94	110.9	3,683	223	3,460	31.1	.33
CHESAPEAKE BAY TOTALS	93	238.3	6,738	560	6,178	25.9	.27

TABLE 20.—*Shore Erosion Totals in Maryland Tidewater Counties*

County	Time Interval	Miles Measured	Erosion	Deposition	Net Loss	Rate of Loss	Annual Rate of Loss
	years		*acres*	*acres*	*acres*	*acres*	*acres*
Anne Arundel	89	138.1	1931	295	1636	11.9	.14
Baltimore	89	67.1	893	82	811	13.5	.15
Calvert	90	68.7	893	232	661	9.6	.11
Charles	61	92.3	415	198	217	2.4	.04
Harford	94	80.6	1101	131	970	12.0	.13
Prince George's	81	21.3	107	35	72	3.4	.04
St. Mary's	82	127.3	1801	267	1534	12.1	.15
Western Shore Totals	84	595.4	7141	1240	5901	9.7	.11
Caroline	93	13.1	128	2	125	9.2	.10
Cecil	94	77.5	843	171	672	8.7	.09
Dorchester	94	333.2	7319	433	6886	20.7	.22
Kent	96	100.2	1302	122	1180	11.8	.12
Queen Anne's	96	129.4	2026	247	1779	13.7	.14
Somerset	93	233.0	3555	251	3304	14.2	.15
Talbot	93	189.0	3435	213	3222	17.0	.18
Wicomico	93	35.0	552	9	543	15.5	.17
Worcester	92	233.6	3070	1970	1100	4.7	.05
Eastern Shore Totals	94	1,344.0	22,230	3419	18,811	14.0	.15
MARYLAND TOTALS	90	1,939.4	29,371	4,659	24,712	12.6	0.14

Appendix D

MECHANICS OF SHORE EROSION

Shore or beach erosion is the process of detachment and transportation of soil particles from a shore line. The kinetic energy of wind and water acting against the shore material causes the detachment and transportation of the soil particles from exposed shore reaches.

Detachment and transportation of soil particles may be caused directly by wind and rain. Alternate freezing and thawing, together with surface runoff and sub-surface drainage, may contribute materially to the shore erosion hazard, particularly on vertical or nearly vertical faces. Currents from streams and tidal ebb and flow are continuously causing detachment and transportation of the shore material. However, waves generated by wind over large open areas of water are the greatest erosion hazard.

Wind, except in the case of shifting dunes, is primarily an indirect hazard through the generation of water waves. Through the generation of waves, a considerable portion of the total energy of wind acting over great expanses of water is enabled to reach the shore. In an area of water over which the wind is blowing and generating waves, known as a fetch or fetch area, the growth of the waves is governed by at least three factors: the velocity of the wind; the length of time the wind blows, or duration; and the length of the fetch in the direction of the wind. In addition to these factors, the depth of water in the fetch limits wave growth in relatively shallow water areas. Waves generated in deep water are usually of the type known as oscillatory waves, in which the particles of water making up the wave oscillate in a circular orbit about some mean position.

In most coastal locations the wind may induce a surface current in the general direction of the wind movement and cause an increase or decrease in water level above or below that due to tidal action. The wind-induced surface current produces a piling up of water at the leeward side and a lowering of water level at the windward side with a return flow along the bottom. Wave forecasting procedures may be used to translate meteorological data into wave data. Because this procedure involves many factors and is of a highly technical nature, it is omitted from this report but may be found in appropriate literature.

The tide is the alternate rising and falling of the level of the sea caused by the attractive forces of the sun and moon on the rotating earth. There are usually two high and two low waters in a tidal or lunar day. Tides follow the moon more closely than they do the sun. As the lunar day is about 50 minutes longer than the solar day the tides occur about 50 minutes later each day. Because of the varying effects of the sun and moon, a diurnal inequality in tides occurs in which, at certain places, there may be little difference between one high water and the succeeding low water of a day but a marked difference in height between the other high water and its succeeding low water. Along the Atlantic coast the two tides each day are of nearly the same height. The tidal range between Cape May, New Jersey and Cape Henry, Virginia has a mean approximate range of from 3 to 4 feet except that spring tides range from 3 to 5 feet. The extreme range is from 3 feet below Mean Low Water to 3.5 feet above Mean High Water.

Beaches or shore lines, unless naturally protected by marshland, other vegetation, stone, or man-made defenses, have a dynamic existence. Wind and water are constantly moving shore material. Most of the material is moved adjacent to the shore in the littoral zone under the influence of waves and currents. The material subject to such movement is referred to as littoral drift and the movement as littoral transport.

Waves and currents supply the forces necessary to move the littoral materials. The mechanics of littoral transport are not precisely known, but it may be generally stated that littoral material is moved by one of three basic modes of transport.

(1) material, known as "beach drift", moved along the foreshore in a more or less scalloped path due to uprush and back wash of obliquely approaching waves.

(2) material moved principally in suspension in the surf zone by littoral currents and the turbulence of breaking waves.

(3) material moved close to the bottom by sliding, rolling and

saltation, collectively known as "bed load", within and seaward of the surf zone by the oscillating currents of passing waves.

Regardless of the mode of transport, the direction and rate of littoral drift depend primarily upon the direction and energy of waves approaching the shore. Exceptions exist on short reaches of shore adjoining tidal inlets where the tidal currents pattern may be dominant.

Wherever sandy beaches exist or where the surf zone and near shore bottom are composed of sand, the grain size of material decreases generally as the water depth increases until depths are reached where normal wave currents are incapable of moving bed material. The coarsest material is usually found in the surf zone in the vicinity of the plunge point of waves, though in protracted periods of mild wave action the foreshore and surf zone material may be nearly equal in size.

This graduation of grain sizes along the beach profile is due to the process of slope sorting of beach materials. Slope sorting is ascribed generally to the differential velocity in the oscillating wave currents in shallow water. Where the slope becomes sufficiently steep, gravity counterbalances the current effect and an equilibrium condition results.

The three main natural sources of material for any beach segment are:

(a) material moving into the area by natural littoral transport from adjacent beach areas.

(b) contributions by streams.

(c) contributions through erosion of coastal formations, other than beaches, exposed to wave attack.

In addition, there may occasionally be some long range net movement of material onshore apart from normal seasonal or other periodic fluctuations. The latter might occur, for example, with permanent or semipermanent changes in water level. Considering coasts as a whole, maintenance of beaches must be attained at the expense of erosion of the land mass. For any individual segment of beach, the largest source of material moving into the area is generally littoral drift eroded from the adjoining updrift segment unless some major sediment bearing stream enters the segment in question or cliff or dune erosion is sufficiently rapid to provide appreciable supply.

The amount of the various contributions to the littoral supply streams carrying sand can be determined approximately by these general methods:

(a) direct measurements.

(b) studies of terrestrial sedimentation.

(c) computation of the sediment carrying capacity of the streams.

To date, the only method upon which any great degree of reliance can be placed is that of direct measurements.

Eroding coastal formations are the last major source of beach material. Along much of the sea coast it is relatively unimportant. As long as a beach berm is maintained between the formation and the action of the waves, such a formation contributes negligibly to the littoral supply. At some locations, littoral transport has been interrupted by artificial barriers and the ocean has turned to the upland for its supply, causing serious recessions of the coast line. The amount of such contribution can only be estimated through comparative surveys, sub-division plot maps, property surveys, and statements of long-time residents of an area. In shore areas containing bluffs, rises in the water level may allow waves to attack the bluffs, which are generally of a friable material. This causes recession of the shoreline and contributes to the supply of potential beach material. However, the formations frequently contain much material too fine to remain on the beach. When most of the potential beach material is fine sand, silt or clay, once it is in the littoral drift it is only deposited in deep water and cannot contribute to a protective beach.

Certain losses of littoral drift from a shore area tend to accelerate shore erosion. The principal avenues of loss of littoral material from a specific beach area include:

(a) movement of material laterally out of the area.

(b) movement of material offshore into water of sufficient depth that it is lost to the littoral supply.

(c) loss of material into submarine canyons.

(d) loss of material inland.

The movement of materials out of the area is measured by the net rate of transport at the downdrift end of the beach segment under study. At best this is a rough estimate because the unknown factors of added supply and losses throughout the area must also be taken into consideration.

It has been observed that changes in the shore profile occur with changes in water depth or in wave characteristics. Profile adjustment due to change in water depth is relatively slow and therefore, minor with respect to single tidal cycles. A single storm of a few hours may cause a major change in profile. The continual onshore and offshore shifting of material results in a longshore movement of material at a sluggish rate and may be classed as a type of transport, the relative importance of which is unknown at this time.

The existence of a submarine canyon or a more modest depression in the littoral zone provides a repository for important losses of material into the offshore depths. When combined with a jetty or breakwater, the submarine canyon may constitute an essentially complete littoral barrier by drawing off all material passing around the jetty or breakwater.

When a beach widens and the expanse of permanently dry sand increases, the losses by deflation or removal by wind action increase and generally result in the development of a dune belt immediately behind the beach. Rates of loss by deflation are generally difficult to determine. In some instances loss can be determined by measurement of the changes in dune size between successive surveys.

Appendix E

METHODS OF CONTROLLING SHORE EROSION

When depletion exceeds accretion, shores may be stabilized by aggressive measures or by defensive measures; sometimes a combination of both will provide the best solution. Construction of groins or jetties for the entrapment of sand from littoral drift is the most common aggressive measure. Beach nourishment, or placement of sand on protective beaches, has been feasible in Delaware and other places. Defensive measures include construction of seawalls and bulkheads, sloping and terracing of banks, and modification of vegetative cover. Because of the high cost of protection against storm it seems likely that shore front property owners will always have to accept a calculated risk for damage from extremely severe storms.

In selection of the shape, size, and location of protective works, the objective should be to design an engineering work which will accomplish the desired results most economically and with full consideration of its effects on adjacent shore lines. The cost of maintenance, as well as interest on and amortization of first costs, must always be evaluated. A convenient yardstick for comparing various plans is the total cost per year foot of shore protected.

The following sections describe the most common engineering solutions now used to meet functional requirements and give guides for their application.

Seawalls, bulkheads, and revetments are structures placed parallel, or nearly parallel to the shore line, separating a land area from a water area. Primary purpose of a bulkhead, is to retain or prevent sliding of the land, with a secondary purpose of affording protection to the banks against damage by wave action. The primary purpose of a seawall or revetment is to protect the land and upland structures from wave forces, with incidental functions as as retaining wall or bulkhead. There is normally a distinction between the three structures; however, many cases exist where the same type of structure bears different names in different localities. Thus, it is difficult to say whether a stone or concrete facing designed to protect a vertical bank is a seawall or a revetment and often just as difficult to determine whether a retaining wall subject to wave action should be termed a seawall or bulkhead. All these structures, however, have one feature in common in that they separate land and water areas. They are generally used where it is necessary to maintain the shore in an advanced position relative to that of adjacent shores, where there is a scant supply of littoral material to the area and little or no protective beach, as along an eroding slope, or where it is desired to maintain a depth of water along the shore line as for a wharf.

Seawalls, bulkheads and revetments afford protection only to the land immediately behind them and none to adjacent areas up or down coast. When these structures are built on a receding shore line, recession will continue down drift. In addition, any tendency for loss of beach material in front of such a structure may well be intensified; where it is desired to maintain a beach in the immediate vicinity, companion works may be necessary.

The planning of these structures is a relative simple process, since their functions are restricted to the maintenance of fixed boundaries. The features which must be analyzed in adequately planning such a structure are its use and its overall shape, its location with respect to the shore line, its length, its height, and often the ground level in front of the wall.

The shape to be chosen must be determined by consideration of desired collateral uses. Face profile shapes may roughly be classed as vertical or nearly vertical face, sloping face, convex curved face, concave curved or reentrant face, and stepped face. Each silhouette has certain functional applications and so may be used in combination with any other if diverse functional criteria are to be met.

A vertical or nearly vertical face structure lends itself to use as a quay wall or landing place where other shapes need to be provided with additional work to be so adapted. In addition, especially where a relatively light structure is required, a vertical face (of sheet pile, for example) may often be constructed more quickly and more cheaply than any other type. This may be an important consideration where emergency protection is needed. Against wave attack, and specifically in regard to reduction of overtopping, a vertical face is more effective than any but the concave curved and reentrant face.

A backward sloping or convex curved face is the least effective of all types against wave attack for a given height of structure. It is, however, more adaptable to use as emergency protection, (sand bag, or dumped stone mounds, for example) than the other types. Actually the use of such a face type should be restricted to those areas in which wave overtopping is not a problem or where esthetic, emergency, or structural considerations prohibit the use of other shapes.

Concave curved or reentrant faced structures are the most effective in reducing wave overtopping to a minimum. Where the crest of the structure is to be used (for a roadway or promenade, for example), a wall so designed will be the most desirable shape for protecting the crest. This is especially true if the beach in the vicinity is narrow or entirely absent or if the water level is over the base of the structure.

A stepped face provides the most ready access to beach areas from protected areas and in addition acts to disrupt the scouring action of the wave backwash.

In general, a seawall or bulkhead would be constructed along that line landward of which recession of the shore line is not to be permitted. Where an areas is to be reclaimed, a wall may be constructed along the seaward edge of the reclaimed area. (A seawall constructed in the water, isolated from shore, becomes an offshore breakwater).

A seawall, bulkhead or revetment protects no more than the land and improvements immediately behind it. No protection is afforded either to upcoast or downcoast areas as is the case with beach fills. It must be emphasized that in the usual case where erosion may be expected to occur at either end of a structure, wing walls or tie-ins to adjacent land features must be provided to prevent flanking and progressive failure of the structure from the ends. Short term beach changes due to storms, as well as seasonal and annual changes, must be considered. Changes updrift from such a structure will continue unabated after the wall is built, and downdrift, these changes will be, if anything, intensified.

Any of these structures can be built to such a height that no water would overtop them regardless of wave attack though it is not ordinarily economically feasible to do so. At present, there are no entirely adequate overtopping criteria. Tests relating to quantity of overtopping water to various wave parameters have been carried out by the Beach Erosion Board. Data taken during these tests make it possible to obtain some quantitative solutions to specific problems dealing with vertical walls.

Bulkheads so located as to have a permanent beach berm to protect them from the direct impact of the waves may have their crest height reduced to a minimum of two feet above the height of maximum wave uprush or to the height of fill the bulkhead is designed to retain. Note, however, that some seemingly permanent protective beaches have been scoured, under certain storm conditions, to the point where little or no protection was afforded.

Seawalls and revetments are usually built to protect the upland area from the effects of continuing erosion as well as to protect shore improvements from damage by wave attack. Although the exact nature of the effect of such a wall on the processes of erosion cannot be determined (in certain instances these processes seem to have been halted or reversed), for safety in design they must be considered to continue. An exact determination of the beach profile that will exist after the construction of the wall is impossible; therefore, approximate methods must be relied upon.

As an initial short-term effect, scour may be anticipated at the toe of the structure in the form of a trough, dimensions of which are governed by the type of structure face, the nature of wave attack, and resistance of the bed material. In the case of a rubble mound seawall, the effect of scour is to undermine the toe stone, causing it to sink to an ultimately stable position. This will result in settlement of stone on the seaward face, which may be provided for by overbuilding the cross-section to provide for the settlement. Another method is to provide excess stone at the toe in order to fill the anticipated scour trough. The face of a vertical structure may similarly be protected against scour by use of stone. A gravity wall must be protected from undermining as a result of scour by providing impermeable cut-off walls at the base. As a general rule, the depth of scour trough below the natural bed may be considered as approximately equal to the design wave height. For long-term effects, it is preferable to assume that the structure would have no effect on the erosion regime fronting it. In other words, the structure is designed with the assumption that the beach seaward of the wall would erode in the same manner as if the wall were not there.

Protective beaches are the most effective means of dissipating wave energy and afford the most effective protection for the adjoining upland when they can be maintained to adequate dimensions. In seeking a solution for an erosion problem it is usually advisable to investigate the feasibility of artifically providing and maintaining an adequate beach in addition to any other remedial measures considered. When conditions are suitable for artificial nourishment, long reaches of shore may be protected by this method at relatively low cost as compared with other adequate defensive structures. An equally important advantage is that this treatment directly remedies the basic cause of most erosion problems, that is, a deficiency in natural sand supply, and thereby benefits rather than damages the shore beyond the immediate problem area.

A protective beach may also be provided, under favorable conditions, by properly designed groins. Groin systems should be used with caution for, if the natural supply of littoral material is used to restore or widen a beach, a deficiency in supply is likely in adjoining areas with resulting expansion of the problem area. Detrimental effects of groins may be prevented in most cases by artificial fill in suitable quantity placed concurrently with groin construction. When groins are considered for use in conjunction with artificial fill, it is desirable to carefully evaluate benefits attributable to them to justify their inclusion.

An obvious limitation in providing a protective beach, with or without groins, is the availability of suitable material for the purpose. Also, beach nourishment is usually quite costly per front foot protected when applied to short segments of shore. The cost is not necessarily prohibitive if, by artificial nourishment, the enlargement of a problem area can be prevented. Perhaps, the most serious limitation is that of financing a shore protection system designed to provide protection beyond the immediate problem area.

In planning a protective beach, the first task is to determine the predominant direction of littoral transport and to determine quantitatively the deficiency in material supply in the problem area. This deficiency is the rate of loss of beach material and is the rate at which material supply must be increased to balance the transport capacity of littoral forces so that no net loss will occur. If there is no natural supply available, as may be the case on shores downdrift from a major littoral barrier, the deficiency in supply will be equal to the full rate of littoral transport. If the problem area is part of a continuous and unobstructed sandy beach, it is likely that the deficiency will be relatively small compared with the transport rate.

Comparison of surveys over a long period of time is the only accurate means of determining the rate of nourishment required to maintain stability of shore. Since surveys in suitable detail for volumetric measurements are rarely available at the problem areas, approximations computed from changes in the shore position determined by aerial photographs or any other suitable records are often necessary. For such approximations a rule of thumb equation, wherein one square foot of surface area equals one cubic yard of beach material, appears to provide acceptable values on exposed seacoasts. For less exposed shores this ratio would probably result in volumetric estimates somewhat in excess of the true figure and would thus produce conservative values. The various methods by which the predominate direction of littoral movement may be determined are referred to in Appendix D.

Having established the direction and magnitude of the forces that will operate on a proposed fill, the next problem to be encountered is that of selecting a suitable beach material. Adequate criteria have not yet been established for evaluating the qualities of beach materials. However, some information is now available pertaining to the sorting of beach sands and the relation of grain size to beach slope which may be applied in selecting materials for artificial nourishment. When sand is deposited on a shore, waves operating in the area immediately start a sorting action on the surface layer of the fill moving the finer particles seaward and leaving the coarser material shoreward of the plunge point. This sorting action continues until a layer of coarse particles compatible with the wave spectrum of the area armors the beach and renders it relatively stable. However, if the armor is broken by a storm, underlying material is again subjected to the sorting process. The sorting process permits use of beach fill materials containing substantial proportions of material other than sand with assurance that natural processes will clean the sand and make it an entirely suitable material for nourishment. This has been confirmed by experience with such fills in California and in Florida, both of which contained foreign matter.

Material finer than that occupying the natural beach will, when placed on the surface, move seaward to a depth compatible with its size. Materials of coarser characteristics may be expected to produce a steeper than normal beach. Almost any source of borrow near the shore will produce some material of proper beach size. Since the source of artificial nourishment will control the cost to a major degree, evaluation of material characteristics is an important factor in economic design. At present such evaluation must be made largely on a basis of experience at other localities.

If the beach fill is placed at an elevation lower than the natural crest height, a ridge will subsequently develop. Concurrent high water stage and high waves will overtop the ridge and cause ponding and temporary flooding of the backshore. Such flooding, if undesirable, may be avoided by fixing the berm height slightly above the natural beach crest height. If there is an existing beach at the site, the natural crest height can be determined therefrom. Otherwise, determination must be made on a basis of comparison with other sites possessing similar exposure characteristics and beach material. There is at present no acceptable theoretical basis for predicting beach crest height.

Criteria for specifying berm width depends upon a number of factors. If the purpose of the fill is to restore an eroded beach damaged by a major storm, berm width may be determined from the protective width which experience had demonstrated to be required. Where beach fill is to serve as a stockpile, to be periodically replenished, berm width should be sufficient to provide for expected recession during intervals between replenishment. Generally the toe of fill of a stockpile beach should not extend to such depth that transport of any material forming the surface of the fill would be retarded. There are no firm specifications for this limiting depth at present but available data indicate that depths of twenty feet below low water datum on seacoasts may be used. It is obvious that the initial overall slope of any beach fill must be steeper than that of the natural shore area upon which it is placed. Subsequent behaviour of the slope depends principally upon the characteristics of the fill material. In ordinary practice the initial fill slope is designed parallel to the local or comparable natural beach slope above low water datum and thence slopes of 1:20 to 1:30 from low water datum to intersection with the existing bottom. It is undesirable and unnecessary to grade beach slopes artifically below the berm crest for they will be naturally shaped by wave action.

The length of a stockpile beach may vary greatly depending upon local conditions. Lengths from a few hundred feet to a mile have been employed successfully. Since the updrift end of a stockpile beach will be depleted first, long stockpiles are usually most suitable where a bulkhead or seawall exists to protect the backshore as erosion progresses along the stockpile. In general, dimensions of the stockpile will be governed primarily by economic considerations involving comparisons of costs for varying replenishment intervals.

Sand dunes perform the function of beach fills in preventing waves from reaching the upland but are located landward of the beach itself. A belt of sand dunes will provide effective protection to improve upland property locations which have an adequate natural supply of sand and which are subject to inundation by storm tides and high seas; a belt of sand dunes may provide more effective protection and at lower cost, than either a bulkhead, seawall or revetment.

The problem of dune control resolves itself into two fundamental objectives: (1) the stabilization and maintenance of sand dunes at locations where they exist naturally, and (2) the inducement of dune formation where they do not exist naturally, by the direct and permanent stoppage or impounding of sand before the location to be protected, and the stabilization of the dune formation after its creation.

Wind blown sand accumulates in several distinctive ways and characteristic forms. Any appreciable accrual is loosely termed a dune. According to the most generally accepted definition, a true dune is one capable of moving freely as a unit and existing independently of any fixed surface structure. The loose definition is used herein. Sand accumulations caused directly by fixed obstructions in the path of the wind, unlike true dunes, are dependent for their continued existence on the presence of the obstacle which causes and fixes them so they cannot move away.

When an object is placed so as to interrupt wind flow, the air path in front and behind the obstacle is divided into two parts by a somewhat ill-defined surface of discontinuity. Outside this surface the air stream flows smoothly by; the volume within the wind shadow of the obstacle is filled with swirls and vortices of air whose average forward velocity is less than that of the air stream outside. Downwind from the obstacle, forward velocity of the air inside the shadow gradually increases to merge with the general flow of the wind. The sand grains which strike the obstacle rebound from it and come to rest in the relatively stagnant air in front. When the resulting heap has grown up so that its slopes stand at the limiting angle of repose (about 34°), all additional material slides down the slope to join the sand stream passing along the side of the obstacle.

Sand fences can be constructed in movable sections or made of individual pickets driven into the sand. The width and length of the pickets may vary but the spacing of the pickets is important, with no more than 50 percent of the surface covered. For best results the space between the pickets should equal the width of the pickets. In order to widen the crest of the dune and facilitate establishment of vegetation, two lines of fence about 30 feet apart should be used. The use of a single fence tends to make dunes with a sharp crest unfavorable to establishment of cover. As the dune builds up on the fence, the fence can be raised until the desired height is attained. The belt can be broadened by shifting the second fence windward as the dune grows or by adding a third fence.

The sand fences should be constructed perpendicular to the prevailing wind direction unless it is desired to cause the sand to move longitudinally along the fence to fill in the low gaps. In this case the fences may be built slightly quartering to the general shifting direction of the sand movement or panelling may be resorted to.

Coats of hot crude oil may be used to stabilize the face of the dune and cause the dune to widen. Penetration is deeper when the upper few inches of sand are dry. Oiling is expensive and special equipment is necessary for highest efficiency. Oiling is effective for only a few years and must be repeated frequently. Oiling increases the saltation coefficient of material flowing over the surface. The sand blows up and over the top, depositing in front of the slip face in successive advancing fill increments. This widening of the dune continues until a streamlined body is built downwind from the paved face. The entire mass is permanently stored as long as the oiled surface remains intact.

After protective dunes have been formed they should be stabilized with vegetation. This is expensive in the beginning but minimizes future difficulty. The most satisfactory plants are long lived perennials, with extensive root systems, that spread rapidly either vegetatively or by seed or both, and maintain surface growth even though sand is accumulating around them to increasing depths. Such plants are not numerous but in practically every section a few satisfactory ones are obtainable at reasonable costs. Information on best adapted grasses is available from Agricultural Extension and Soil Conservation Service personnel.

Usually grasses are available and can be transplanted from naturally established plantings. Transplanting is most satisfactory by using small clumps ½ to 1 inch in diameter, setting about 8 to 10 inches deep in staggering rows with plants in rows about 18 inches apart. Staggering the rows prevents direct wind action over long areas and offers more opportunity to hold sand than straight line planting. Dunes are low in fertility and contain practically no organic matter. Nitrogeneous fertilizers are stimulating and, while not effective very long in the sand, they are of benefit in inducing vigor and enabling newly set plants to get firmly established the first year. The use of coarse fertilizers such as manure, is generally not practicable because its effect is so slow that little of its value would be realized.

Brush barriers may be used effectively to control the sand on newly filled areas while grasses, shrubs, or trees are gaining a foothold. These barriers are usually built in rows 4 feet apart, crosswise with the prevailing wind, about 2 feet high, 1 to 2 feet wide, and anchored firmly with stakes. Any kind of brush will suffice, although evergreen material is most satisfactory.

A groin is a shore protective structure devised to provide, build or widen a protective beach by trapping littoral drift or to retard loss of an existing beach. It is usually perpendicular to the shore, extending from a point landward of possible shore line recession into the water a sufficient distance to stabilize the shore line at a desired location. Groins are relatively narrow in width (measured parallel to the shore line) and vary in length from a few feet to several hundred feet. Groins differ from jetties in that jetties generally are larger with more massive component parts and are used primarily to direct and confine the stream or tidal flow at the mouth of a river or entrance to a bay and to prevent littoral drift from shoaling the channel. In some sections of the country groins are commonly referred to as jetties or piers.

A groin interposes a total or partial barrier to littoral drift moving in that part of the littoral zone between the seaward end of the groin and the limit of wave uprush. The extent to which littoral drift is modified depends on height, length, and permeability of the groin. The manner in which a groin operates to modify the rate of littoral drift is approximately the same whether it operates singly or as one of a system, provided spacing between adjacent groins is adequate. However, under some conditions a single groin or the updrift groin of a system, may have a somewhat smaller capacity than other individual groins of the system.

The groin acts as a partial dam to intercept a portion of normal drift. As material accumulates on the updrift side, supply to the downdrift shore is correspondingly reduced causing it to recede. This process results in a progressively steepening slope on the updrift side and a flattening slope on the downdrift side as both slopes reach a common elevation at or near the end of the groin. Since the grain size of the beach material normally increases to establish a steeper than normal slope, the accreted material is the coarser fraction of the material that was in transport.

When the accreted slope reaches ultimate steepness for the coarser fraction of the material available, impoundment ceases and all littoral drift passes the groin. If the groin is sufficiently high that no material may pass over it, all transport must be in depths beyond the end of the groin. Because of the nature of transporting currents the material in transit does not move directly shoreward after passing the groin, and transport characteristics do not become normal for some distance on the downdrift side of the groin. Thus, a groin system too closely spaced would divert littoral transport offshore rather than create a widened beach.

The accretion fillet on the updrift side of the groin creates a departure from normal shore alignment, tending toward a stable alignment perpendicular to the resultant forces of wave attack.

Groins may be classified as permeable or impermeable, high or low, and fixed or adjustable. They may be constructed of timber, steel, stone, concrete, or other materials, or combinations thereof. Impermeable groins have a solid or nearly solid structure which prevents littoral drift passing through the structure. Permeable groins have openings through the structure of sufficient size to permit passage of appreciable quantities of littoral drift. Some permeable stone groins may become impermeable with heavy marine growth. A series of groins acting together to protect a long section of shore line is commonly called a groin field. "Groin system" is a preferable term.

Many types of permeable groins have been employed in efforts to avoid the abrupt offset in shore alignment which normally occurs at impermeable groins. The primary effect of permeability is to reduce the impounding capacity, which can ordinarily be accomplished at less cost with a properly designed impermeable groin. An important disadvantage of permeable groins is their relative ineffectiveness in holding a beach under storm conditions. As a means of river bank control, where sediment transport results from ordinary current flow, their value is well established. (Such structures are normally called permeable dikes.) Where wave action is the principal cause of transportation, permeable groins are unlikely to prove fully satisfactory as a shore protection measure.

The amount of sand passing a groin depends to some extent on the height of the groin. Groins based on a headland or reef or at the entrance to a bay or inlet, where it may be either unnecessary or undesirable to maintain a sand supply downdrift of the groin, may be built to such a height as to block completely the passage of material moving in that part of the littoral zone covered by the groins. Where it is necessary to maintain a sand supply downdrift of a groin, it may be built to such a height as to allow overtopping by storm waves or by waves at high tide. Such low groins serve the same purpose as that intended by designers of permeable groins.

The majority of groins are fixed or permanently built structures. In England, the Case and Du-Plat-Taylor adjustable groins have been used with reported success. These groins are essentially adjustable batter boards between piles, with a raising and lowering system so that the groin can be maintained at a fixed height (usually one to two feet) above the sand level and allow a considerable part of the sand to pass over the groin and maintain the downdrift beach. Adjustable groins are reported to be particularly useful where an attempt is being made to widen a beach with a minimum of erosion damage to the downdrift area. However, they are effective only where there is an adequate supply of littoral material.

The width and side slope of a groin depend on wave forces to be withstood, the type of groin, the materials with which it is constructed, and the construction methods used. These features are considered under structural design. The length, profile and spacing are important considerations with respect to functional success.

The length of a groin is determined by the depths in the offshore area and the extent to which it is desired to intercept the littoral stream. The length should be such as to interrupt such a part of the littoral drift as will supply enough materials to create the desired stabilization of the shore line or the desired accretion of new beach areas. Care must be exercised that these ends are attained without a corresponding damage to downdrift areas. For functional design purposes, a groin may be considered in three sections:

(a) The horizontal shore section

(b) the intermediate sloped section,

(c) the outer section.

The horizontal shore section would extend from the desired location of the berm crest as far landward as is required to anchor the groin to prevent flanking. The height of the shore section depends on the degree to which it is desirable for sand to overtop the groin and replenish the downdrift beach. The minimum height of the groin is the height of the desired berm, which is usually the height of maximum high water that occurs frequently plus the height of normal wave uprush. The maximum height of groin to retain all sand reaching the area (a high groin) is the height of maximum wave uprush during all but the least frequent storms. This section is horizontal or sloped slightly seaward, paralleling the existing beach profile or the desired slope, in case a wider beach is desired or a new beach is to be built.

The intermediate sloped section would extend between the shore section and the more or less level outer section. This part of the groin should approximately parallel the slope of the foreshore the groin is expected to maintain. The elevation at the lower end of the slope will usually be determined by the construction methods used, the degree to which it is desirable to obstruct the movement of the material, or the requirements of swimmers or navigation interest.

The outer section includes all of the groin extending seaward of the sloped section. With most types of groins, this section is horizontal at as low an elevation as is consistent with economy of construction, since it will be higher than the design updrift slope in any case. The length of the outer section will depend upon the design slope of the updrift beach.

The spacing of groins in a continuous system is a function of length of the groin and the expected alignment of accretion fillet. The length and spacing must be correlated so that when the groin is filled to capacity the fillet of material on the updrift side of each groin will reach to the base of the adjacent updrift groin with sufficient margin of safety to maintain the minimum beach width desired or prevent flanking of the updrift groin.

Before the total length of a groin and the position of the shore line adjacent to a groin can be determined, it is necessary to predict the ultimate stabilized beach profile on each side of the groin. The steps involved for a typical groin are:

(a) Determine the original beach profile in the vicinity of the groin.

(b) Determine the conditions of littoral transport.

(c) Plot a refraction diagram for the mean wave condition, i.e. the wave condition which would produce the predominant direction and net rate of littoral drift.

(d) Determine the minimum width beach desired updrift of the groin. This may be a width desired to provide adequate recreational area, adequate protection of the upland area, or in the case of a groin system, adequate depth of beach at the next groin updrift to prevent flanking of this groin by wave action.

(e) The slope of the ground line from the crest of the berm seaward to about the mean low water line will depend upon the gradation of the beach material and the character of the wave action.

Examples of almost every conceivable groin alignment may be found and advantages are claimed by proponents of each type. Based on the theory of groin operation, which established the depth to which the groin extends as the critical factor affecting its impounding capacity, maximum economy is achieved with a straight groin perpendicular to the shore line. Various modifications such as a "T" or "L" head usually designed with the primary purpose of limiting recession on the downdrift side of a groin. While these may achieve the intended purpose in some cases, the zone of maximum recession is often simply shifted to a point some distance away from the groin (on the downdrift side) and benefits are thus limited. Storm waves will normally produce greater scour at the extremities of "T" or "L" head structures than at the end of a straight groin perpendicular to the shore and delaying the return to normal profile after storm conditions have abated.

Curved, hooked or angle groins have been employed for the same purposes as the "T" or "L" head types and have the same objectionable features; that is, they invite excessive scour and are more costly to build and maintain than the straight groin perpendicular to the shore. In cases where the adjusted shore alignment expected to result from a groin system will differ greatly from the alignment at the time of construction, it may be desirable to align the groins normal to the adjusted shore alignment in order to avoid angular wave attack on the structures after the shore has stabilized. This condition is most likely to be encountered in the vicinity of inlets and along the sides of bays.

The sequence of groin construction is of concern only to sites where a groin system is under consideration. Here two conditions arise:

(1) where the groin system will be filled artificially and it is necessary to stabilize the new beach in its advanced position.

(2) where littoral transport is depended upon to make the fill and it is necessary to stabilize the existing beach or build additional beach with a minimum of detrimental effect on downdrift areas.

In the first instance the only interruption of littoral transport will be between the time the groin system is constructed and the time the artificial fill is made. In the interests of economy the fill is normally placed at one time, especially if it is being accomplished by hydraulic dredge. Accordingly, to reduce the time interval between groin construction and deposition of fill, all groins should be constructed concurrently or as rapidly as practicable if constructed consecutively. Deposition of fill should commence as soon as construction will permit.

In the second instance no groin can fill until all of the preceding updrift groins have been filled. The time required for the entire system to fill and the material to resume its unrestricted movement downdrift may be such that severe damage will result. Accordingly, only the groin or group of groins at the downdrift end should be constructed initially. The second groin or group should not be started until the first has filled and material passing around or over the groins has again stabilized the downdrift beach. Although this method may increase costs, it will not only aid in holding damage to a minimum but will verify the design spacing and permit modification if necessary.

In an analysis of the forces exerted on structures by waves, a division should be made between the action of non-breaking waves, breaking waves, and broken waves. Pressures due to non-breaking waves will be essentially hydrostatic. Broken and breaking waves exert additional pressures due to the dynamic effects of the turbulent water in motion and the compression of entrapped air pockets. These pressures may be much greater than those due entirely to hydrostatic forces. Therefore, structures located in an area in which storm waves may break should be designed to withstand much greater forces and moments than those structures which would be attacked only by non-breaking waves. Ordinarily, bulkheads and seawalls are located so that storm waves may break directly on them. Even those structures which are located landward of the low water shore line may be exposed to the action of breaking waves at times of high water.

Each unit of shore line has its inherent physical characteristics: the range of tide, littoral transport, beach composition, wave characteristics, tidal currents, marine borers, and beach dimensions and slope. Other factors to be considered include beach and upland topography, the character of the foundation, the availability and cost of construction materials, maintenance costs, economic life, and the use made of the upland areas. After planning considerations have indicated that use of groins is practicable, the selection of groin type is affected in overlapping and varying degrees by the foregoing inter-related factors.

With consideration to beach and upland topography, a steep beach is an indication of heavy wave action and generally requires substantial structures, usually of concrete, stone, or steel. Under these conditions light timber groins will not be adequate seaward of the crest of berm. However, timber can be used for the inshore section above the crest of berm if the beach is backed by sandy areas, such as sand dunes. On gently sloping beaches, lighter construction of timber, steel, or concrete generally can be used except in the vicinity of inlets. A thorough consideration of foundation materials is essential to the selection of groin type. Borings and probings should be taken to determine subsurface conditions for penetration of piling. Where the foundations are poor or where little penetration is possible, some type of cellular or stone groin may be indicated despite its greater cost. Good penetration may indicate the economy of sheet piling, provided materials are available.

Availability of materials affects selection of type because of the economic aspects. The material which would normally be the most economic with full consideration given to life of the material and maintenance costs is not available except at a cost that would make some other material or type of construction more economical. The first costs of timber groins and of steel sheet pile groins are often less than for other types of construction. The concrete groin is considerably more expensive than timber but often costs less than the massive stone groin. However, concrete and stone groins require less maintenance and have much longer economic life than the timber or steel sheet pile groins. These factors, the amount of funds available for initial construction, the annual charges, and the period during which protection will be required must all be studied before deciding on a particular type.

It is sometimes desirable to nourish beaches downdrift from a natural or artificial barrier within the littoral zone, the trapped material acting as a source of supply. Such a littoral barrier may be a jettied entrance to a harbor, a natural inlet, an offshore breakwater, or a shore connected breakwater. A sand by-passing plant is a plant designed to mechanically transport littoral drift past a barrier to a point on the downdrift shore from which it will again be moved by natural forces. Several methods for by-passing sand have been considered with a view to reducing the cost of the operation:

a. Fixed land-based dredging plants

b. Portable land-based dredging plants

c. Eductor method with a fixed plant

d. Floating plant.

MISCELLANEOUS DESIGN PRACTICES

The more important lessons learned from experience on the deterioration of concrete and steel and timber waterfront structures may be summarized as follows:

a—The elimination of bracing within the tidal zone to the maximum practicable extent is desirable, since maximum deterioraation occurs in that zone.

b—Round members, because of their smaller area and better flow characteristics for wave action, generally have a longer life than other shapes.

c—All steel or concrete deck framing should be located above normal spray level.

d—Untreated timber piles should never be used in waterfront structures unless located below the permanent wet line and protected from marine borer attack.

e—The most effective injected preservative appears to be creosote oil having a high phenolic content. For piles subject to marine borer attack a maximum penetration of creosote-coal tar solution is recommended.

f—Salt-treated timber gives satisfactory service when protected from the weather.

g—Boring and cutting of piles after treatment should be avoided, and where unavoidable, cut surfaces require field treatment.

h—Single timber caps have a longer life than pairs of cap timbers dapped into the piles.

i—Untreated timber piles when encased in a gunite armor and properly sealed at the top will give economical service.

j—Concrete to last in the tidal zone must have a high cement content; a minimum of 6½ bags per cubic yard is recommended.

k—The lower the water-cement ratio, the more durable concrete will be in salt water.

l—Care must be exercised in the selection of coarse and fine aggregates both for density of grading and to avoid unfavorable chemical reaction with the cement.

m—Maintenance of specified clear cover over all reinforcing steel is of the greatest importance.

n—Smooth formwork and rounded corners improve the durability of concrete structures.

o—All steelwork in and above the tidal range will last longer if protected. A good method is to provide a concrete envelope.

Appendix F

MARYLAND LAWS PERTAINING TO SHORE EROSION

The investigation and recommendation of plans and policies for protection of the waterfront and waterways from erosion is assigned to the Department of Geology, Mines and Water Resources, in Section 16, subsection (7), Article 66c, Annotated Code of 1957. This legislation was enacted in 1941 and assigned the functions of the Maryland Waterfront Commission to the Department of Geology, Mines and Water Resources.

The powers of the various county commissioners in the state are set forth and defined in the Annotated Code of Maryland, (1957 Edition) Article 25, Sections 161 through 167.

Under the provisions of this Article, land which is subdivided for either residential or business uses and which abuts and borders upon the Chesapeake Bay or its tributaries is created as a separate taxing and assessment district. The name of the district shall be the same as the subdivision out of which it is created. The county commissioners are authorized and empowered to act as district council of each district and may use all of their normal powers and authority as the district council. The commissioners are specifically given the power of condemnation to acquire any land or building deemed necessary for the construction of erosion prevention works.

The district council is authorized to act as such where 75 per cent of the property owners in a district petition them to do so. The council shall thereafter provide the necessary engineering work. In order to finance the erosion prevention projects the commissioners, acting as district council, are authorized to borrow money upon the full faith and credit of the taxing and assessment district secured by notes or bonds, not to exceed thirty years and guaranteed by the county in which the taxing and assessment district is located.

When plans and specifications for construction of erosion prevention works shall have been completed, the county commissioners shall notify the property owners affected that the plans may be inspected and the probable cost of such project. The property owners shall also be notified of the date of a public hearing on the project. Following the hearing, the district council shall decide whether or not to proceed with the erosion prevention works. If the project is approved, a contract is advertised, bid and let in the same manner as other types of construction work.

After any such project is completed, the district council shall fix and levey a benefit charge upon the real property benefited by the erosion prevention works. Before assessing the benefit charge, the district council shall hold a hearing for owners of benefited lands. After the hearing the district council shall determine the benefits accruing to each parcel of land and shall fix and levy a benefit charge to the extent it is benefited by the construction work. This benefit charge shall be a lien upon the real estate and shall be levied for a period of years coextensive with the period of maturity of the notes or bonds. In addition to the benefit charge there shall be levied upon all properties in the district a tax which, together with the benefit charge, shall be sufficient to pay for retirement of bonds, interest thereon, maintenance of construction and administration expenses. This tax shall be collected in the same manner similar as other taxes collected by the county. If the funds collected in one year be insufficient to pay all the obligations, then such deficiency shall be added to the following year's levy.

In 1959 the legislature provided an alternative method in financing an erosion control works on a county-wide basis. Under this alternative method the county commissioners may pay up to 25 per cent of the costs of any erosion control project by issue of bonds or notes. The commissioners are authorized to accept from either the State of Maryland or the Federal Government any portion or all of the remaining 75 per cent of the total cost. The principal and interest of any bond or note shall be paid by a county-wide tax. If this alternative provision is used, the county commissioners shall not be constituted as a district council.

Article 66B of the Annotated Code of Maryland authorizes the counties of the state to set up planning commissions. Where such a commission has been established, it is required to adopt regulations for the control of subdivision development. After official adoption of such regulation, all new subdivision plats must be submitted for approval by the planning and zoning commission and their approval must be given to the plat of a proposed subdivision before recordation can be made among the land records of the county. Subdivision regulations may provide for arrangements of streets, for adequate open spaces for traffic, utilities, access of fire fighting apparatus, recreation, light and air, and for the avoidance of conjunction of population including minimum width and area of lots. Such regulations may include provision that these facilities shall be installed as a condition precedent to the approval of the plat or for a tentative approval of the plat previous to installation.

This enabling legislation does not, as presently written, appear to be broad enough to enable county planning and zoning commissions to require effective erosion control as a condition precedent to approval of the subdivision plat. If the county planning and zoning commissions are to be given power to require erosion control on the same basis that they are able to control other facets of subdivisions, an amendment to present legislation appears necessary.

In 1961 the county commissioners of Worcester County were authorized to regulate destruction of protective sand dunes by prohibiting removal of sand or destruction of protective vegetation except by permit. The Worcester County Commissioners were also authorized to contract with the Corps of Engineers, United States Army, for conduct of shore and beach erosion studies and to use county funds to pay necessary local costs (50%) therefor.

In 1961 the State Roads Commission was authorized to make, or cause studies to be made, for adequate control of shore and beach erosion to protect the highways.

Appendix G

SHORE EROSION CONTROL ACTIVITIES

The State Roads Commission received an appropriation of $20,000 in 1921 for use in protection of the ocean highway adjacent to Ocean City from shore erosion. This amount has been a continuing budget item since that time and has been supplemented to some extent through use of maintenance funds.

The system of treated timber groins constructed by the State Roads Commission extends from the north stone jetty of the Ocean City Inlet northward to Twenty Sixth Street. The structures from the inlet to approximately N. Ninth Street are buried under the higher and widened beach, caused principally by the north stone jetty at the inlet. Those structures northward to N. Twenty Sixth Street are performing creditably and have contributed to the preservation of the shoreline in this area, although it is only in the last several years that the proper spacing between groins has been achieved. In 1960-61, three timber groins were installed between N. Seventy Second and N. Seventy Fifth Streets because a massive change inland in that area threatened damage to the adjacent ocean highway.

From the Delaware line, approximately seven miles southward, an effort was made in 1954-55 to install groins that would be helpful in arresting constant erosion forces which were causing shoreline losses in many areas of this stretch of fine beach. These groins, composed of asphalt and native beach sand, were mounded to a height of approximately three feet above the existing elevation. The seaward end of these units reached to low water in the ocean and generally the inshore ends extended to the dune line or to a higher elevation, whichever was found within 200 feet of the low water in the ocean. These structures, while very economical, suffered losses at the ocean end of the units with few exceptions. However, all of the structures are in evidence and are still contributing to the maintenance of the higher elevation of the beach back to the dune line. These groins did not perform to maximum possible efficiency because their spacing along this seven mile stretch of beach line was nearly 1,000 feet rather than 400 feet, the optimum interval between groins at this location.

All costs of beach protection devices, exclusive of the stone jetty north of the inlet, have been under the direction of the State Roads Commission in connection with the Commission's responsibility for the overall protection of the adjacent Ocean Highway, Maryland State Route 528. It is important that recognition be given to the State Roads Commission's specific responsibility because that agency is not directly charged with the preservation and maintenance of the coastline and beach in the area described.

Plans by the State Roads Commission were on paper prior to 1933 to cut through the sand bar at Ocean City to let fresh sea water into Sinepuxent Bay. This work to nurture oysters and provide harboring facilities for coastal vessels was not necessary since nature provided the inlet in approximately the same location as planned. With the establishment of the inland harbor at Ocean City, maintenance of the inlet for navigation became the responsibility of the Corps of Engineers, United States Army. The Corps of Engineers has maintained jetties north and south of the inlet which direct currents so as to maintain navigability. The north jetty has contributed materially to the widening of the Ocean City Beach. The jetty, together with currents of the inlet, have intercepted southward littoral drift so that the northern part of Assateague Island beach is starved.

In 1933 the Erosion District law, discussed in another section, was passed as a local law for Anne Arundel County. Erosion Districts were formed and by 1936, 29,000 linear feet of shore line had been protected. In 1951 this law was given statewide scope and some protection has been established in Calvert, St. Mary's and Anne Arundel Counties since that time.

The State Department of Geology, Mines and Water Resources initiated studies in 1943 which provided data for Bulletin 6. This report is the only complete study made of shore erosion in the Bay area. Since 1951 this Department has had a budget item of $1,000 for shore erosion studies. Upon request, inspections have been made of problem areas and recommendations prepared for property owners. The highest number of inspections made was 25 in 1961 and the lowest was 9 in 1954. A total of 223 inspections were made in the eleven year period. Few of the recommendations have been carried out except by the Anne Arundel erosion districts because of the inability or unwillingness of individual owners to finance the costs of construction.

About 1955, the State Soil Conservation Committee authorized the expenditure of a few hundred dollars by a Soil Conservation District in one of the Eastern Shore counties. In cooperation with a shore front landowner, a limited trial in low cost protection proved unsatisfactory.

Since 1955 the Agricultural Extension Service Drainage Specialist has made about 15 recommendations for shore erosion control measures on farms where he was doing other work. Only a small portion of these recommendations have been executed.

Many individual property owners attempt, from time to time, to protect their frontage. Varying degrees of success and failure can be observed but far more of the latter. Few protective works have been designed; most have simply been built and "rules-of-thumb" have frequently given poor results.

Under existing law, protection of shore frontage is the responsibility of the individual owner except in sub-divisions where group action is possible through formation of erosion distircts.

Appendix H

GLOSSARY OF TERMS

Compiled by
Walter C. Hopkins

ACCRETION—May be either NATURAL or ARTIFICIAL. Natural accretion is the gradual build-up of land over a long period of time solely by the action of the forces of nature, on a BEACH by deposition of water— or air-borne material. Artificial accretion is a similar build-up of land by reason of an act of man, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means. Also AGGRADATION.

ADVANCE (OF A BEACH)—(1) a continuing seaward movement of the shore line; (2) a net seaward movement of the shore line over a specified time. Also PROGRESSION.

AGE, WAVE—The ratio of wave velocity to wind velocity (in wave forecasting theory).

ALLUVIUM—Soil (sand, mud, or similar detrital material) deposited by flowing water or the deposits formed thereby.

ALONGSHORE—Same as LONGSHORE.

AMPLITUDE, WAVE—(1) in hydrodynamics, one-half the wave height; (2) in engineering usage, loosely, the wave height from crest to trough.

ARTIFICIAL NOURISHMENT—The process of replenishing a beach by artificial means, e.g. by the deposition of dredged materials.

AWASH—(1) (Nautical) condition of an object which is nearly flush with the water level; (2) (Common usage) condition of being tossed about or washed by waves or tide.

BACKBEACH—See BACKSHORE.

BACKRUSH—The seaward return of the water following the uprush of the waves. For any given tide stage the point of farthest return seaward of the backrush is known as the LIMIT of BACKRUSH or LIMIT of BACKWASH.

BACKSHORE—That zone of the shore or beach lying between the foreshore and the coast line and acted upon by waves only during severe storms, especially when combined with exceptionally high water. Also BACKBEACH.

BACKWASH—(1) See BACKRUSH; (2) Water or waves thrown back by an obstruction such as a ship, breakwater, cliff, etc.

BANK—(1) The rising ground bordering a lake, river, or sea, on a river designated as right or left as it would appear facing downstream; (2) An elevation of the sea floor of large area, surrounded by deeper water, but safe for surface navigation; a submerged plateau or shelf, a shoal, or shallow.

BAR—An offshore ridge or mound of sand, gravel, or other unconsolidated material submerged at least at high tide, especially at the mouth of a river or estuary, or lying a short distance from and usually parallel to, the beach.

BAR, BAYMOUTH—A bar extending partially or entirely across the mouth of a bay.

BARRIER BEACH—A bar essentially parallel to the shore, the crest of which is above high water. Also OFFSHORE BARRIER.

BARRIER REEF—A reef which roughly parallels land but is some distance offshore, with deeper water intervening.

BEACH—(n.) (1) The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form . . . or to the line of permanent vegetation (usually the effective limit of storm waves.) The seaward limit of the beach—unless otherwise specified—is the mean low water line. A beach includes FORESHORE and BACKSHORE; (2) Sometimes, the material which is in more or less active transport, alongshore or on-and-off shore, rather than the zone.

BEACH ACCRETION—See ACCRETION.

BEACH, BARRIER—A bar essentially parallel to the shore, the crest of which is above high water level. Also OFFSHORE BARRIER.

BEACH BERM—A nearly horizontal portion of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

BEACH EROSION—The carrying away of beach materials by wave action, tidal currents, or littoral currents, or by wind.

BEACH FACE—The section of the beach normally exposed to the action of the wave uprush.

BEACH FEEDER—An artificially widened beach serving to nourish downdrift beaches by natural littoral currents or forces.

BEACH WIDTH—The horizontal dimension of the beach as measured perpendicular to the shore line.

BENCH MARKS (B.M.)—a fixed point used as a reference for elevations.

BERM, BEACH—A nearly horizontal portion of a beach formed by the deposit of material by wave action. Some beaches have no berms; others have one or several.

BLUFF—A high steep bank or cliff.

BOTTOM—The ground or bed under any body of water; the bottom of the sea.

BOTTOM (NATURE OF)—The composition or character of the bed of an ocean or other body of water; (e.g. clay, coral, gravel, mud, ooze, pebbles, rock, shell, shingle, hard, or soft).

BOULDER—A rounded rock more than 12 inches in diameter; larger than a cobble stone.

BREAKER—A wave breaking on the shore, over a reef, etc. Breakers may be (roughly) classified into three kinds although there is much overlapping: Spilling breakers break gradually over quite a distance; Plunging breakers tend to curl over and break with a crash; and Surging breakers peak up, but then instead of spilling or plunging they surge up the beach face.

BREAKER DEPTH—The still water depth at the point where the wave breaks. Also BREAKING DEPTH.

BREAKWATER—A structure protecting a shore area, harbor, anchorage, or basin from waves.

BULKHEAD—A structure separating land and water areas, primarily designed to resist earth pressures. See also SEAWALL.

BUOY—A float; especially a floating object moored to the bottom, to mark a channel, anchor, shoal rock, etc. Some common types:

- A **nun** or **nut** buoy is conical in shape;
- A **can** buoy is squat, and cylindrical or nearly cylindrical above water and conical below water;
- A **spar** buoy is a vertical, slender spar anchored at one end;
- A **bell** buoy is one having a bell operated mechanically or by the action of waves, usually marking shoals or rocks;
- A **whistling** buoy is similarly operated, marking shoals or channel entrance;
- A **dan** buoy carries a pole with a flag or light in it.

BUOYANCY—The resultant of upward forces exerted by the water on a submerged or floating body, equal to the weight of the water displaced by this body.

CANAL—An artificial watercourse cut through a land area for use in navigation, irrigation, etc.

CANYON—(1) (Oceanographical) A deep submarine depression of valley form with relatively steep sides; (2) (Geographical) A deep gorge or ravine with steep sides, often with a river flowing at the bottom of it.

CAUSEWAY—A raised road, across wet or marshy ground or water.

CHANNEL—(1) A natural or artificial waterway or perceptible extent which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water; (2) The part of a body of water deep enough to be used for navigation through an area otherwise too shallow for navigation; (3) A large strait, as the English Channel; (4) The deepest portion of a stream, bay, or strait through which the main volume or current of water flows.

CLIFF—A high, steep face or rock, a precipice. See also SEA CLIFF.

COAST—A strip of land of indefinite width (may be several miles) that extends from the seashore inland to the first major change in terrain features.

COASTAL AREA—The land and sea area bordering the shore line.

COASTAL PLAIN—The plain composed of horizontal or gently sloping strata of clastic materials fronting the coast and generally representing a strip of geologically recently emerged sea bottom.

COASTAL LINE—(1) Technically, the line that forms the boundary between the COAST and the SHORE; (2) Commonly, the line that forms the boundary between the land and the water.

COMBER—(1) A deep water wave whose crest is pushed forward by a strong wind, much larger than a whitecap; (2) a long-period spilling breaker.

CONTINENTAL SHELF—The zone bordering a continent extending from the line of permanent immersion to the depth (usually about 100 fathoms) where there is a marked or rather steep descent toward the great depths.

CONTOUR—(1) An imaginary line connecting points on a land or submarine surface that have the same elevation; (2) in topographic or hydrographic work, a line connecting all points of equal elevation above or below.

CONTROLLING DEPTH—The least depth of water in the navigable parts of a waterway, which limits the allowable draft of vessels.

COVE—A small sheltered recess in a shore or coast, often inside larger embayments.

CREST LENGTH, WAVE—The length of a wave along its crest. Sometimes called CREST WIDTH.

CREST OF WAVE—(1) The highest part of a wave; (2) That part of the wave above still water level.

CURRENT—A flow of water.

CURRENT, COASTAL—One of the offshore currents flowing generally parallel to the shore line with a relatively uniform velocity (as compared to the littoral currents). They are not related genetically to waves and resulting surf may be composed of currents related to distribution of mass in ocean waters (or local eddies), wind-driven currents and/or tidal currents.

CURRENT, DRIFT—A broad, shallow, slow-moving ocean or lake current.

CURRENT, EBB—The movement of the tidal current away from shore or down a tidal stream.

CURRENT, EDDY—A circular movement of water of comparatively limited area formed on the side of a main current. Eddies may be created at points where the main stream passes projecting obstructions.

CURRENT, FEEDER—The current which flows paralled to shore before converging and forming the neck of a rip current. See also RIP.

CURRENT, FLOOD—The movement of the tidal current toward the shore or up a tidal stream.

CURRENT, INSHORE—A current inside the breaker zone.

CURRENT, LITTORAL—The nearshore currents primarily due to wave action, e.g. **Longshore** currents and **Rip** currents.

DATUM PLANE—The horizontal plane to which soundings, ground elevations, or water surface elevations are referred. Also REFERENCE PLANE. The plane is called a TIDAL DATUM when defined by a certain phase of the tide. The following datums are ordinarily used on hydrographic charts;

MEAN LOW WATER—Atlantic Coast (U. S.)

A common datum used on topographic maps is based upon MEAN SEA LEVEL. See also BENCH MARK.

DECAY OF WAVES—The change that waves undergo after they leave a generating area (fetch) and pass through a calm or region of lighter winds. In the process of decay, the significant wave height decreases and the significant wave length increases.

DEEP WATER—Water of depth such that surface waves are little affected by conditions on the ocean bottom. It is customary to consider water deeper than one-half the surface wave length as deep water.

DEFLATION—The removal of material from a beach or other land surface by wind action.

DEPTH—The vertical distance from the still water level (or datum as specified) to the bottom.

DEPTH OF BREAKING—The still water depth at the point where the wave breaks. Also BREAKER DEPTH.

DIKE (DYKE)—A wall or mound built around a low-lying area to prevent flooding.

DRIFT (noun)—(1) The speed at which a current runs; (a) also, floating material deposited on a beach (driftwood); (3) a deposit of a continental ice sheet, as a DRUNLIN; (4) sometimes used as an abbreviation of LITTORAL DRIFT.

DUNES—Ridges or mounds of loose, wind-blown material, usually sand.

EBB CURRENT—The movement of the tidal current away from shore or down a tidal stream.

EBB TIDE—A non-technical term referring to that period of tide between a high water and the succeeding low water; falling tide.

EMBANKMENT—An artificial bank, mound, dike or the like, built to hold back water, carry a roadway, etc.

EROSION—The wearing away of land by the action of natural forces. (See also SCOUR). On a BEACH, by carrying away of beach materials by wave action, tidal currents, or littoral currents or by the action of the wind (See DEFLATION).

ESTUARY—(1) That portion of a stream influenced by the tide of the body of water into which it flows; (2) A bay, as the mouth of a river, where the tide meets the river current.

FATHOM—A unit of measurement used for soundings. It is equal to 6 feet (1.83 meters).

FETCH LENGTH—In wave forecasting, the horizontal distance (in the direction of the wind) over which the wind blows.

FLOOD CURRENT—The movement of the tidal current toward the shore or up a tidal stream.

FLOOD TIDE—A non-technical term referring to that period of tide between low water and the succeeding high water; a rising tide.

FOLLOWING WIND—In wave forecasting, wind blowing in the same direction that waves are travelling.

FORESHORE—The part of the shore, lying between the crest of the seaward berm (or the upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

FREEBOARD—The additional height of a structure above design high water level to prevent overflow. Also, at a given time the vertical distance between the water level and the top of the structure. On a ship, the distance from the water line to main deck or gunwale.

GROIN—(BRIT. GROYNE)—A shore protective structure to trap littoral drift or retard erosion of the shore. It is narrow in width (measured parallel to the shore line), and its length may vary from a few feet to several hundred feet extending from a point landward of the shore line out into the water. Groins may be classified as permeable or impermeable; impermeable groins having a solid or nearly solid structure, permeable groins having openings through them of sufficient size to permit passage of appreciable quantities of littoral drift.

GROUND SWELL—A long high ocean swell; also, this swell as it rises to prominent height in shallow water.

HEIGHT OF WAVE—The vertical distance between a crest and the preceding trough.

HIGH TIDE: HIGH WATER (HW)—The maximum height reached by each rising tide.

INLET—A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water. An arm of the sea (or other body of water), that is long compared to its width, and that may extend a considerable distance inland.

JETTY—(1) (U. S. usage) An open seacoasts, a structure extending into a body of water, and designed to prevent shoaling of a channel by littoral materials and to direct and confine the stream or tidal flow. Jetties are built at the mouth of a river or tidal inlet to help deepen and stabilize a channel. (2) (British usage) Jetty is synonymous with "wharf" or "pier."

LAND BREEZE—A light wind blowing from the land caused by unequal cooling of land and water masses.

LAND-SEA BREEZE—The combination of a land breeze and a sea breeze as a diurnal phenomenon.

LENGTH OF WAVE—The horizontal distance between similar points on two successive waves measured perpendicularly to the crest.

LEVEE—A dike or embankment for the protection of land from inundation.

LITTORAL—Of or pertaining to a shore, especially of the sea. A coastal region.

LITTORAL DEPOSITS—Deposits of littoral drift.

LITTORAL DRIFT—The material moved in the littoral zone under the influence of waves and currents.

LITTORAL TRANSPORT—The movement of material along the shore in the littoral zone by waves and currents.

LOW WATER LINE—The intersection of any standard low tide datum plane with the shore.

MEAN SEA LEVEL—The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings.

NODAL ZONE—An area at which the predominant direction of the littoral transport changes.

OCEANOGRAPHY—That science treating of the oceans, their forms, physical features, and phenomena.

OFFSHORE (n. or adj.)—(1) In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the continental shelf. (2) A direction seaward from the shore.

OFFSHORE CURRENT—(1) Any current in the offshore zone. (2) Any current flowing away from shore.

ONSHORE—A direction landward from the sea.

PERMEABLE GROIN—See under GROIN.

PIER—A structure, extending out into the water from the shore, to serve as a landing place, a recreational facility, etc., rather than to afford coastal protection.

PILE—A long, slender piece of wood, concrete, or metal to be driven or jetted into the earth or sea bed to serve as a support or protection.

PILING—A group of piles.

PILE, SHEET—A pile with a generally flat cross-section to be driven into the ground or sea bed and meshed or interlocked with like members to form a diaphragm, wall, or bulkhead.

PLUNGE POINT—(1) For a plunging wave, the point at which the wave curls over and falls; (2) The final breaking point of the waves just before they rush up on the beach.

POINT—The extreme end of a cape; or the outer end of any land area protruding into the water, usually less prominent than a cape.

PORT—A place where vessels may discharge or receive cargo; may be the entire harbor including its approaches and anchorages or may be the commercial part of a harbor, where the quays, wharves, facilities for transfer of cargo, docks, repair shops, etc., are situated.

PROFILE BEACH—The intersection of the ground surface with a vertical plane; may extend from the top of the dune line to the seaward limit of sand movement.

PROPAGATION OF WAVES—The transmission of waves through water.

REEF, BARRIER—A reef which roughly parallels land but is some distance offshore, with deeper water intervening.

REFLECTED WAVE—The wave that is returned seaward when a wave impinges upon a very steep beach, barrier, or other reflecting surfaces.

REVETMENT—A facing of stone, concrete, etc., built to protect a scarp, embankment or shore structure against erosion by the wave action or currents.

RIP—A body of water made rough by waves meeting an opposing current, particularly a tidal current; often found where tidal currents are converging and sinking. A TIDE RIP.

RIPRAP—A layer, facing, or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also the stone so used.

RUBBLE—(1) Loose angular water-worn stones along a beach. (2) Rough, irregular fragments of broken rock.

RUN-UP—The rush of water up a structure on the breaking of a wave. Also UPRUSH. The amount of run-up is the vertical height above still water level that the rush of water reaches.

SALTATION—That method of sand movement in a fluid in which individual particles leave the bed by bounding nearly vertically and, because the motion of the fluid is not strong or turbulent enough to retain them in suspension, return to the bed at some distance downstream. The travel path of the particles is a series of hops and bounds.

SAND BAR—(1) See BAR. (2) In a river, a ridge of sand built up to or near the surface by river currents.

SCARP—A more or less continuous line of cliffs or steep slopes facing in one general direction which are caused by erosion or faulting. Also ESCARPMENT.

SCOUR—Erosion, especially by moving water. See also EROSION.

SEA—(1) An ocean, or alternatively a large body of (usually) salt water less than an ocean; (2) Waves caused by wind at the place and time of observation; (3) State of the ocean or lake surface in regard to waves.

SEA BREEZE—(1) A breeze blowing from the sea toward the land; (2) A light wind blowing toward the land caused by unequal heating of land and water masses.

SEASHORE—The SHORE of a sea or ocean.

SEAWALL—A structure separating land and water areas primarily designed to prevent erosion and other damage due to wave action. See also BULKHEAD.

SHORE—The strip of ground bordering any body of water. A shore of unconsolidated material is usually called a BEACH.

SLACK TIDE (SLACK WATER)—The state of tidal current when its velocity is near zero, especially the moment when a reversing current changes direction and its velocity is zero. Sometimes considered the intermediate period between ebb and flood currents during which the velocity of the currents is less than 0.1 knot.

SLIP—A space between two piers, wharves, etc. for the berthing of vessels.

SOUNDING—A measured depth of water. On Hydrographic charts the soundings are adjusted to a specific plane of reference (SOUNDING DATUM).

SPRING TIDE—A tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

STONE—(1) Rock or rocklike matter used as a material for building; (2) A small piece of rock or a specific piece of rock.

STORM TIDE—The rise of water accompanying a storm caused by wind stresses on the water surface.

STREAM—(1) A course of water flowing along a bed in the earth; (2) A current in the sea formed by wind action, water density differences, etc. (Gulf Stream) See also CURRENT, STREAM.

SURF—The wave activity in the area between the shore line and the outermost limit of breakers.

SURF ZONE—The area between the outermost breaker and the limit of wave uprush.

SWAMP (noun)—A tract of wet spongy land, frequently inundated by fresh or salt water, and characteristically dominated by trees and shrubs.

SWAMP (verb)—To overset, sink, or fill up a craft with water.

SWASH—The rush of water up onto the beach following the breaking of a wave. Also UPRUSH, RUN-UP.

SWELL—Wind-generated waves that have advanced into regions of weaker winds or calm.

TIDAL CURRENT—A current caused by the tide-producing forces of the moon and the sun, a part of the same general movement of the sea that is manifested in the vertical rise and fall of the tides. Also CURRENT, PERIODIC. See also CURRENT, FLOOD and CURRENT, EBB.

TIDAL FLATS—Marshy or muddy land areas which are covered and uncovered by the rise and fall of the tide.

TIDAL INLET—(1) A natural inlet maintained by tidal flow; (2) Loosely an inlet in which the tide ebbs and flows. Also TIDAL OUTLET.

TIDAL PERIOD—The interval of time between two consecutive like phases of the tide.

TIDAL POOL—A pool of water remaining on a beach or reef after recession of the tide.

TIDAL PRISM—The total amount of water that flows into the harbor or out again with movement of the tide, excluding any fresh water flow.

TIDAL RANGE—The difference in height between consecutive high and low waters.

TIDE—The periodic rising and falling of the water that results from gravitational attraction of the moon and sun acting upon the rotating earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as TIDAL CURRENT, reserving the name tide for the vertical movement.

TIDE, EBB—That period of tide between a high water and the succeeding low water; falling tide.

TIDE, FLOOD—That period of tide between low water and the succeeding high water; a rising tide.

TIDE, SLACK—The state of a tidal current when its velocity is near zero, especially the moment when a reversing current changes direction and its velocity is zero. Sometimes considered the intermediate period between ebb and flood currents during which the velocity of the currents is less than 0.1 knot. See TIDAL STAND. Also SLACK WATER.

TIDE, SPRING—A tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

TIDE, STORM—The rise of water accompanying a storm caused by wind stresses on the water surface.

TOPOGRAPHY—The configuration of a surface including its relief, the position of its streams, roads, buildings, etc.

TROUGH OF WAVE—The lowest part of a wave form between successive crests. Also that part of a wave below still water level.

UNDERTOW—A current, below water surface, flowing seaward; also the receding water below the surface from waves breaking on a shelving beach. Actually "undertow" is largely mythical. As the backwash of each waves flows down the beach, a current is formed which flows seaward; however, it is a periodic phenomenon. The most common phenomena expressed as "undertow" are actually the rip currents in the surf. Often uniform return flows seaward or lakeward are termed "undertow" though these flows will not be as strong as rip currents. See also CURRENT SYSTEM, NEARSHORE.

UPCOAST—In United States usage; the coastal direction generally trending towards the north.

UPDRIFT—The direction opposite that of the predominant movement of littoral materials.

UPLIFT—The upward water pressure on the base of a structure or pavement.

UPRUSH—The rush of water up onto the beach following the breaking of a wave. Also SWASH, RUN-UP.

VELOCITY OF WAVES—The speed with which an individual wave advances.

WATER LINE—A juncture of land and sea. This line migrates, changing with the tide or other fluctuation in the water level. Where waves are present on the beach, this line is also known as the limit of backrush. (Approximately the intersection of the land with the still water level).

WAVE—A ridge, deformation, or undulation of the surface of a liqiud.

WAVE AGE—The ratio of wave velocity to wind velocity.

WAVE DIRECTION—The direction from which a wave approaches.

WAVE GENERATION—(1) The creation of waves by natural or mechanical means. (2) In wave forecasting, the growth of waves caused by a wind blowing over a water surface for certain period of time. The area involved is called the GENERATING AREA or FETCH.

WAVE HINDCASTING—The calculation from historic synoptic wind charts of the wave characteristics that probably occurred at some past time.

WAVE LENGTH—The horizontal distance between similar points on two successive waves measured perpendicularly to the crest.

WAVE PROPAGATION—The transmission of waves through water.

WHARF—A structure built on the shore of a harbor, river, canal, etc., so that vessels may lie alongside to receive and discharge cargo, passengers, etc.

WHITECAP—On the crest of a wave, the white froth caused by wind.

WIND—The horizontal natural movement of air; air naturally in motion with any degree of velocity.

WIND, FOLLOWING—In wave forecasting, wind blowing in the same direction that waves are travelling.

WIND, OFFSHORE—A wind blowing seaward over the coastal area.

WIND, ONSHORE—A wind blowing landward over the coastal area.

WINDWARD—The direction from which the wind is blowing.

WIND WAVES—(1) Waves being formed and built up by the wind, (2) loosely, any wave generated by wind.