Shore Stabilization with Salt Marsh Vegetation

by

Paul L. Knutson and W. W. Woodhouse, Jr.

SPECIAL REPORT NO. 9

JANUARY 1983

U.S. ARMY, CORPS OF ENGINEERS
COASTAL ENGINEERING RESEARCH CENTER
Kingman Building
Fort Belvoir, Va. 22060

U.S. Army Coastal Engineering Research Center
Kingman Building
Fort Belvoir, Virginia 22060

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER SR-9	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SHORE STABILIZATION WITH SALT MARSH VEGETATION		5. TYPE OF REPORT & PERIOD COVERED Special Report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Paul L. Knutson W.W. Woodhouse, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CERRE-CE) Kingman Building, Fort Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS D31234
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center Kingman Building, Fort Belvoir, VA 22060		12. REPORT DATE January 1983 13. NUMBER OF PAGES 95
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Marsh vegetation   Shore stabilization   Erosion control

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is published to provide engineers and scientists with guidelines on using coastal marsh vegetation as a shore erosion control measure in coastal regions of the United States. This erosion control alternative is suitable for relatively sheltered shorelines such as those found on bays, sounds, and estuaries. For various reasons this alternative has not been found to be effective in the Great Lakes, Alaska, or Hawaii. Criteria are provided on (1) determining site suitability, (2) selecting plant materials, (3) planting procedures and specifications, (4) estimating project costs, and (5) assessing impact.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This report is published to provide engineers and scientists with guidelines on the use of salt marsh vegetation as a shore erosion control measure in coastal regions of the United States.

This is one of a series of reports to be published to form a Coastal Engineering Manual (CEM). The report is based, in part, upon information presented in SR-4 "Building Salt Marshes Along the Coasts of the Continental United States" (Woodhouse, 1979). The work was carried out under the U.S. Army Coastal Engineering Research Center's (CERC) Development of Functional and Structural Design Criteria work unit, Coastal Structure Evaluation and Design Program, Coastal Engineering Area of Civil Works Research and Development.

The report was prepared by P.L. Knutson, Ecologist, Coastal Ecology Branch, CERC, and W.W. Woodhouse, Jr., Professor Emeritus of Soil Science, North Carolina State University, under the general supervision of E.J. Pullen, Chief, Coastal Ecology Branch, and Mr. R.P. Savage, Chief, Research Division, CERC. R.A. Jachowski, former Chief, Coastal Design Criteria Branch, Engineering Development Division, was the CEM project monitor.

The authors express appreciation to S.W. Broome and E.D. Seneca for their review and comments.

Technical Director of CERC was Dr. Robert W. Whalin, P.E.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

CONTENTS

CONTENTS--Continued

CONTENTS--Continued

CONTENTS--Continued

TABLES

FIGURES

CONTENTS

FIGURES--Continued

CONTENTS

FIGURES--Continued

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

GLOSSARY

ERGOT - A dark, spongy, parasitic mass of fungus found on the ovaries of various grasses.

FETCH LENGTH - The horizontal distance wind blows over open water to generate waves.

IRREGULARLY FLOODED - Areas of the shoreline which are not covered and uncovered by the rise and fall of the tide on a daily basis, but are subject to flooding during extreme lunar tides or wind setup. Generally, the region between mean high water and the estimated highest tide.

PRIMARY PRODUCTIVITY - The rate at which energy is stored by photosynthesizing organisms (chiefly green plants) in the form of organic substances.

PLANT PROPAGATION - Increase in number, or multiplication, of plants to perpetuate the species or variety. Also, the process and methods employed by man to promote natural increase in some plants and to bring increase about under conditions when it would not otherwise take place.

PLUG - A root-soil mass with attached aerial stems of living plants. A type of PROPAGULE.

POTTED NURSERY SEEDLINGS - Plants raised in nurseries in peat moss or plastic pots, usually the latter. Seeds are placed in the pots, germinated, and plants are raised for 3 to 7 months. A type of PROPAGULE.

PROPAGULE - A plant material such as seeds, SPRIGS, or seedlings used in PLANT PROPAGATION.

RHIZOME - A horizontal underground stem.

REGULARLY FLOODED - Areas of the shoreline which are usually covered and uncovered by the daily rise and fall of the tide. Generally, the region between mean low water and mean high water.

SPRIG - A part of a plant consisting of at least one node (joint of a stem from which the leaves arise) with attached stems and roots of living plants. A type of PROPAGULE.

SHORE STABILIZATION WITH SALT MARSH VEGETATION

by
Paul L. Knutson and W.W. Woodhouse, Jr.

I. INTRODUCTION

Shore erosion is a common problem in the bays, sounds, and estuaries of the coastal United States. A wide variety of structures have been developed and used to control this erosion. However, due to environmental objections and economic limitations it is often impractical to use even the most innovative of these structures. This is particularly true for relatively low wave energy areas where erosion may be costly but is not yet catastrophic. Low-cost, nonstructural techniques are now available for controlling erosion in salt and brackish water, low wave energy areas of the contiguous United States using native marsh plants. Vegetation, where feasible, is usually lower in cost than structures and may be more effective.

This report provides comprehensive guidelines on the use of marsh plants to control shore erosion resulting from wind waves and tidal currents. The report has been carefully organized to facilitate its use as a reference document. Each major section addresses a specific facet of project planning, design, or construction; most sections end with a summary of information generally presented in the form of graphs, tables, and matrices.

II. BACKGROUND

This section provides a background of information on the subject of using marsh plants to control shore erosion. It discusses the role of marshes in providing stability to the shore, describes natural coastal marshes by region, and provides an introduction to the concept of encouraging marsh establishment to reduce shore erosion.

1. Role of Marshes in Shore Stabilization.

Marsh plants perform two functions in abating erosion. First, their aerial parts form a flexible mass which dissipates wave energy. As wave energy is diminished, both the offshore transport and the longshore transport of sediment are reduced. Optimally, dense stands of marsh vegetation can create a depositional environment, causing accretion rather than erosion of the shoreface. Second, many marsh plants form dense root-rhizome mats which add stability to the shore sediment. This protective mat is of particular importance during severe winter storms when the aerial stems provide only limited resistance to the impact of waves.

a. Wave Attenuation and Sediment Trapping. Wave attenuation in marshes has not been studied extensively. Wayne (1975) measured small waves passing through a smooth cordgrass marsh at Adams Beach, Florida. Dean (1979) gives the following empirical methodology for describing wave dampening in marshes, based on empirical estimates of the fluid drag forces occurring on vertical cylinders and laboratory observation of various arrays of cylinders:

It can be shown that with reasonable assumptions, the ratio of incident wave height H_i, seaward of a stand of marsh grass, and height $H_{\ell e}$, landward of the stand of marsh grass, are related as follows:

$$\frac{H_{\ell e}}{H_i} = \frac{1}{1 + AH_i}$$

where

$$A = \frac{C_D \; D\ell}{3\pi \; S^2 d}$$

C_D = Drag coefficient (≈1.0)

D = grass stalk diameter

ℓ = length of "stand" through which waves propagate

S = average spacing of grass stalks (assumed on square centers)

d = water depth (assumed to be constant)

Example: Consider the following: grass stalks 4 millimeters in diameter on a 6-centimeter spacing in a water depth of 25 centimeters extending over a stand length, ℓ, of 10 meters. For this example an incident wave height, H_i, of 15 centimeters will be considered. The height, $H_{\ell e}$, at the landward end of the stand is

$$A = \frac{C_D \; D\ell}{3\pi \; S^2 d}$$

$$A = \frac{1(0.4)1000}{3\pi(6)^2 25}$$

$$A = 0.0471$$

and

$$H_{\ell e} = \frac{H_i}{1 + AH_i}$$

$$H_{\ell e} = \frac{15}{1 + 0.0471(15)}$$

$$H_{\ell e} = 8.8 \text{ cm}$$

This is a 41-percent reduction in the incident wave height. The associated rate at which energy will be dissipated against the shoreline will be reduced by 65 percent. In a series of field experiments Knutson, Seelig, and Inskeep (in preparation, 1983) found a modified version of the Dean model useful in predicting wave damping in sloping, natural marshes. They found that under conditions similar to those used in the above example about 64 percent of the energy associated with a 15-centimeter wave was dissipated by only 2.5 meters of natural, sloping marsh.

As the wave energy impacting the shore is reduced, there is increased potential for sediment deposition and decreased potential for erosion. Woodhouse, Seneca, and Broome (1974) measured sediment deposition resulting from marsh plantings and reported the deposition of 15 to 30 centimeters of sediment along three planted profiles at Snow's Cut, North Carolina, during a 30-month period.

The influence marshes have on waves depends primarily on the width of the marsh ("ℓ" in Dean's equation). The width to which a marsh can extend, under optimal conditions, depends on the geographical area in which the marsh is located and the tidal amplitude and slope of the shoreline. The density of plants within a particular marsh depends on many variables including (1) species, (2) geographical area, (3) elevation zone within the marsh, (4) season, (5) substrate, (6) maturity of the marsh, (7) salinity, and (8) wave climate.

b. Soil Reinforcement. Though it is empirically evident that plant root systems improve soil stability, there is little experimental evidence on this subject. Gray (1974) summarized findings concerning soil reinforcement with vegetation. He noted that some independent studies have shown that plant roots do significantly increase soil stability (Endo and Tsuruta, 1969; Manbeian, 1973). In these studies the shear strength of vegetated soils was as much as two and three times greater. In addition, the shear strength of soils was higher when the volume fraction or weight density of the root system was greater.

2. Coastal Salt Marshes of the United States.

A coastal marsh is an herbaceous (plants lacking woody stems) plant community found on the part of the shoreline which is periodically flooded by salt or brackish water. A number of species in the grass family (Poaceae), sedge family (*Cyperacea*), and rush family (*Juncaceae*) commonly form coastal marshes.

Coastal marshes occur naturally in the intertidal zone of moderate- to low-energy shorelines along tidal rivers and in bays and estuaries. These marshes may be narrow fringes along steep shorelines, but can extend over wide areas in shallow, gently sloping bays and estuaries. Such lands were extensive and widely distributed along the Atlantic, peninsular Florida, gulf, and Pacific coasts of the United States before development by man (Fig. 1).

There are two major groups of coastal salt marshes in the United States, based on physiographic differences--marshes of the Atlantic, peninsular Florida, and gulf coasts (the eastern region) and those characteristic of the northern and southern Pacific coasts (the western region). The eastern

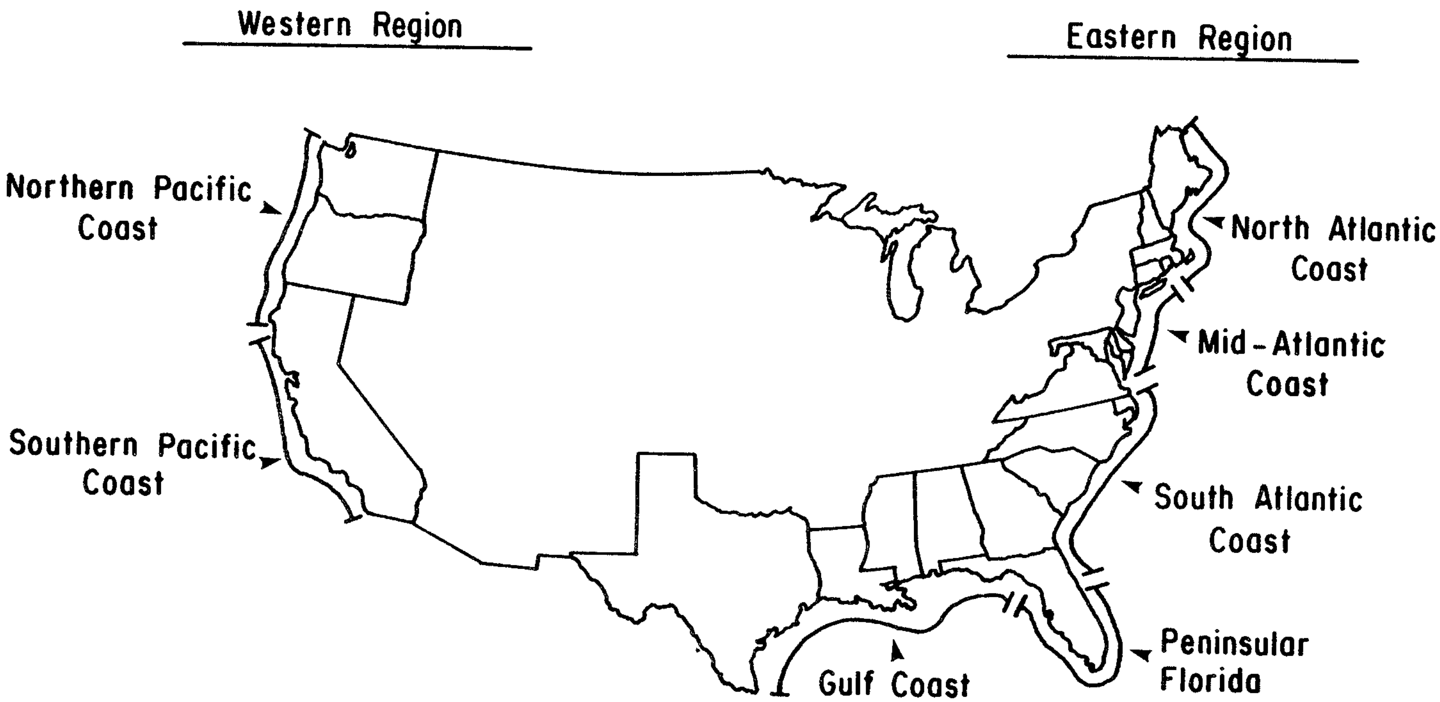

Figure 1. Coastal regions of the United States.