

# PERTINENT FACTORS IN THE PROTECTION OF THE GULF COAST

## Chapter 19

### PERTINENT FACTORS IN THE PROTECTION OF THE GULF COAST

Martin A. Mason  
Dean of Engineering, George Washington University  
Washington, D. C.

Protection of the U. S. shores of the Gulf of Mexico against erosion or damage by waves, currents, or other littoral forces involves unique physical and economic conditions that make this area quite different from other shore regions. It is the purpose of this paper to discuss these conditions and the factors that contribute to them.

#### ECONOMIC CONDITIONS

It is a poorly recognized fact that there is only one major concentration of development and population located immediately on the Gulf coast of the U. S., namely Galveston, Texas. Other major concentrations, such as Tampa, Mobile, New Orleans, Corpus Christi, (see Figure 1) are located inland from the shore in areas relatively well-sheltered from the open Gulf. Numerous small concentrations are bunched on the shore in a few areas, such as the Naples to Tarpon Springs area in Florida, and the Pascagoula-Biloxi-Gulfport-Pass Christian recreational center of Mississippi. These areas are primarily recreational in character and derive their economic importance from this usage. The concentration of population is relatively low on an annual basis but reaches high values during "the season" which may last five months. In these areas the most important single element in the economy is the existence of a beach whose character is pleasing to the population seeking recreation at the particular resort. The loss of or reduction to a less satisfactory condition of any one of these recreational beaches would be serious to the local property owners and resort business proprietors, but probably would not be of sufficient national significance to be noticed.

Long stretches of the Gulf coast are essentially wilderness areas; such as the extensive barrier islands of the Texas coast and the isolated chandeleur chain off the Mississippi and Louisiana coast, or the vast marshlands of western Louisiana. At the present time the economic significance of these areas, constituting well over half the total coast-line must be considered as slight.

Under these circumstances the problem of the economic worth of these lands and the protection of their shores needs to be examined carefully. In at least one case submitted to analysis, that of Anna Maria and Longboat Keys located just south of the Tampa Bay entrance, the Beach Erosion Board could find no economic justification for protection of the area and reported its opinion that no public interest was involved in the protection. It was recognized however that local property owners might nevertheless desire to protect their property in spite of the lack of economic justification and methods of achieving protection were outlined in the

## COASTAL ENGINEERING

Board's report. Particularly in regard to the Gulf coast one must guard against blind acceptance of the usual view of the property owner that the mere existence of the beach or shore is adequate reason for maintaining the existence of that beach or shore by protective measures. One cannot help but subscribe to the concept that, under present conditions of use and development, protection of major portions of the Gulf coast cannot be justified on an economic basis. In fact, probably the best treatment for the area in general is to leave it in its natural condition and confine development to regions that are known to be relatively stable, planning the development with adequate allowance for the free play of natural forces and the normal processes of development of unprotected shores. It is to be noted that the development of the Gulf coast whether by chance or design, now follows this latter pattern, with some notable exceptions.

### PHYSICAL CONDITIONS

The uniqueness of the Gulf environment in respect to shore protection lies as much in its physical attributes as in its economic development. In broad terms the Gulf of Mexico is a roughly elliptical basin of quite shallow rim and relatively flat offshore slopes leading to a central portion with depths in excess of 6,000 feet (See Figure 1). The Gulf is almost landlocked, communicating with the Caribbean by the deep Yucatan Channel and with the Atlantic by the Straits of Florida. There is a well-developed continental shelf in the Gulf with a continental slope leading to a central deep of roughly the same outline as the land border of the Gulf. The dominant morphologic feature of the Gulf is the Mississippi Delta, which seems to lie upon and cross the continental shelf. The land borders of the northern Gulf are very low-lying; with the 100 ft. elevation contour located from twenty-five to more than a hundred miles inland. The principal topographic characteristic of the landscape is its monotonous flatness. The shore is principally of the barrier-beach type, where extensive sand, or sand and shell, beaches front lagoon or marsh areas that stretch for miles along the coast.

In any locality the problem of shore protection is, in its broadest terms, a matter of maintaining some selected land-water boundary. This is attempted in a variety of fashions, ranging from massive sea walls to the repeated artificial deposit of sand as needed to maintain a favorable balance of sand supply on a protective beach. The various factors controlling the protection method to be employed have been discussed in other articles and will not be repeated here, except to recall that in general one must have available adequate knowledge for the locality concerned of water levels, or tides; wave action; currents; storms; the sources of material for the beaches; and any unusual natural forces, such as hurricanes. Some of these factors as they apply in the Gulf area will be discussed.

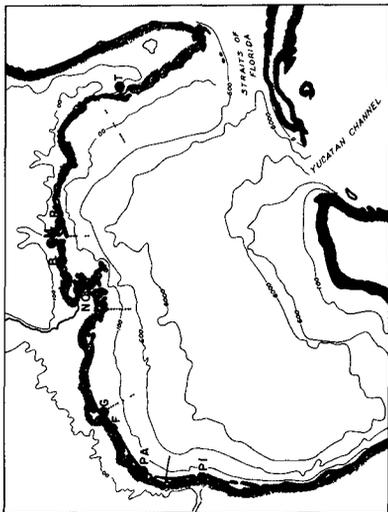


Fig. 1. The Gulf of Mexico. Depths and elevations are in feet. Dotted lines represent locations of profiles shown on Fig. 4.

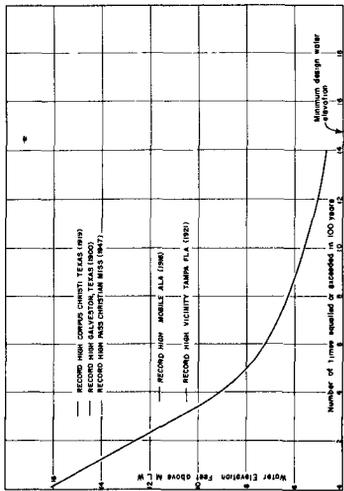


Fig. 2. Hurricane tide frequency. Based on observations 1900-1951 at various locations.

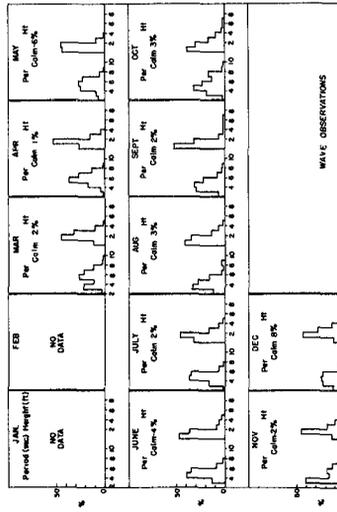


Fig. 3. Significant periods and heights of waves at Humble Platform 8 miles offshore Grand Isle, La. 1948-1949.

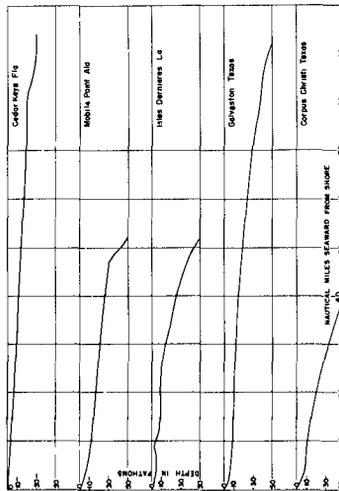


Fig. 4. Typical profiles of Gulf bottom.

## COASTAL ENGINEERING

### TIDES - WATER ELEVATIONS

The periodic tides in the Gulf of Mexico are small, varying from about 0.7 ft. to 1.8 ft. mean range, and about 0.9 ft. to 4.0 ft. spring range. Extreme tides, exclusive of hurricane epochs, range from 1.5 to 3 ft. below mean low water, and 3 to 6 ft. above mean low water. In the region from about Cape San Blas, Fla., to about the U. S. - Mexican border the tides are irregular and mostly diurnal, i.e. there is one high and one low water daily; elsewhere on the U. S. Gulf coast there are two high and low tides daily.

Although the tidal fluctuation in water elevation is usually low, variations in water elevation of about 4 ft. below and 4 ft. above tidal stage due to the effects of wind occur sufficiently often to be considered of the same importance as tidal fluctuations, and are the controlling factor in design rather than tides.

Variations in water elevation due to hurricane effects along the Gulf coast are large and may occur with sufficient frequency to justify their use in designing protective works.

The elevations reached on the coast by the Gulf waters and the frequency of their occurrence determine the elevations to which protective structures or works must be built to prevent inundation of the protected areas. In addition consideration must be given to the wave heights that may occur coincidentally with high water elevations in arriving at the design elevation of the protective works. Figure 2 is a frequency curve of water elevations prepared from hurricane tide records for the Gulf Coast, and shows also the record high water elevations for several typical locations. Data of this type prepared for various localities being considered for protection allows an evaluation to be made of the minimum design elevation of works to prevent inundation and provides part of the basic data required for economic analysis of other-than-minimum works. In the absence of more complete data the information in Figure 2 can be used for design purposes for any of the U. S. Gulf coastal locations.

Minimum works should be considered as being those whose top elevations will prevent overtopping during frequently occurring water stages under non-hurricane conditions; in the Gulf area these top elevations are of the order of 4 to 6 ft. above mean low water.

### WAVES

Knowledge of wave action is important in shore protection design for several reasons. In the case of structures, such as seawalls and bulkheads, an increase in the height of the structure commensurate to the wave height over that required for simple inundation protection against rising water levels is necessary. If there is material available to build or maintain a protective beach the direction, height, and frequency of occurrence of waves is of value in evaluating littoral drift characteristics, designing the protective beach (particularly its top elevation and

## PERTINENT FACTORS IN THE PROTECTION OF THE GULF COAST

width), designing the groin profile if groins are to be employed, and in the structural design of the groin. Other uses may exist.

Relatively little is known about wave action nearshore in the Gulf of Mexico. For a short time the Beach Erosion Board and the Humble Oil organization operated jointly a wave measuring apparatus on a Humble drilling platform about 8 miles offshore of Grand Isle, La. The results obtained are summarized, by months, as shown on Figure 3. It will be noted that the nature of the wave action in this location is quite uniform, with periods averaging about 5 seconds, and wave heights about 1 foot, throughout the year. The hurricane months of July through October show some waves of up to about 7 feet height and 8-9 second period but they are of infrequent occurrence and short duration.

In comparison and as additional data the reader is referred to Sea and Swell Charts - Northeastern Pacific Ocean (U.S. Navy) which presents in detail the results of ship observation of sea and swell in the open Gulf over a number of years. The data is not reproduced here because of its volume. In summary it shows that on the average the Gulf is calm 50 to 60 percent of the time during May through August, and about 30 percent of the time during the remainder of the year. When waves exist in the northern half of the Gulf they travel from the east or southeast most of the time, and range from 1 to 12 ft. in height predominantly. No information on wave period is given on these charts.

It is of particular interest to note that the Florida West Coast is peculiarly fortunate in respect to wave action in that it is sheltered almost completely from high, destructive swell and is subject, for all practical purposes, only to locally generated and hurricane wave action.

Although detailed information on wave action in the northern part of the Gulf is deficient for analysis purposes the topographic character of the Gulf bottom and its effect in modifying waves by refraction make it possible to specify some important wave characteristics at the shore. Figure 4 shows several typical profiles of the Gulf bottom at the locations shown on Figure 1.

If it be considered that the maximum waves to be expected in the Gulf result from hurricane action some idea of their magnitude may be derived from the Sverdrup-Munk wave prediction method. It may be assumed that under these conditions maximum wind velocities of 60 knots blow over fetches of about 150 miles for durations not exceeding 20 hours. These conditions can produce maximum waves of 55 feet height and about 11 seconds period in deep water. This wave can transport bottom material in depths of about 500 ft. and will break in depths of the order of 70 ft., (say 12 fathoms). Referring to Figure 1 it is seen that the bottom can be affected as far offshore as about 150 miles, and that the maximum waves will break as far as 40 miles offshore.

## COASTAL ENGINEERING

A moment's thought leads to the belief that probably the most useful criterion of wave height to be expected at the shore is the water depth existing there under hurricane conditions. Reference to Figure 2 then leads to the belief that the probable maximum wave height to be expected at the shore near Tampa would be that of a wave breaking in about 11.6 ft. depth, or say 9 ft., at Galveston in about 14.5 ft. depth, or say 11 ft.

The probability that any particular Gulf coast location may be subject to maximum hurricane tide and wave action is illustrated by Figure 5, which shows the paths of hurricanes of record by month of occurrence. It is seen that maximum conditions, which are associated with passage of the hurricane over the area, can be expected to occur at any U. S. Gulf coast location. The maximum conditions to be expected are, as noted above, dependent upon location and hurricane intensity.

### MATERIAL SUPPLY TO GULF SHORE

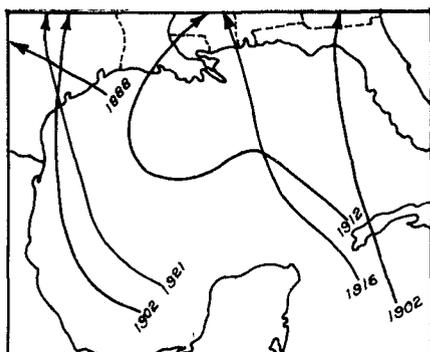
The most striking feature of the U. S. Gulf coast to an observer interested in shore protection is the seemingly unlimited quantities of beach material in the area, as evidenced by the miles upon miles of wide, sandy beaches. Even in the western Louisiana marsh area one finds excellent beaches. Associated with this profusion of sandy shore is the immense delta of the Mississippi River, spreading octopus-like as a "sedimentary section some 30,000 feet thick, extending coastwise for over a thousand miles, with a width, in its landward limb, at places exceeding 350 miles" (Russell, 1940). One can find nearly as many opinions as to the extent and character of the Mississippi delta as one can find writers. It is sufficient for the purposes of this paper to accept the apparently incontrovertible opinion that the sediments of the northern Gulf of Mexico coast are very closely related to the sediments carried to the Gulf by the Mississippi.

Study of the wealth of geologic data on the Mississippi delta has led to the conclusion that the Gulf coast geologic record is "one of continuous sedimentation, southward migrating shore lines, interrupted only slightly by minor advances and retreats of the sea and structural deformation related to sedimentary loading - - ." (R.J. Russell, *ibid*)

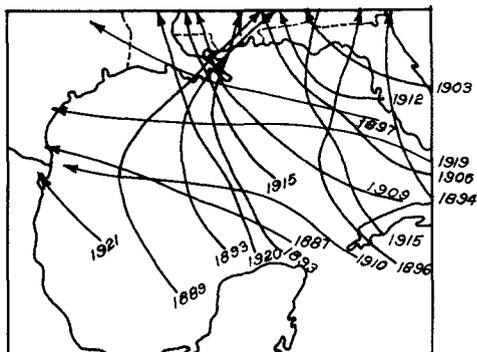
Contributing factors to this situation have been evaluated variously by different authors, some of whom have argued to variant conclusions from the same basic data. The truth does not seem to have been established, and the figures or quantities stated hereinafter must be regarded then as approximations to the truth.

The true nature of the sediment burden brought to the Mississippi is not known. There is, however, abundant evidence that the burden has included significant amounts of gravel, sand, and fine-grained soils down to colloidal clays. The materials are carried in solution, suspension, colloidal dispersion, and bed load. Russell seems to attribute

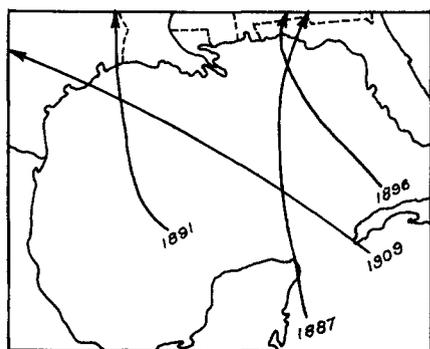
PERTINENT FACTORS IN THE PROTECTION OF THE GULF COAST



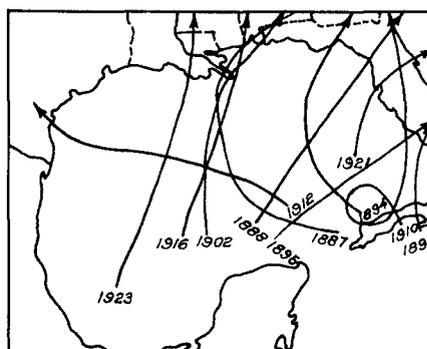
JUNE



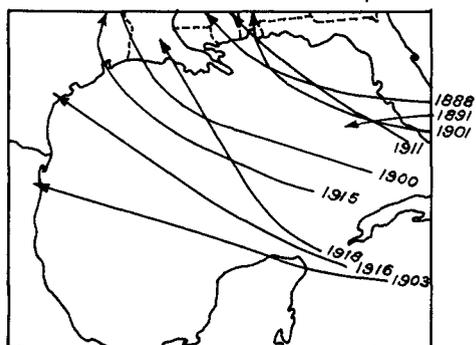
SEPT



JULY



OCTOBER



AUGUST

Fig. 5  
Hurricane paths of record, shown by month of occurrence. The dates on the paths are the years of occurrence.

## COASTAL ENGINEERING

the sandy shores of the Gulf to selective sorting of the river sediments, so that coarse materials are carried shoreward and finer materials out toward the sea, following a concept of De La Beche expressed in 1853.

Estimates of the quantity of material brought to the Gulf by the Mississippi vary between quite wide limits with a probable minimum average of 2,000,000 tons per day, or about 730,000,000 tons annually.

The age of the delta has been estimated variously as being from about 4,000 years minimum to about 140,000 years maximum, the median of the estimates being about 40,000 years. Thus there is fair evidence that the Gulf basin has received at least about 29,000,000 million tons of sediment for distribution over its extent and around its shoreline. Little would be gained by additional manipulation of these figures. I, at least, am prepared to conclude that a principal source of material for the natural building and maintenance of the extensive sand beaches of the Gulf area has been and is now the sediment brought to the area by the Mississippi River.

Concurrently, however, I am forced to consider that distribution of the material from its area of introduction to the shores must take place primarily during storm or hurricane conditions, the only times when there appear to be available wave or current forces adequate to transport large quantities of material. During other intervals the wave action seems to be, from available evidence, inadequate to perform the transportation role required.

There are, of course, many rivers other than the Mississippi which ultimately reach the Gulf. The principal to be considered as possible sources of material are the Alabama - Tombigbee River complex, the Calcasieu, the Sabine-Neches complex, the Trinity, the Brazos, the Colorado, the Lavaca, the Guadalupe, and the Rio Grande. Among these only the Brazos and the Rio Grande enter the Gulf directly, all the others emptying into lakes, bays, or lagoons separated from the Gulf by barriers, and which serve as immense settling basins.

The Brazos has a well-developed delta in the Gulf near Freeport and therefore undoubtedly contributes some material to the building and maintenance of Gulf beaches. The Rio Grande, on the contrary and in spite of its reputation as a notorious debris carrier, appears to have no Gulf delta associated with its entrance. The meandering character of the stream and the extensive marsh development at its mouth, coupled with lack of a delta lead to the belief that the debris load is dropped before reaching the Gulf. Its present contribution of shore material probably is limited to whatever quantities are derived from its alluvial fan.

# PERTINENT FACTORS IN THE PROTECTION OF THE GULF COAST

## SUMMARY

In summary the Gulf coast appears to be unique, in respect to protection of its U. S. shore, by reason of its physical environment and economic development. The Galveston area is the sole major concentration of development and population in an exposed location on the Gulf shore. From an economic point of view a major part of the Gulf shore must be considered as being presently not sufficiently developed to warrant protection against natural erosion agents.

The physical environment of the Gulf requires that protection methods employ as primary design elements the effects of hurricanes, the influence of the flat offshore bottom slopes, and the predominance of the Mississippi River as the prime source of beach material.

The uniqueness of the Gulf situation does not however result in simplification of the protection problem. In fact, until much more is known about the details of the elements mentioned the Gulf coast will be one of the difficult problem areas for coastal engineering.

## REFERENCES

- U. S. Navy, Hydrographic Office (1944). Sea and Swell Charts, Northeastern Pacific Ocean (includes Gulf of Mexico). H.O. Misc. Publ. No. 10712-D.
- Russell, R. J. (1940). Quaternary History of Louisiana, Bulletin Geological Society of America, Vol. 51, No. 8, pp. 1199-1234.
- De La Beche, H. T. (1853). The Geological Observer, London, 2nd Ed.
- Barton, D. C. (1930). Deltaic coastal plain of southeastern Texas, Bull. Geol. Soc. Am., Vol. 41, pp. 359-382.
- U. S. Coast & Geodetic Survey (1951). Tide and Current Tables, Atlantic Ocean.
- Army Air Forces, Weather Information Branch (1943). Hurricanes affecting the Atlantic Coast, the Gulf Coast, and the Southern California Coast of the United States, Report No. 636.