CHAPTER 34

DESIGN OF DEEP DRAFT NAVIGATION CHANNEL FROM GULF OF MEXICO INTO MATAGORDA BAY, TEXAS

E. A. Weiser
Chief, Advance Planning Section
Planning and Reports Branch
Engineering Division
Galveston District

Jack Armstrong
Project Engineer
Matagorda Ship Channel Project
Advance Planning Section
Engineering Division
Galveston District

INTRODUCTION

It was in July 1956 when the senior writer of this paper was requested to prepare a program for investigations and studies required in connection with the proposed deep-draft channel from the Gulf of Mexico to Point Comfort.

During 1938 to 1940, the senior writer had attempted to analyze the available field and model study data which were then available on Galveston Bay in the hope of thus being able to reduce the shoaling in the various deep draft channels in Galveston Bay.

In 1940, the senior writer had been in charge of two field parties one of which measured the flow of water in the Colorado River and the Gulf Intracoastal Waterway near their crossing near Matagorda, Texas. A peak discharge of about 80,000 cubic feet per second was measured in the Colorado River at the Palacios Road bridge, about 15 miles upstream from its mouth during this period. At that time there were no locks nor gates in the Intracoastal Waterway adjacent to the Colorado River. It was found then that about one third of this peak river discharge flowed southwest through the Intracoastal Waterway.

On the basis of the above experience and the information obtained from a review of the Matagorda Ship Channel, Texas, project report (1) and other literature, then, available (2) thru (5) a program was formulated in June 1958 and submitted to the Division Engineer in Dallas with the request that the Office of the Chief of Engineers, the Southwestern Division Engineer Office, the Beach Erosion Board and the Committee on Tidal Hydraulics review the program.

The program was later placed on the agenda of the Committee on Tidal Hydraulics, which submitted a final report in December 1958, recommending a model study and listing the following more important matters to be resolved:

a. The best location of the entrance channel.

b. The distance between jetties.

c. The best route for the channel from the north boundary of the barrier beach to Point Comfort.

d. Whether the channel across the bays should be diked on one side or both sides.

e. The effects of the proposed project on the salinity and temperature regimens of the bay system.

Lack of funds in fiscal year 1959 prevented the Galveston District from actively starting the necessary gathering of basic field data; however, local interests began collecting prototype data, as outlined by the Committee on Tidal Hydraulics, in January 1959. These data included tide records at selected stations and long term current and salinity observations.

In October 1959 the Waterways Experiment Station, after reviewing the prototype measurements made by the local interests, recommended certain modifications of the prototype data collecting program which had been recommended by the Committee on Tidal Hydraulics.

In the meantime, the River and Harbor Act of 3 July 1958 authorized the Matagorda Ship Channel as described in House Document 131, 84th Congress, 1st session, and in (1). The latter document describes the studies made of various plans for a dependable deep draft navigation channel from the Gulf of Mexico to Point Comfort, Texas, via Pass Cavallo, Greens Bayou, mouth of the Colorado River, and an artificial inlet through Matagorda Peninsula.

Interest in a navigable channel from the Gulf of Mexico to Matagorda Bay goes back more than a hundred years. The first Corps of Engineers report on this area was submitted in 1853 (6). There have been more than fifteen reports submitted by the Corps of Engineers on this area. Those pertaining to the authorized project work are listed in the annual report of the Chief of Engineers under "Matagorda Ship Channel, Texas."

DESCRIPTION

PROBLEM AREA

Matagorda Bay is located near the center of the Texas coast. (see figure 1). Under normal conditions, it is connected with the Gulf of Mexico by Pass Cavallo, which is located at the southwest corner of the bay and about 51 miles northeast of Aransas Pass, Texas, and 79 miles southwest of Freeport, Texas. During periods of high tide, water interchange between the Gulf of Mexico and Matagorda Bay also occurs across the many low areas of Matagorda Peninsula. The largest of these, Greens Bayou, is located about 15 miles northeast of Pass Cavallo. The fresh water runoff and the sediment transported thereby from about 40,000 square miles of area can enter Matagorda Bay.

MATAGORDA BAY

Matagorda Bay is one of the larger bays located along the Texas coast. Including its many arms, it has an area of about 400 square miles (see figure 2). It is separated from the Gulf of Mexico during normal periods by a nearly continuous strip of land about one mile wide known as Matagorda Peninsula, which extends in a northeast to southwest direction a total distance of about 51 miles. Its many arms, which include Lavaca Bay, connect the main area of the bay with the many small fresh water streams which drain into Matagorda Bay.

The main area of Matagorda Bay which is immediately north of Pass Cavallo has a depth of water of about 12 feet over an area about 14 miles long and 13 miles wide. The depth of water in the remainder of the bay, including the arms, drops off rapidly to about 6 feet and then diminishes gradually. Prior to about 1930, the Colorado River emptied into an arm of Matagorda Bay which extended about 37 miles northeast of the 12-foot depth area of the bay. At present, the Colorado River empties into the gulf and the northeast 17 miles of this arm is practically isolated during normal conditions.

PASS CAVALLO

Deep water in Pass Cavallo extends in a general north to south direction for about 6 miles from the 12-foot depth area in Matagorda Bay across the outer bar into the Gulf of Mexico (see figure 3). Depths of 20 to 40 feet extend across a width of about 2,000 feet. The cross-sectional area of the pass is about 100,000 square feet. Records indicate that this deep water channel has been at its present location for at least 200 years. At its junction with the 12-foot depth area in the bay a long narrow bar about 2 miles long separates the main channel into two branch channels, the smaller of the two branch channels continues in a north to south direction and the larger of the branch channels extends in a northeast to southwest direction. The depth of water over the inner bar is only about 3 to 4 feet. The south end of the deep water in Pass Cavallo is separated from deep water in the gulf by a bar over which the water is only about 8 feet deep. The southwest end of Matagorda Peninsula, known as Decros Point, is about 3 miles northeast of the northeast end of Matagorda Island; and a small island known as Pelican Island, is located about midway between Matagorda Island and Matagorda Peninsula. A small channel extends from the deep water channel in a northwest to southeast direction towards the Gulf of Mexico.

MATAGORDA PENINSULA

Matagorda Peninsula (see figure 2), which separates Matagorda Bay from the Gulf of Mexico during normal conditions, varies in elevation

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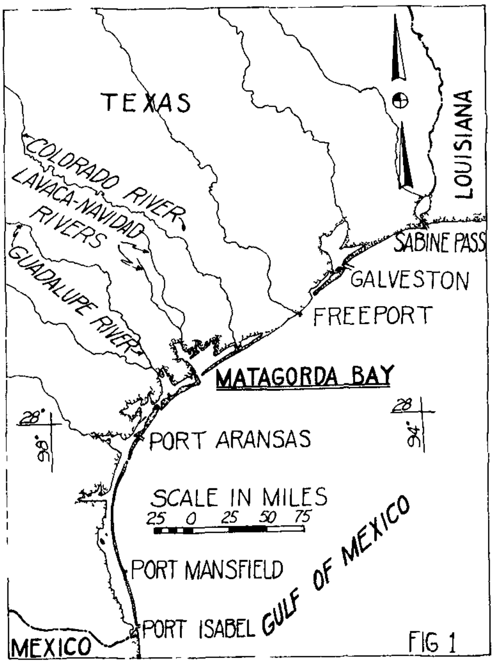

Fig. 1. Texas coast showing Matagorda Bay.

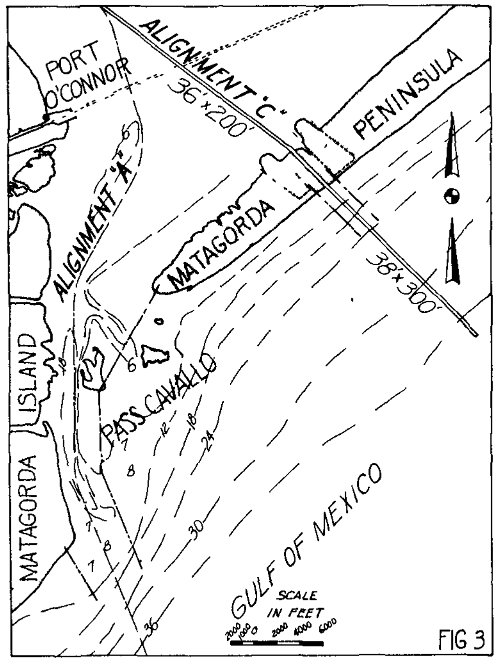

Fig. 3. Pass Cavallo and vicinity showing proposed channel alignment "A" and "C".

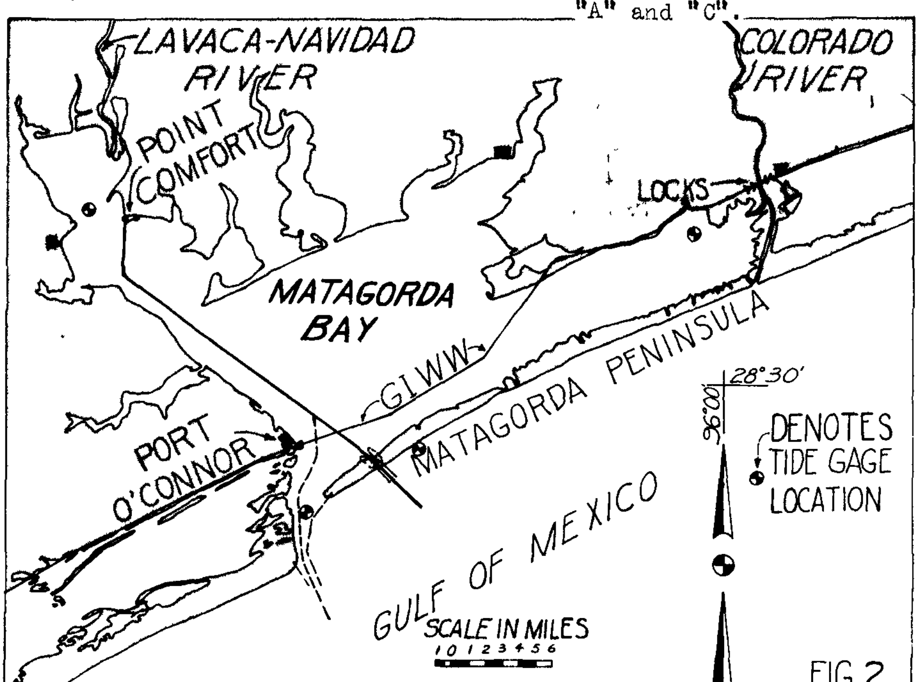

Fig. 2. Matagorda Bay showing the Matagorda deep draft ship channel and the original project plan providing for a channel through the existing pass.

from about 20 feet above mean sea level at the sand dunes to about a foot or two above mean sea level or lower at the various low areas (where high tides pass across the paninsula). During hurricane "Carla" which occurred in September 1961, water from the gulf passed across these low areas and eroded about six channels which persisted for some time after this hurricane. The largest of these channels, known as Greens Bayou, has had sufficient water in it at times to permit navigation by small vessels.

BED MATERIALS

Soil samples were obtained in 6 to 12 feet depth of water in Matagorda Bay along the channel alignment immediately northwest of Matagorda Peninsula, and in 6 to 18 feet depth of water in the Gulf of Mexico on ranges one, two and three miles west of Pass Cavallo. The grain size distribution of some of these samples is shown in the following tabulation:

Bed sample location	Depth	Percent finer than 90%	50%	30%	10%
		(Grain size in mm)			
Bay 2000' from shore	6'	0.23	0.074	.008	
Bay 5000' from shore	10	0.14	0.080	0.033	
Bay 8000' from shore	10	0.14	0.059	0.01	
Bay 11,000' from shore	12	0.15	0.080	0.03	
Bay 14,000' from shore	11	0.18	0.074	0.03	
BP 1W Gulf*	6	0.15	0.092		0.05
BP 2W Gulf	6	0.16	0.12		0.055
3W Gulf	6	0.18	0.12		0.09
1W Gulf	12	0.10	0.074		0.054
2W Gulf	12	0.11	0.072		0.044
3W Gulf	12	0.10	0.088		0.028
1W Gulf	18	0.14	0.09		0.05
2W Gulf	18	0.2	0.09		0.05
3W Gulf	18	0.11	0.088		0.048

*BP 1W - denotes bed sample taken in the gulf on beach profile located one mile west of Pass Cavallo.

SLOPE OF SHORE

The available soundings immediately adjacent to the 12-foot depth portion of Matagorda Bay indicate a slope of about 1 on 240 between mean sea level and the 6-foot depth and about 1 on 100 between the 6 and 12-foot depths. Available soundings along the gulf shore indicate a slope of about 1 on 140 between mean sea level and the 12-foot depth, about 1 on 200 between 12 and 18-foot depths, and about 1 on 350 beyond the 18-foot depth. The slopes near Pass Cavallo differ from the above.

TEMPERATURE

The average temperature in the Matagorda Bay area is about 70 degrees, varying from a maximum of about 102 degrees to a minimum of about 11 degrees. The temperature ranges from an average of 56 degrees in January to 83 degrees in July.

RAINFALL

The average annual rainfall in the Matagorda Bay area is about 41 inches varying from a maximum of about 67 inches, to a minimum of about 13 inches.

WIND

The average wind in the area has a velocity of about 12 miles per hour. During hurricane "Carla" on 11 September 1961, a wind velocity of 153 miles per hour was recorded, and gust velocities up to about 170 miles per hour were estimated (7). Figure 4 shows the percent of time and the direction from which hourly winds of various strength blew at Corpus Christi during 1905 to 1944.

FRESH WATER INFLOW

The principal streams which emptied directly into the Matagorda Bay system prior to about 1930 were the Colorado and Lavaca-Navidad Rivers. Water from the Guadalupe River can enter Matagorda Bay (see figure 1)

Colorado River - The Colorado River drains an area of about 42,000 square miles of which about 30,000 square miles contribute surface runoff. The average annual runoff rate of the Colorado River is about 2,100,000 acre-feet and varies from a maximum of about 6,000,000 acre-feet annually to a minimum of about 770,000 acre-feet annually. From its headwaters to the mouth, the Colorado River is about 900 miles in length over which distance it drops about 3,000 feet. It is estimated that the Colorado River watershed has an annual rate of sediment production of 9,300 acre-feet. Prior to 1929, the Colorado River emptied directly into Matagorda Bay. Between 1925 and 1929 clearing of a log jam in the lower reaches of the river caused an enormous amount of drift and silt to be brought downstream, which deposited in Matagorda Bay and rapidly built a delta across the bay, dividing this arm of the bay into two separate bodies of water. The delta formation caused flooding of the lowlands near the mouth of the river. To relieve this condition a channel was dredged from the original mouth of the river across Matagorda Bay and through Matagorda Peninsula to the Gulf of Mexico. The spoils placed in Matagorda Bay along both sides of the river prevent most of the normal river flows from entering Matagorda Bay directly. During periods of high water in the Colorado River, fresh water can flow across the low areas of ground into Matagorda Bay.

Lavaca River - The Lavaca River is now the only river emptying directly into the Matagorda Bay system. It actually empties into Lavaca Bay, an arm of Matagorda Bay, at a point about 15 miles northwest of the 12-foot depth area of the bay. The Lavaca River, including its major tributary, the Navidad River, drains an area of about 2,500 square miles. The average annual runoff rate of the Lavaca River is about 525,000 acre-feet and varies from a maximum of about 1,770,000 acre-feet annually to a minimum of about 23,400 acre-feet annually. From its headwaters to its mouth, the Lavaca River is about 112 miles in length over which distance it drops about 350 feet. It is estimated that the Lavaca-Navidad Rivers watersheds have an annual rate of sediment production of 625 acrefeet.

Other drainage - It is estimated that the average annual fresh water inflow into Matagorda Bay from the many small creeks emptying into the bay which drain a total of about 1,700 square miles of area is about 450,000 acre-feet.

Total drainage - The average total annual fresh water inflow into Matagorda Bay, exclusive of the flow from the Colorado River, is about 1,850,000 acre-feet, which includes about 875,000 acre-feet of rainfall on the bay system.

SEDIMENT TRANSPORTATION BY FRESH WATER

Sediment deposition rates as measured at various reservoirs were found to vary with the type of land resource and the size of the drainage area (8). The major land resource area of the Colorado River watershed is the Edwards Plateau which covers 13,500 square miles. The High Plains and the Rolling Plains resource areas cover 9,800 and 8,200 square miles respectively (8). The annual sediment production rates are low in the Edwards Plateau and in the High Plains areas. Annual sediment production rates are moderate in the Rolling Plains area. There are 1,300 square miles of Blackland Prairies and 1,250 square miles of West Cross Timbers, in the Colorado River watershed, in which the sediment production rates are high. Sediment from the West Cross Timbers consists of sand which usually is deposited close to its origin. The Blackland Prairies contributes from 1.5 to 2.5 acre-feet of sediment per square mile of area, part of which finds its way to the gulf. The present annual sediment production rate of the Colorado River watershed above Austin, which has a contributing drainage area of about 26,000 square miles is only 0.02 acre-foot per square mile. At Columbus, above which the contributing drainage area is about 29,100 square miles which include Blackland Prairies, the annual sediment production rate is 0.31 acre-foot per square mile.

A survey made in 1941 of Lake Buchanan, above which the watershed drainage area is about 21,000 square miles, indicated an annual rate of sediment production of 0.21 acre-foot per square mile.

There are three types of land resource areas in the Lavaca River watershed. There are 916 square miles of Blackland Prairies, 866 square miles of Coast Prairie, and 693 square miles of East Texas Timberlands. The estimated annual sediment production rate at the mouth of the Lavaca River is 0.25 acre-foot per square mile.

It is possible for sediment from the Guadalupe River to enter Matagorda Bay through the Gulf Intracoastal Waterway. The northeast edge of San Antonio Bay, into which the Guadalupe River empties, is only about 20 miles by the GIWW from Pass Cavallo. The Guadalupe River watershed has a total area of about 6,000 square miles, of which about 2,200 square miles are Edwards Plateau, about 1,700 square miles are

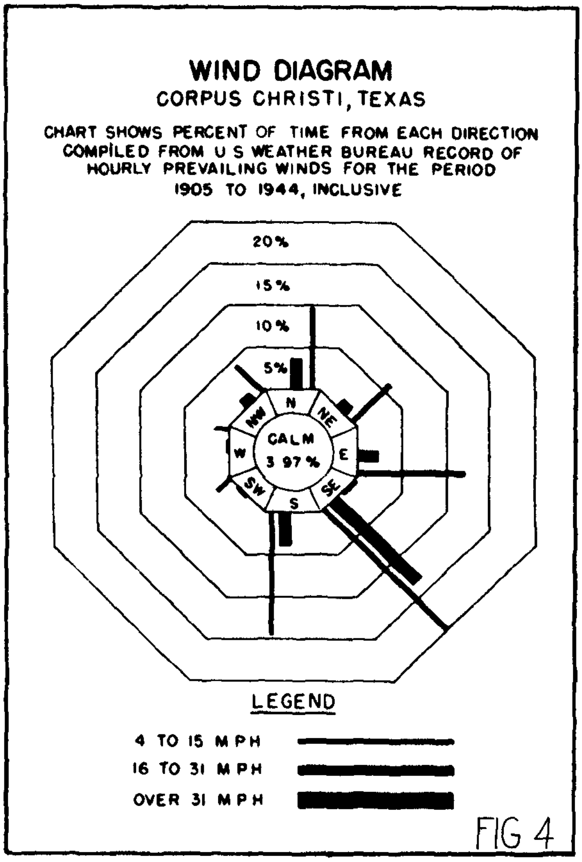

Fig. 4. Wind diagram based on hourly prevailing winds at Corpus Christi, Texas, for the period 1905 to 1944, inclusive.

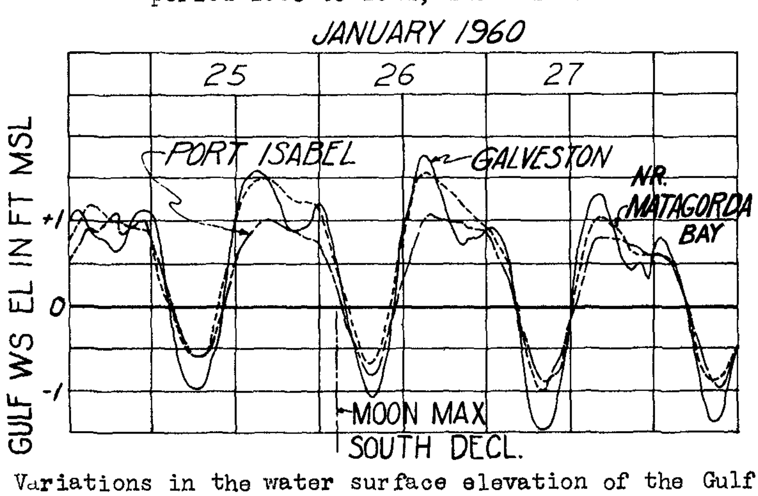

Fig. 5. Variations in the water surface elevation of the Gulf of Mexico at Port Isabel, near Matagorda Bay and at Galveston during 25 through 27 January 1960, when moon was at maximum south declination.

Blackland Prairies, about 1,100 square miles are East Texas Timberlands, about 700 square miles are Rio Grande Plain, and about 300 square miles are Coast Prairie. The Guadalupe River watershed above Victoria, which has an area of about 5,300 square miles, has an estimated annual rate of sediment production of 0.11 acre-foot per square mile.

The annual sediment production rate of the area drained by the small creeks is about 0.23 acre-foot per square mile (9).

TIDES

The movement of the earth in relation to the moon, sun and planets causes the water in the Gulf of Mexico to move, producing a variation in the water surface elevation in the gulf and thus causing an exchange of water between the gulf and Matagorda Bay. The position of the moon in relation to the earth appears to be the major influence on the gulf water.

Observations made along the gulf shore near Pass Cavallo, using a pressure type gage, indicated a 24.84-hour variation in water surface elevation of about 2 feet during the period 25 to 27 January 1960, when the moon was near its maximum south declination. The 12.42-hour variation in water surface of the gulf during 3 to 5 September 1959, when the moon was over the earth's equator, was about 0.7 foot.

The above water surface variations were slightly less than those observed at Galveston where the diurnal tide variation was about 2.5 feet and the semidiurnal tide variation was about one foot. Figures 5 and 6 show the diurnal and semidiurnal water surface variations as observed in the gulf outside of Matagorda Bay, at Glaveston, and at Port Isabel. The tide gage at Port Isabel is located about 5 miles from the gulf in the Port Isabel Turning Basin.

Tide gages were installed at various points in Matagorda Bay to determine the variation in water surface elevation in the bay at these points. The locations of some of these gages are shown on figure 2. Figures 7 and 8 show the actual observed water surface variation at these locations during a period when the moon was near its maximum declination and a period when the moon was near the earth's equator. Note that the variation in the water surface elevation in the bay generally diminishes with the distance of the area from Pass Cavallo. The area in the vicinity of Port O'Connor appears to be an exception to this rule.

TIDAL CURRENTS

Current measurements made on a range across Pass Cavallo on 15 April 1959 indicated flow from the gulf into Matagorda Bay for a period of about 12 hours. During this period a total of about 200,000 acre feet of water entered Matagorda Bay through Pass Cavallo. Figure 9 shows a

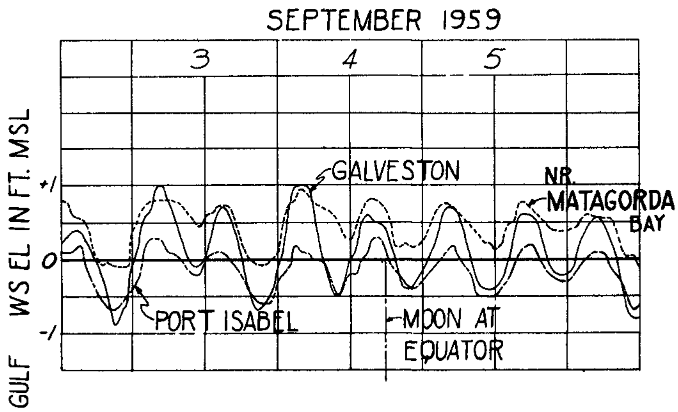

Fig. 6. Variations in the water surface elevation of the Gulf of Mexico at Port Isabel, near Matagorda Bay, and at Galveston during 3 through 5 September 1959, when moon was over earth' equator.

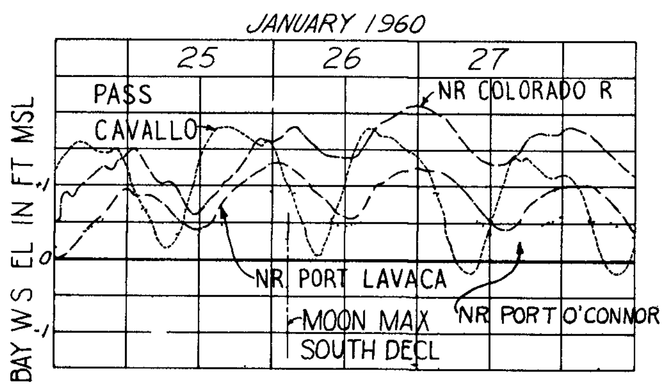

Fig. 7. Variations in the water surface elevation of Matagorda Bay during 25 through 27 January 1960, when moon was at maximum south declination.

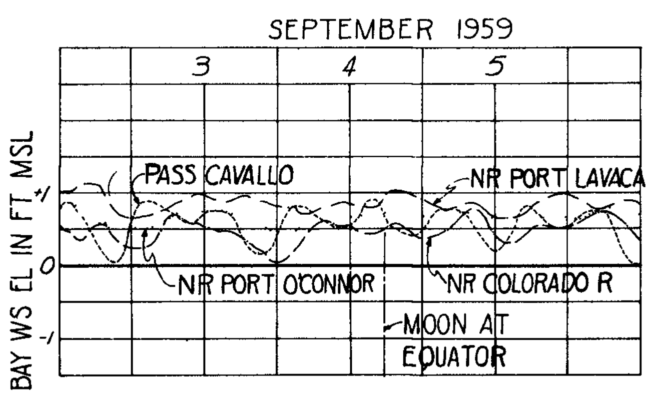

Fig. 8. Variations in the water surface elevation of Matagorda Bay during 3 through 5 September 1959, when moon was over earth's equator.

cross section of Pass Cavallo at this range and the velocities observed at one of the six points where current measurements were made.

SEDIMENT TRANSPORTATION NEAR COAST

The movement of the gulf water, particularly along the shore where the depth of water is less than about 6 feet causes the bed materials to move. Also, there is normally some sediment suspended in the gulf water near the shore. Samples of water taken from the gulf on 29 June and 17 August 1960 contained 50 and 60 parts per million by weight of suspended materials respectively. Bed samples taken near the water's edge and at 6, 12, and 18-foot depths along three ranges immediately west of Pass Cavallo in July 1960 consisted of grains varying in median diameter from about 0.135 millimeter to 0.072 millimeter. The amount of movement of sediment along the gulf coast in the vicinity of Matagorda Bay is not known, however, the information obtained by the New Orleans District of the Corps of Engineers by use of test pits in the vicinity of Chandeleur Sound (9) is probably indicative of the size of this movement.

Test pits near coast - Five test pits were dug, three in 8 to 15 feet of water in Chandeleur Sound and two in 13 and 16 feet of water in the gulf northeast of the mouth of the Mississippi River. Each pit was about 100 feet wide by 500 feet long with bottom at 30 feet below mean low gulf. Soundings were obtained at various intervals of time to determine the rate of sediment deposition in these pits. Soundings taken from 31 to 60 days after completion of the pits indicated a rate of shoaling varying from a maximum of about 292 cubic yards per foot of length of pit per year to a minimum of about 34 cubic yards per foot of length of pit per year. The following tabulation shows the location, depth of water and the median size of initially deposited materials in each of the five pits; and also shows the top width, the original capacity in cubic yards of the center 300 feet of pit, and the initial shoaling rate per annum per foot of length of pit based on the first two sets of soundings obtained after completion of the pits. The number of days between soundings at each pit are indicated.

TEST PIT SHOALING

Pit(1)	Location	Natural depth of water (ft)	Median size of deposited mtl. (mm)	Width top (ft.)	Initial capacity of central 300 ft. of pit(cy)	Initial rate shoaling (cu.yds/ lin.ft/yr)	Interval (days)
A	Gulf	13	0.150	250	32,150	292	31
B	Gulf	16	0.080	230	27,040	286	40
C	Sound	11	0.035	205	38,500	34	59
D	Sound	8	0.030	214	47,060	52	60
E	Sound	15	0.009	180	29,360	34	57

(1) Pit dimensions: approximately 30' x 100' x 500', with 1 on 3 side slopes.

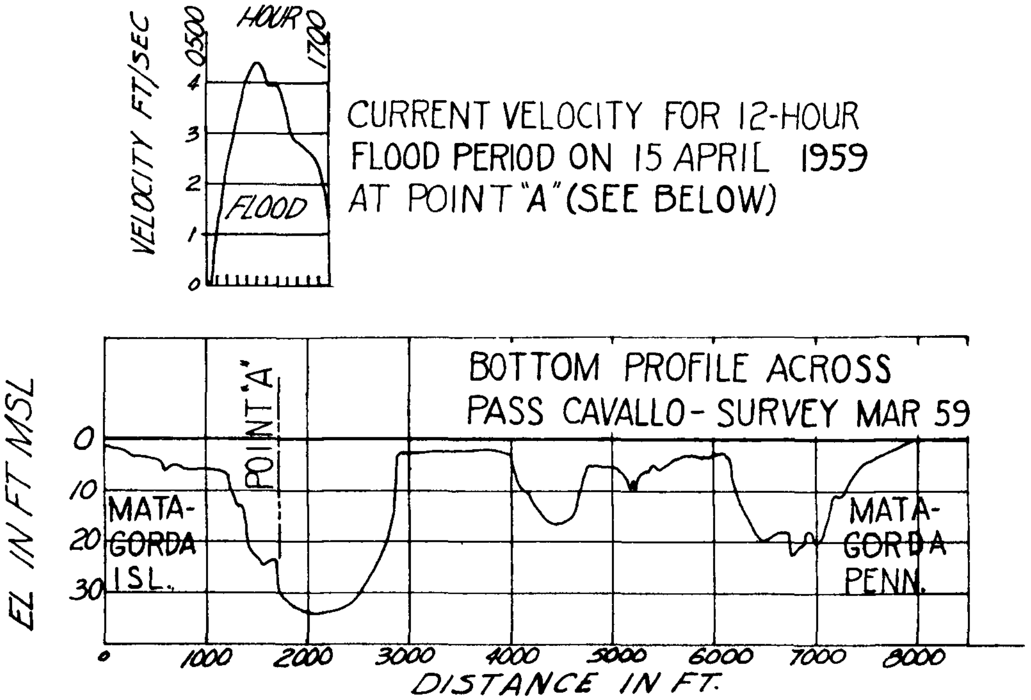

Fig. 9. Variation in velocity of water flowing through Pass Cavallo during 12-hour flood period of 15 April 1959; and cross section of Pass Cavallo showing location of current observation.

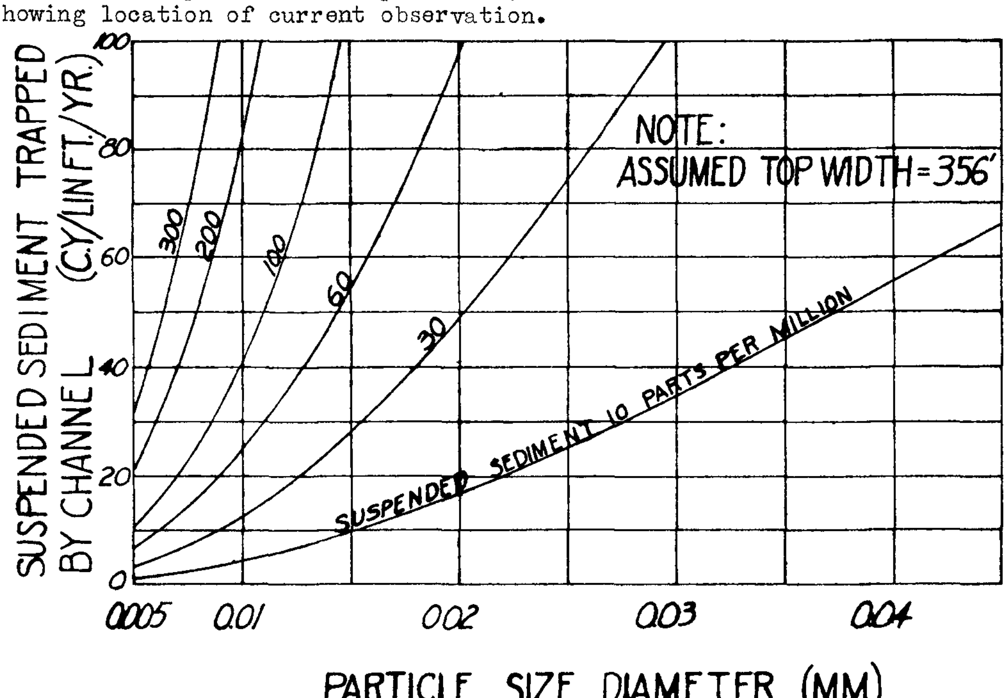

Fig. 10. Volume of suspended sediment which can be trapped by a pit or channel with top width of 356 feet.

Suspended load captured by pits - It is possible to estimate roughly that part of the deposition observed in the test pits which resulted from capture of suspended sediment. The rates at which particles of various size and specific gravity fall in water of a given temperature have been determined (10). These falling velocities of particles are based on ideal laboratory conditions, which exclude convection currents, turbulence and wind action on the surface of the water. Based on purely ideal conditions the rate at which various particles will be trapped during the crossing of the test pits is found to vary directly with (1) the concentration of suspended sediment in the water; (2) the rate of falling of the suspended material in water at a given temperature; and (3) the top width of the channel across which the suspended sediment is being transported. Based on the above, the volume of suspended sediment in cubic yards which can be trapped annually per foot length of pit (or channel) is equal to $2.262\ CV_f\ W$, where C equals the concentration of suspended sediment in parts per million by weight, V_f equals the falling velocity of the suspended particles in feet per second and W equals the top width of the pit or channel in feet. This equation is based on a weight of water equal to 64 pounds per cubic foot and a weight of trapped sediment of 33 pounds per cubic foot. Figure 10 illustrates graphically the above equation for a top width of test pit or channel of 356 feet.

The observed concentration of suspended materials in the vicinity of the test pits was about 50 parts per million by weight. The estimated rate of shoaling due to capture of suspended sediment, based on a grain size of 0.01 millimeter which has a falling velocity through water of 50° F of 0.154 millimeter, or 5.05×10^{-4} feet, per second, varies with the top width of the pit from about 10 to 14 cubic yards per foot of length of pit per year. These rates represent the maximum possible under ideal conditions based on a grain size of 0.01 millimeter. Any turbulence would tend to reduce these rates; and a larger grain size would increase these rates.

Bed movement near coast - Based on the above it was possible to estimate the rate of bed movement into the test pits, which was assumed to be equal to the total rate of sediment capture minus the rate of deposition from suspension. To permit comparison of the rates of bed movement at the different test pits it was assumed that the bed movement takes place in the form of a ribbon having a thickness equal to the diameter of the median bed particle. It is thus possible to represent the rate of bed movement by the velocity at which a ribbon of bed particles, as described above, must advance to obtain the determined volume of bed movement. The following tabulation shows the estimated velocity of the bed movement at the five test pits.

ESTIMATED VELOCITY OF BED MOVEMENT

Pit	Initial rate of shoaling (cu.yds./ lin.ft./ year)	Top width of pit (ft.)	Est. rate of suspended sediment capture (cu.yds./ lin.ft./ year)	Rate of bed movement trapped (cu.yds./ lin.ft./ year)	Median size of deposited material (mm)	Est. velocity* of bed movement (ft/sec.)
A	292	250	14	278	0.150	0.48
B	286	230	13	273	0.080	0.89
C	34	205	12	22	0.035	0.16
D	52	214	12	40	0.030	0.35
E	34	180	10	24	0.009	0.70

* Current velocities observed in Chandeleur Sound at 13-foot depth varied from 0.34 ft/sec during 72 percent of the time to 1.02 ft/sec during 0.28 percent of the time. Velocities at 9-foot depth varied from 0.34 ft/sec during 72 percent of the time to 1.19 ft/sec during 0.39 percent of the time.

Sediment capture by jetties - There have been no test pits excavated in the Galveston District; however, there have been completed recently two jetties near Raymondville. These jetties are about 35 miles north of Port Isabel (see figure 1). Hydrographic surveys made in November 1960 and in August 1961 south of the south jetty indicate a deposition behind the south jetty between the 2-foot contour and the -4.5-foot contour of the November 1960 survey of about 48,500 cubic yards of sediment, which is equivalent to about 432 cubic yards per foot per year.

Inasmuch as sediment can be brought into the test pits from both sides, whereas sediment was brought into the area behind the jetties from only one side, it would be expected that the rate of sediment capture by the jetties should be less than by test pits if other conditions were the same. The large rate of deposition behind the south jetty near Raymondville may be due to the shallow depth of water in which the deposition was observed and the large component of the prevailing wind parallel to the gulf shore near Raymondville during the period of observation.

ECONOMIC DEVELOPMENT

The towns of Port O'Connor, Port Lavaca, Point Comfort, Palacios, and Matagorda are located along Matagorda Bay. All of Matagorda, Jackson, and Calhoun Counties; and adjacent parts of Wharton, Victoria, and Refugio Counties would receive the most benefit from a deep draft channel from the Gulf of Mexico to Point Comfort. The total area of the above counties and partial counties is about 4,000 square miles. This area has a population in excess of 100,000, of which about 80,000 is urban. The city of Victoria in Victoria County is the largest in the area; and has a population of about 33,000.

The 4,000-square mile area is largely an agricultural region producing principally cotton, corn, grain, sorghums, rice, hay and vegetables. Several producing gas wells are located in Matagorda Bay and there are numerous active oil and gas wells throughout the area. Because of the availability of natural gas at seaside, the Aluminum Company of America constructed a giant plant at Point Comfort. There is a Union Carbide plant located at Seadrift, which is about 18 miles west of Port O'Connor; and Du Pont plant located at Bloomington, which is about 18 miles west of Port Lavaca. There are oyster beds, shrimp, and fish in Matagorda Bay. According to the Bureau of Commercial Fisheries, the acceptable ranges of salinity are: 10 to 20 parts per thousand for oysters; 10 to 17 parts per thousand for shrimp; and 10 to 25 parts per thousand for 13 of the most important finfishes inhabiting local estuaries. The salinity of Matagorda Bay varies from nearly zero near the mouths of the existing streams to 25 to 32 parts per thousand near Pass Cavallo.

PROBLEM

It is possible on the basis of a thorough knowledge of the forces of nature involved and the best means for controlling these forces (11) to determine which of several or many possible plans would produce the results desired at the least annual costs, in other words, the plan which would provide the greatest benefits at the least cost, including first cost and cost of annual maintenance and operation.

Various public hearings were held in 1949 and 1954 to determine the desires of the local interests. These developed the fact that all of the communities along Matagorda Bay were interested in obtaining a navigable channel from the Gulf of Mexico to their area. Originally, the local interests desired a shallow draft channel. In 1955, the Calhoun County Navigation District requested Federal assistance in the construction of a pass and main channel, 36 feet deep and 200 feet wide, extending from the Gulf of Mexico through Matagorda and Lavaca Bays to a proposed turning basin 36 feet deep and 1,000 feet square at Point Comfort, Texas, with jetties extending into the gulf to protect the pass from shoaling by littoral drift and to afford a reliable outlet to the gulf. In support of this latter request local interests stated that the Aluminum Company of America proposed to construct in Calhoun County adjacent to its existing smelting plant a refining plant for the production of 3,000,000 pounds of aluminum daily, which would require using 3,000 tons of bauxite daily. The bauxite would be imported from the Dominican Republic and Surinam, South America and would be carried by carriers of the Alcoa Steamship Company. Two units of the refining plant were completed in 1959. Bauxite is being shipped to Port Aransas where it is transferred to shallow draft vessels and brought to Point Comfort via an existing shallow draft channel.

Various plans which would provide a navigation channel from the Gulf of Mexico to Point Comfort were investigated. The problem was to determine which of these plans for a deep-draft channel to Point Comfort was the most feasible at the present time.

DESIGN OF DEEP DRAFT NAVIGATION CHANNEL FROM GULF OF MEXICO INTO MATAGORDA BAY, TEXAS

DISCUSSION

The Aluminum Company of America plant at Point Comfort is located about 26 airline miles northwest of the 40-foot depth of water in the Gulf of Mexico. Considering only the aluminum plant, a channel with a nearly straight northwest to southeast alignment extending from deep water in the gulf to the plant would have certain advantages, particularly from the standpoint of time of travel and ease of navigation.

The interchange of water between the gulf and Matagorda Bay takes place through Pass Cavallo. Considering the desirability for a channel to coincide as nearly as practicable with the direction of the predominant water currents, the channel alignment should follow the existing deep water at Pass Cavallo.

A landlocked channel would have certain advantages. There would be no cross currents in a landlocked channel.

It is not too difficult to determine the first cost of a deep draft channel, including the auxiliary works considered necessary to control the velocities and directions of flow in the channel and thereby control the movement of waterborne materials which would otherwise shoal the channel; and the work required to prevent the entrance of wind blown materials. To determine the shoaling which would occur with the various plans of improvement is much more difficult with our present knowledge of the science of tidal hydraulics.

On the basis of the high first cost and the possible adverse effect to existing oyster beds, the plan for a landlocked channel was dropped.

On the basis of first cost, it was evident that the existing shallow draft channel between a point near Port O'Connor and Point Comfort should be utilized as part of the deep-draft channel project. The total length of the existing channel between near Port O'Connor and the proposed turning basin near Point Comfort is about 17 miles, which is less than 0.5 mile longer than the straight line distance. The existing channel is about 12 feet deep and the water depths along the straight line alignment are less than 12 feet.

There remained only to determine the best alignment for the deep-draft channel from opposite Port O'Connor to deep water in the gulf. The distance from opposite Port O'Connor via a straight alignment to deep water in the gulf is about 8.5 miles; and via Pass Cavallo - about 11.0 miles. Based on the latest available data it was estimated that the alignment through Pass Cavallo, which is about 2.5 miles longer than the straight alignment, would require about 2.5 million cubic yards of dredging more than for the straight alignment (about 16.5 vs about 14 million).

It was thought at first that jetties along the alignment through Pass Cavallo could be built at nearly the same cost as those along the straight alignment. This thinking was based on the data which were available in 1955, which showed a maximum depth of water of about 10 feet between the end of Matagorda Peninsula and Pelican Island. It was reasoned that timber sheet piles only 15 feet long could be used along 17,400 feet of the necessary training works along the east side of Pass Cavallo immediately south of the end of Matagorda Peninsula. It was thought that the littoral drift material being transported along the gulf coast in this area would soon cover these timber piles. The latest thinking is that rubble mound jetties are best suited for the Texas gulf coast, providing sufficient crown width to permit construction and maintenance with vehicles.

In 1959 while making flow measurements near the end of Matagorda Peninsula, it was discovered that the water depth between the peninsula and Pelican Island had increased to about 20 feet.

Near the end of 1959 it was decided to make a model study of the Matagorda Ship Channel problem. A fixed-bed model was built by the Waterways Experiment Station at Vicksburg, Mississippi. It was not considered practicable to build a movable bed model of the entire problem area. Model tests were started on three different alignments. Alignment A as shown on figure 3 is that through Pass Cavallo, which was considered to be the most feasible at first. Alignments B and C are variations of a straight alignment. Alignment B extends in a direction nearly normal to the gulf shore; and alignment C extends along the extension of the existin shallow draft channel between Port O'Connor and Port Lavaca Bay.

The first model tests made showed very little difference in current patterns produced by alignments B and C. It was, therefore, decided to eliminate alignment B and make further model tests only on alignments A and C. Alignment C was preferred to B, because it placed the artificial opening from the bay into the gulf farther from Pass Cavallo and the cross currents.

Tests were made of alignments A and C using the model to try to determine which of these would produce the greater amount of shoaling. Sediment was introduced into the model at both the bay and gulf ends of the entrance channels. It was found, when the sediment was introduced in the bay, that more shoaling occurred in the channel following alignment C than alignment A. When the sediment was introduced in the gulf, the greater amount of shoaling occurred in the channel following alignment A.

The movement of sediment along the gulf shore is probably many times that in the bay areas because air and water movement are generally greater along the gulf shore. Observations made using test pits in Chandeleur Sound and in the gulf immediately outside the sound indicated that much more sediment moves along the gulf shore than in the sound. The actual transport of sediment along various reaches of the gulf shore can be expected to vary with the type of bed materials present, the velocity and direction of the wind in relation to the shore, and the depth of water in the area. An area with little offshore slope and thus with a larger area of shoal water is more conducive to sediment movement than one with a steep offshore slope.

Both plans for the Matagorda Ship Channel, A and C, include jetties to protect the gulf entrance. The sediment moving along the gulf shore would be trapped by the jetties at either location; therefore, sediment movement along the gulf shore was not a prime consideration in choosing the more feasible of these two plans.

The sediment movement in Matagorda Bay depends on the velocity and direction of tidal and wind produced currents, the depth of water in the bay, and the type of bed material. In a bay it can be expected that suspended sediment brought into it by fresh water streams may play a large role. The amount of sediment moving from the outer bar at Pass Cavallo to the inner bar at this pass may become the important factor.

Under existing conditions, the inner bar at Pass Cavallo has not grown, indicating that a sort of equilibrium exists - as much sediment moves away from the inner bar as moves towards it. As long as existing conditions in the vicinity of Pass Cavallo are not disturbed, it would be reasonable to assume that this near equilibrium would continue. Excavation of a deep draft channel along alignment C may disturb this near equilibrium and cause a movement of sediment into the deep draft channel. If this amount of sediment is found to be very large, say more than about one million cubic yards per year, consideration would need to be given to providing training works along alignment C to reduce the movement of sediment into the channel.

At the same time that model tests were being made, the Galveston District prepared estimates of costs of various plans for a deep draft channel from the gulf to Point Comfort and found that the plan which would provide for alignment C would cost approximately $7,000,000 less than the plan which would provide for alignment A through Pass Cavallo ($25,000,000 vs $32,000,000). Reduced to annual charges on the basis of a 100-year life, the first cost for alignment C is about $205,000 per year less than for alignment A. There are other advantages that alignment C would have over alignment A such as fewer navigation aids and thus a lesser amount required for maintenance and replacement of navigation aids. Also alignment C is about 2.5 miles shorter and straighter - thus would reduce cost of transportation.

It is obvious from the above that alignment C is preferable to alignment A in all respects except possibly cost of annual maintenance.

CONCLUSIONS

The obvious conclusion from the above is that our knowledge, particularly of sediment movement, is not complete enough to enable a determination of the amount of shoaling which will occur under the proposed plan of improvement. Also, it is questionable whether a model study, even using a movable bed model would answer this question on the amount of shoaling.

This points up the fact that the amount of shoaling which can be expected in connection with any navigation improvement in tidal waters is the factor about which our present knowledge is most incomplete.

Test pits, which are one way to obtain more information on this subject, can provide only partial answers to the amount of shoaling which will actually occur in a channel where currents will be present which can move some of the sediment.

Studies of the tractive forces required to move sediment of various shapes, sizes, and specific gravity would provide more basic information. It is known for instance, that water would at times during the tidal cycle move through the jetty channel of alignment C at velocities of nearly 6 feet per second. Such velocities would produce sufficient tractive forces along the bed of the channel to move a large part if not all of the sediment carried into the channel by cross currents. Beyond the confined reach of entrance channel these velocities become small and would not be capable of moving sediment brought into the channel by cross currents.

A detailed study of the velocities of the water in and adjacent to the proposed improvement, particularly the velocities near the bed, and knowledge of the bed materials and the forces required to move them could perhaps lead to an answer of the question on the amount of shoaling which will occur.

Acknowledgments

The tests described and the resulting data presented herein, unless otherwise noted, were obtained from research conducted by or under the United States Army Corps of Engineers. The permission granted by the Chief of Engineers to publish this information is appreciated.

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