

## CHAPTER 35

# CONTRIBUTION OF MATAGORDA BAY MODEL TO DESIGN OF MATAGORDA BAY DEEP DRAFT NAVIGATION PROJECT

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### INTRODUCTION

#### DESCRIPTION OF PROTOTYPE

The area under discussion in this paper is located on the central Texas coast in the Matagorda Bay area (see Fig 1). Matagorda Bay is one of the larger coastal bays on the Texas coast and is separated from the Gulf of Mexico by a long, narrow barrier beach known as Matagorda Peninsula. The long northeast arm of the bay is divided into two separate bodies of water by the delta of the Colorado River. Natural depths of 11 to 12 feet are available over a large portion of Matagorda Bay. Lavaca and Tres Palacios Bays, arms of Matagorda Bay, have natural depths of 6 to 7 feet.

The Lavaca and Navidad Rivers, which are the two major fresh-water streams emptying into Matagorda Bay, drain a total of 2,500 square miles. They discharge an average of about 525,000 acre feet of water annually into the bay, with a maximum annual discharge of four times the average. Observations of suspended sediment concentrations indicate that these rivers bring an average of about 700,000 cu yds of silt into Matagorda Bay annually. The lower six and one-half miles of the Colorado River, from its crossing of the Gulf Intracoastal Waterway to the Gulf of Mexico, is located across a low delta area in Matagorda Bay. This delta is subject to inundation by floods on the Colorado River, so that a large volume of fresh water may enter Matagorda Bay from this source during flood stages on the Colorado River. The Colorado River is also connected to Matagorda Bay by Tiger Island Cut; however, the fresh water contributed to Matagorda Bay by the Colorado River from this source is unknown.

Matagorda Peninsula is about 50 miles long and has an average width of about 1 mile. The normal erosional process is one of erosion and regression landward of the bay shore. The general elevation of the peninsula is about 4 to 5 feet above mean low tide. Off the west tip of Matagorda Peninsula lies Pass Cavallo. Pass Cavallo is a natural pass between Matagorda Bay and the Gulf of Mexico that has been in its approximate present position for over 200 years. The pass is approximately 1.8 miles wide. The gorge channel, about 2,000 feet wide with depths of 20 to 42 feet between the submerged bars on the gulf and bay side of the pass, lies approximately in a north-south direction

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against the northeast end of Matagorda Island. The deepest water over the outer bar is a narrow tortuous channel on the downdrift end of the bar with a controlling depth of about 7 feet. Controlling depths in the channels adjacent to the inner bar are 10 to 11 feet. Navigation through Pass Cavallo has long been considered hazardous because of the shifting channel of shallow depth across the outer bar. In 1948 a controlling depth of about 9 feet was available, but the bar shoaled considerably during the summer of 1949 and navigation was limited to boats drawing less than 6 feet. A channel with controlling depth of 17 feet, width of 135 feet, and length of 3,000 feet was dredged in 1949 across the outer bar as an emergency measure to relieve the restricted navigation conditions. The channel was completed on 9 September 1949, but shoaled to a controlling depth of 10 feet by 2 November 1949, and to a controlling depth of 8 feet in March 1952. Existing information indicates a large littoral drift of sand towards the southwest along the gulf shore of Matagorda Peninsula. The origin of some of the beach material appears to extend at least as far northward as the Brazos River. Under normal conditions, the materials are moved to Pass Cavallo where an expansive shoal area has formed southward from Decros Point at the southwest tip of Matagorda Peninsula. Tide action moves these materials into and out of lower Matagorda Bay.

Congress recently authorized construction of a deep-draft navigation channel from the Gulf of Mexico through Pass Cavallo, or other suitable location, to a turning basin at Point Comfort; consisting of an outer bar and jetty channel, 38 feet deep, 300 feet wide, and about 6 miles long, from the Gulf of Mexico through Pass Cavallo; an inner channel, 36 feet deep, 200 feet wide, and about 22 miles long across Matagorda and Lavaca Bays; a turning basin, 36 feet deep and 1,000 feet square; and dual jetties at the entrance, the southwest jetty extending to the 16-foot depth in the gulf and the northeast jetty extending to the 24-foot depth. It was recommended by the Committee on Tidal Hydraulics that a hydraulic model study be conducted by the Waterways Experiment Station at Vicksburg, Mississippi, to determine the following important features of the project: (a) the best location for the entrance channel, together with such appurtenant structures as may be required in the interests of navigation and maintenance of the entrance; (b) the best route for the channel from the north boundary of the barrier beach to Point Comfort; (c) whether the channel across the bays should be diked on one or both sides; (d) the effects of the deep-draft navigation project on the salinity and hydraulic regimens of the bay system. The model was constructed at the Waterways Experiment Station in June 1960.

This paper covers in a general way the use of a hydraulic model as an aid to design engineers in the design of a deep-draft navigable channel from the Gulf of Mexico across Matagorda and Lavaca Bays. It covers problems subject to model analysis, the type of model used, field data requirements, adjustment and verification of the model, testing of proposed improvement plans, the analysis of test results, and the limitations of the model.

COASTAL ENGINEERING

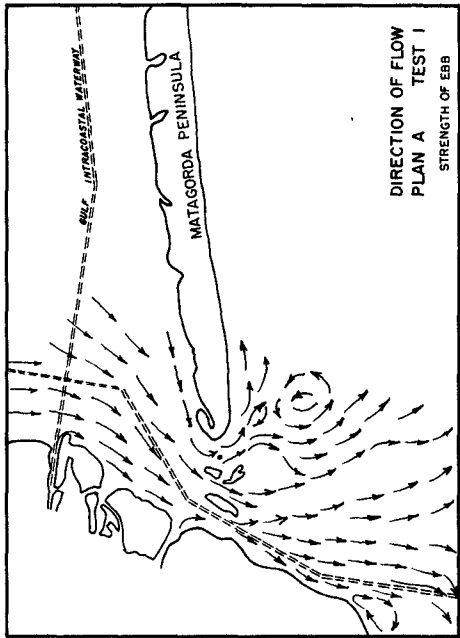


Fig. 2

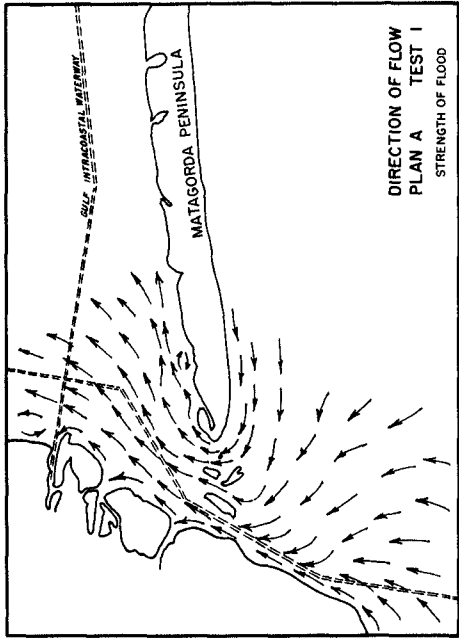


Fig. 3

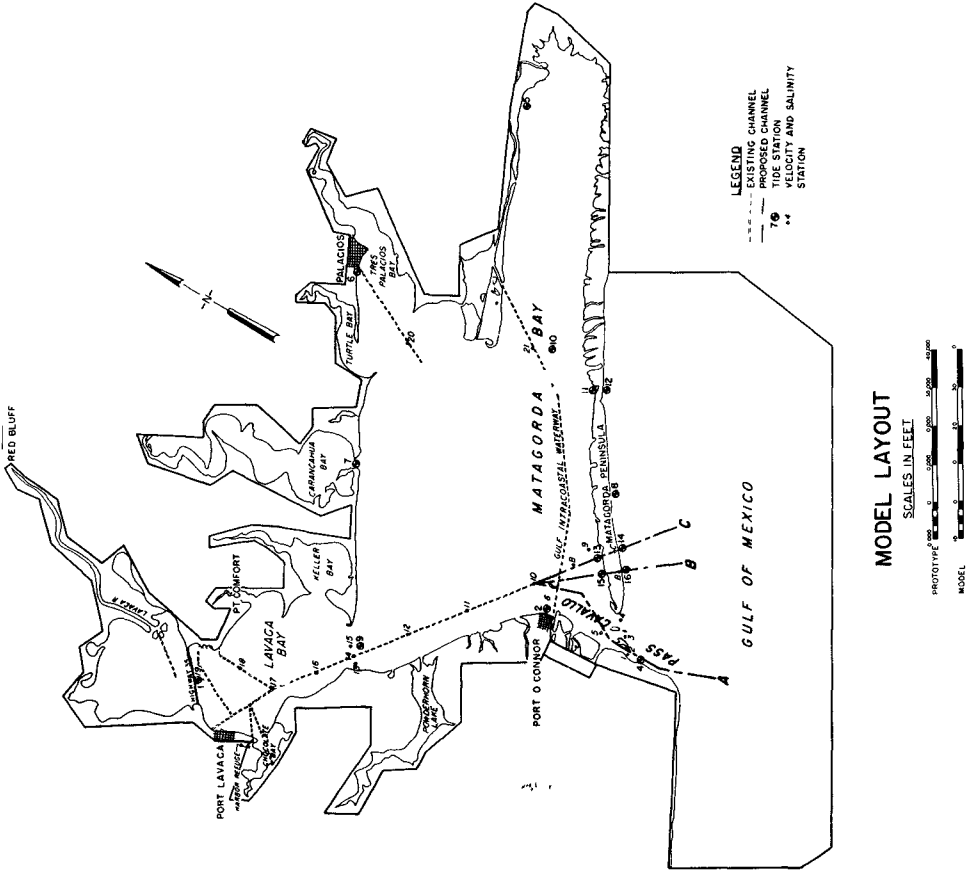


Fig. 1

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## THE MODEL

### DESCRIPTION AND SCALES

The Matagorda Ship Channel model reproduces approximately 800 square miles of prototype area, including all of Matagorda Bay and connecting bay systems from the Colorado River on the east to Espiritu Santo Bay on the west and Lavaca Bay and River to Red Bluff, at the head of the authorized project. A portion of the Gulf of Mexico adjacent to Pass Cavallo is included in the model; this area extends 19 miles to the east and 11 miles to the west of the pass and offshore to about the 70-foot contour of depth in the gulf. The limits of the area reproduced are shown in Fig 1.

The entire bed of the model is molded of concrete to conform to the prototype conditions that existed in 1960. All areas affected by alignments of the proposed ship channel were molded in removable blocks so that desired alterations could be readily made.

The model was equipped with the necessary appurtenances to reproduce and measure all pertinent phenomena such as tidal elevations, salt water concentrations, current velocities, and fresh-water inflow. Apparatus used in connection with the reproduction and measurement of these phenomena included a primary tide generator and recorder, secondary tide generator, fresh-water inflow devices, skimming and measuring weirs, chemical titration equipment, current velocity meters, photographic equipment, and tide gages.

The reproduction of tidal action in the model gulf area was accomplished by means of a primary tide generator located in the model gulf and a secondary tide generator located in Espiritu Santo Bay. The primary tide generator maintained a differential between a pumped inflow of salt water to the model and a gravity outflow of salt water from the model as required to reproduce all characteristics of the prototype tides at the model control stations. The primary tide generator was equipped with a continuous tide recorder so that the accuracy of the model tide reproduction could be checked visually at any time. The secondary tide generator reproduced, in phase, the proper flow conditions in and out of Espiritu Santo Bay.

Constant-head tanks were located at the fresh-water inflows of tributaries emptying into the bay system. Calibrated valves were used on the tanks to obtain precise measurements of the fresh-water inflow values obtained from prototype data.

The mixed salt and fresh water that accumulated in the model gulf had to be removed in order to maintain a constant source salinity. This was accomplished by means of a skimming weir which removed a quantity of mixed water from the surface layer and returned it to the sump where provisions

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were made to constantly maintain salinities and levels of salt water. There were provisions in the return line from the model to add additional salt to keep the gulf salinity at the correct level.

Salinity concentrations were determined by chemical titrations with silver nitrate in all cases involving a large number of simultaneous measurements or requiring a high degree of accuracy. Water samples were taken from selected locations in the model by hand, or with a special sampler which would simultaneously draw samples at various desired depths. The samples were then titrated with equipment consisting of a graduated burette for measuring silver nitrate, a selected group of pipettes for measuring the volume of the salinity samples, sample jars, and potassium chromate for use as an end-point indicator in the titration process.

Current-velocity measurements were made in the model with miniature Price-type current meters. The meter cups were about 0.04 ft in diameter, representing 4.0 ft in the prototype. The center of the cups were 0.05 ft from the bottom of the frame, representing 5.0 ft prototype. The meters were calibrated frequently to insure their accuracy and were capable of measuring current velocities as low as about 0.05 ft per sec (0.5 ft per sec prototype).

Permanently mounted point gages were installed on the model at the locations used for collection of field tide data. The model gages were graduated in 0.001 ft (0.1 ft prototype) and were used to measure tidal elevations throughout the model. When necessary, portable gages were used to obtain more detailed tidal data at specific locations.

The model was constructed to linear scale ratios, model to prototype, of 1:1000 horizontally and 1:100 vertically. From these basic ratios, the following scale relations were computed: slope, 10:1; velocity, 1:10; time, 1:100; discharge, 1:1,000,000; volume, 1:100,000,000. The salinity scale ratio required for an investigation of this type is 1:1.

One prototype tidal cycle of 24 hr and 50 min is reproduced in the model in 14.9 min. The model is approximately 200 ft long and 225 ft wide at the widest point, and covers an area of about 24,500 sq ft. It is completely inclosed in a shelter to protect it from the weather and to permit uninterrupted operation.

### PROTOTYPE DATA REQUIREMENTS

The accuracy of results from any model study depend to a large extent upon the accuracy and completeness of data obtained from comprehensive prototype investigations. The completeness and accuracy of such prototype studies are most essential, since the model study would unquestionably produce erroneous results if its adjustment and

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verification were based upon inaccurate or incomplete field data. It is also essential that adequate field data be available for a proper analysis of the problem before the selection of model scales and design of the model and appurtenances are undertaken.

A field data collection program was set up to insure that all field measurements needed for construction, verification, and operation of the Matagorda Bay Ship Channel model were adequate. Tide gages were located throughout the model limits. Their locations were as follows:

1. Southwest of Colorado River
2. Near mouth of Tres Palacios Bay
3. Near Alcoa Plant site
4. Near Port O'Connor
5. Near northwest end of Espiritu Santo Bay
6. Near Pelican Island
7. Gulf of Mexico

The above recording tide gages were operated for the duration of all other measurements carried out under the program. Other gages in the model area were put in use when the need arose.

Other prototype data needed for the model study were:

1. Current observations at particular ranges and points.
2. Salinity and temperature observations.
3. Fresh water and solids entering Matagorda Bay.
4. Topographic and hydrographic surveys.

## VERIFICATION OF MODEL

### HYDRAULIC VERIFICATION

The accurate reproduction of hydraulic and salinity phenomena in an estuary model is an important phase in the preparation of the model for its ultimate use in evaluating the effects of proposed improvement works.

It should be emphasized that the worth of any model study is wholly dependent upon the proven ability of the model to produce with a reasonable degree of accuracy the results which can be expected to occur in the prototype under given conditions. It is essential, therefore, before there are undertaken any model tests of proposed plans of improvement with a view to predetermining their effects in the prototype, that the required similitude first be established between the model and prototype and that all scale relationships between the two be determined.

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The hydraulic verification was preceded by a series of hydraulic adjustment tests to obtain a proper reproduction of prototype tidal phenomena throughout the bay system. Prototype tidal data from nine recording tide gages, the locations of which are shown on Fig 1, were available to verify the accuracy of the model adjustment. These prototype gages operated continuously in 1959 and 1960 during the periods in which prototype observations of current velocities and salinity were being observed.

The tide selected for reproduction in the model gulf area was of the typical one-a-day type of spring tide having a range of about 1.8 ft. This type of tide is known as a "great declination" tide, since such tide occurs when the moon reaches its greatest north or south declination. The reason for selecting a tide of maximum range was to obtain the greatest possible tidal influence in the bay area and thereby produce maximum current velocities in Pass Cavallo and in the entrance to the bay.

Adjustment of the model tidal elevations and times was accomplished by reproducing in the model gulf a tide of about 1.8 ft in range, then adjusting the roughness (strips) in Pass Cavallo until the tidal elevations throughout the bay were reproduced as correctly as possible. Further refinements were made in the model roughness during the adjustments of current velocities, until a satisfactory model verification of tidal heights and phases had been obtained. The maximum discrepancy between model and prototype was of the order of 0.1 ft prototype, or 0.001 ft in the model, while the times of high and low tides were identical for the model and prototype at all tide gage locations. Ratio of ranges of tides reproduced in the model indicate very close agreement with ranges that occurred in prototype.

The next step in the model adjustment was to obtain an accurate reproduction of the vertical and lateral distribution of prototype currents in Pass Cavallo and throughout the bay system. Prototype current velocity data was available for 21 stations (see Fig 1). The procedure followed for adjustment of currents was to reproduce a spring tide of 1.8 ft in the model gulf and adjust the model roughness until the distributions of velocities were similar to prototype velocities for each velocity station.

Based on the accuracy with which the model reproduced tidal elevations and phases and current velocities and directions observed in the prototype during the field data collecting program, it was the consensus that the hydraulic verification of the model was entirely satisfactory.

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## **SALINITY VERIFICATION**

The model salinity verification involved reproducing the inflow hydrographs of all tributaries to the bay system, in accordance with inflow data furnished by the Galveston District, for the prototype period January 1959 through June 1960. Salinity measurements were made in the model at locations, depths, and times of tidal events corresponding to the prototype measurements, and direct comparisons were made to determine the accuracy with which the model reproduced prototype salinities. The results of the test indicated excellent agreement between model and prototype for all portions of the model except in Lavaca Bay. Beginning at about Sand Point (the south end of Lavaca Bay), model salinities were slightly higher than those of the prototype, and the difference between the two increased with distance upstream so that, in the northerly portion of the bay, model salinities were substantially greater than those of the prototype. It was the consensus that excessive salinities in the Lavaca Bay portion of the model could be attributed to a deficiency in runoff from the Lavaca-Navidad watersheds. A detailed review of the runoff data was made by the Galveston District and the results indicated that the runoff from the Lavaca-Navidad watersheds was the equivalent of about 8 inches per year rather than the 4 inches per year that was used in the salinity verification test. The average runoff of 8 inches per year was used for both base and plan tests for sustained flow conditions.

## **GENERAL INVESTIGATIONS IN MODEL**

### **SELECTION OF OPTIMUM ENTRANCE CHANNEL**

The three entrance routes for the navigation channel that were chosen to be tested in the model, designated Routes A, B, and C, are shown on Fig 1. Route A was essentially the same as the deep-draft navigation channel authorized for construction. The dimensions and alignment of this route were covered in the description of the prototype. Routes B and C consisted of a 300-ft-wide channel 38 feet deep, running from deep water in the Gulf of Mexico to the gulf shore of Matagorda Peninsula; thence a decrease depth from 38 feet to 36 feet in first 500 feet of land cut from gulf shore, width remaining at 300 feet, to the bay shore of Matagorda Peninsula; thence a decrease in width to 200 feet, depth remaining at 36 feet, in the first 500 feet of the Bay starting at the bay shore of Matagorda Peninsula; thence 200 feet wide and 36 feet deep to Point Comfort. Each route was tested separately, in conjunction with a common channel route from the vicinity of Port O'Connor to Point Comfort, as a basis for selection of the optimum route from deep water in the Gulf of Mexico into Matagorda Bay. These tests were made with and without jetties extending into the Gulf of Mexico.



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In the model test of the three alternate entrance routes, special attention was given the following: (a) the effects of each channel route on the tidal prism of the bay system; (b) the effects of each channel route on current velocities at critical locations throughout the bay; (c) the maximum velocities in each entrance channel; (d) the effects of Routes B and C on current velocities in the existing Pass Cavallo; (e) the directions and strengths of surface and subsurface currents along the navigation channel; and (f) the effects of each entrance channel route on salinities for conditions of sustained fresh-water inflow. In addition, some very qualitative shoaling tests were made as an indication of relative shoaling characteristics of the Routes A and C entrances.

Each proposed channel route was tested first without jetties to aid in the design of a jetty system for each route. The initial model tests without jetties showed that the Route A entrance would have no measurable effects on the tidal prism of the bay or on current velocities throughout the bay. Salinities within the new channel, below the plane of the existing bottom, were appreciably higher than now occur at comparable locations; however, there were no appreciable changes in salinity outside the limits of the new channel, or within the limits of the new channel above the plane of the existing bottom. Maximum current velocities in the Pass Cavallo portion of the Route A entrance were of the order of 5.3 ft per sec during ebb, with velocities of this magnitude extending over approximately a 0.5 mile length of the entrance channel. The directions of tidal currents were in fairly good agreement with the channel alignment during both flood and ebb, except in the outer portion of the entrance channel (see Figs 2 and 3).

The addition of jetties at the Route A entrance caused an appreciable reduction in the tidal prism of the bay, accompanied by reductions in current velocities throughout the bay. Velocities throughout most of the length of the jettied portions of the entrance channel were increased, the maximum velocities being of the order of 5.0 ft per sec during flood and 5.8 ft per sec during ebb. Maximum velocities in excess of about 5.0 ft per sec were observed over essentially the full length of the jettied channel, or a length of about 5 miles. The alignment of the tidal currents was in good agreement with the channel alignment, except at the outer ends of the jetties where some eddy action was noted.

Tests of the Route B entrance without jetties indicated that the tidal prism of the bay would be increased slightly, accompanied by slight increases in tidal current velocities throughout the bay.

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Velocities in Pass Cavallo were not changed, thus indicating that hydraulic conditions in the existing channel would not be affected by the Route B entrance. Maximum current velocities in the Route B entrance were about 5.0 ft per sec during flood and 5.5 ft per sec during ebb. Cross-current action in that portion of the entrance channel between the bay shore of Matagorda Peninsula and Port O'Connor was rather severe because of the normal flow patterns into and out of Pass Cavallo during both flood and ebb currents (see Figs 4 and 5). As was the case with the Route A entrance, salinities in the new channel below the plane of the present bottom were substantially greater than occur at present at comparable locations; however, salinities outside the channel, especially in Lavaca Bay and the east portion of Matagorda Bay were also increased by as much as 2 parts per thousand.

The addition of jetties extending into the Gulf of Mexico had no measurable effects on hydraulic or salinity conditions observed during tests of the Route B entrance without jetties. The spacing between the jetties was 2400 feet, so the jetties did not change the tidal discharge through the Route B entrance.

The effects of the Route C entrance without jetties on the tidal prism of the bay, on current velocities throughout the bay and in Pass Cavallo, and on salinities throughout the bay system were essentially the same as for the Route B entrance. However, since the Route C entrance was farther from Pass Cavallo than the Route B entrance, the effects of tidal currents in Pass Cavallo in producing cross-current action in the Route C entrance were appreciably less severe than for Route B. Detailed measurements of current directions and velocities in the Route C channel showed that cross currents extended only down to about the plane of the present bottom, or to about -10 ft MSL, while currents below this plane were in almost perfect alignment with the navigation channel during both flood and ebb. Surface flow patterns for Route C are shown in Figs 6 and 7. The addition of jetties extending into the Gulf of Mexico at the Route C entrance, spaced 2400 ft apart, indicated no measurable effects on hydraulic or salinity conditions observed during tests without jetties.

Based on the results of the hydraulic tests described above, it was agreed by all concerned that Route C was superior to Route B in all respects, and Route B was therefore excluded from further consideration. As a basis for selection of either Route A or Route C, it was felt that some information was needed on the relative tendencies toward shoaling of these two routes downstream from about Port O'Connor.

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Three different model operating techniques were employed for qualitative shoaling tests. In the first technique, equal quantities of synthetic sediment, representing suspended sediments of the prototype, were injected into the model on one range running from Port O'Connor to the bay shore of Matagorda Peninsula east of the Route C entrance, and a second range running across Pass Cavallo just north of Decros Point. Material at the Port O'Connor range was injected during the ebb current phase only, while that at the Pass Cavallo range was injected during flood only. Identical tests were made with the Route A entrance installed in the model and with the Route C entrance installed. The second technique involved injection of all the material on the Port O'Connor range during the ebb current phase, while the third involved injecting all of the material on the Pass Cavallo range during the flood current phase.

The three techniques described above were employed because it was not possible to determine the primary source of sediment to the channel, and this procedure permitted a rough evaluation of the shoaling characteristics of the two entrance routes under all possible combinations of primary source. For example, the first technique assumed an upstream source and a downstream source of equal magnitude, the second assumed a primary upstream source, and the third assumed a primary downstream source. Since there is no basis for estimating rates of shoaling in the area involved, either under present conditions or following construction of one or the other of the deep channel routes, these tests were designed to determine only if one channel route showed a marked tendency to shoal more rapidly than the other, and the conditions of direction of source material under which such tendency was most marked.

The results of the qualitative shoaling tests indicated the following: (a) the Route C entrance would shoal at a slightly greater rate than the Route A entrance if the source of shoaling material is equally divided between upstream and downstream; (b) the Route C entrance would shoal at an appreciably greater rate than the Route A entrance if the primary source of sediment is upstream; and (c) the Route A entrance would shoal at an appreciably greater rate than the Route C entrance if the primary source of sediment is downstream. The meager information on shoaling of the area under consideration for existing conditions indicates that active shoaling takes place at the Intracoastal Waterway entrance into Matagorda Bay, just south of Port O'Connor, and that the sediments responsible for such shoaling come from Pass Cavallo. On the other hand, that portion of the Intracoastal Waterway to the east of the deep draft channel route, which lies below the plane of the natural bay bottom, shows little if any tendency to shoal. This provides some evidence, therefore, that Matagorda Bay is probably not a primary source of sediment, but that Pass Cavallo is a primary

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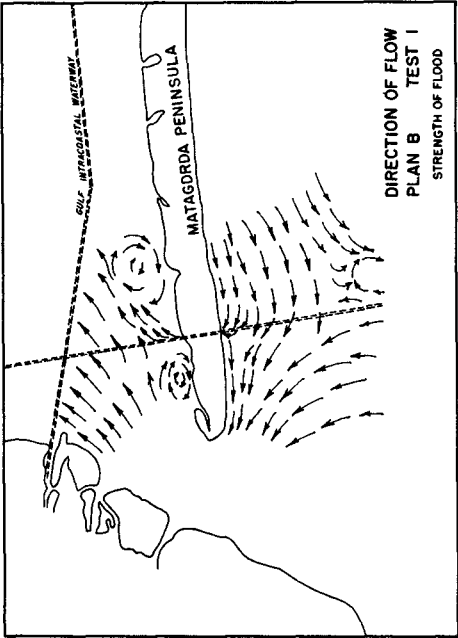


Fig. 5

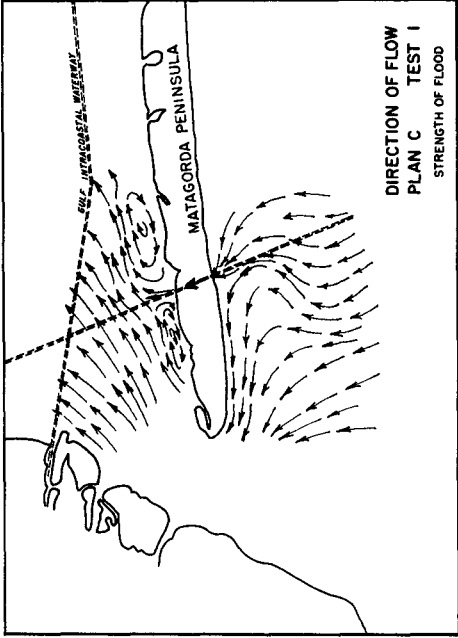


Fig. 7

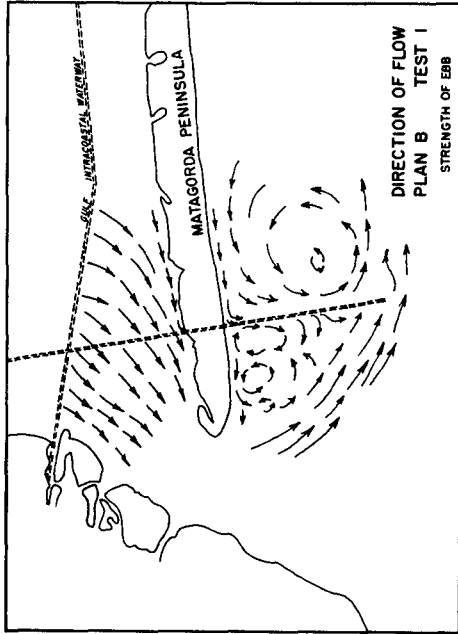


Fig. 4

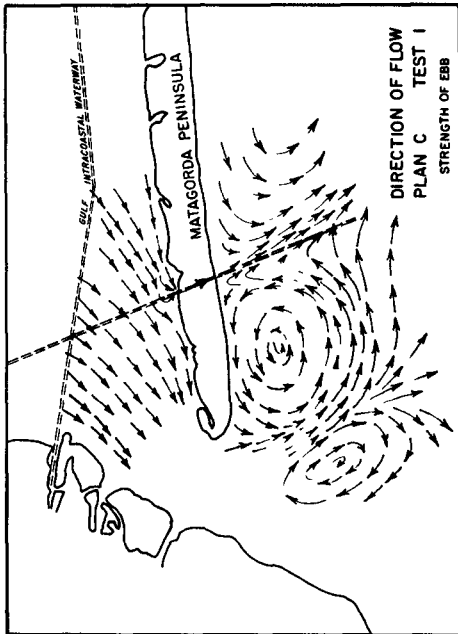


Fig. 6

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source of sediment, and under such conditions the qualitative shoaling tests indicate that shoaling of the Route C entrance would probably be less than that of the Route A entrance.

Based on the results of hydraulic and shoaling tests made in the model, it appears that the Route C entrance is superior to the Route A entrance for the following principal reasons: (a) the Route C entrance provides the shortest and straightest route to deep water in the Gulf of Mexico; (b) the initial cost of dredging the Route C entrance would be significantly less than for Route A; (c) the jetties required for Route C are much less extensive than would be required for Route A, and thus the cost of construction and maintenance of jetties would be appreciably less; (d) if the principal source of potential shoaling material is from downstream, as appears to be the case, maintenance dredging of Route C would be less than for Route A; and (e) ships navigating the Route C entrance would be exposed to fairly high velocity currents (in excess of about 4.0 ft per sec) only in the short land cut across Matagorda Peninsula, while for Route A currents of this magnitude would be encountered over essentially the full length of the jetty channel, or for a distance of about 5 miles.

The only apparent advantage of Route A over Route C is that cross-current action in that portion of the channel downstream from Port O'Connor would be less for Route A. However, detailed observations of the directions and velocities of cross currents in this portion of the Route C channel indicate that such currents are confined to the upper 10 ft or less of the depth, with currents below this plane being in good alignment with the navigation channel. Furthermore, the results of observations made in the Galveston Harbor model have shown that cross currents in the approach to the Texas City Channel are equal to or greater than those which would be encountered in the Route C entrance, and since no complaints have been registered that cross-current effects are detrimental to navigation in the Texas City Channel, it appears that currents of equal or lesser magnitude would cause no serious problem in the Route C entrance.

Following the conclusion that the Route C entrance was the optimum route, a series of tests was made to determine the effects of parallel jetties varying in length from 2,950 ft to 15,500 ft (from the 15-ft contour in the Gulf to the 36-ft contour of depth) on flow patterns and velocities in the Gulf portion of the entrance and in the land cut across Matagorda Peninsula. The results of these tests showed that jetty length, with a spacing of 2400 ft between jetties, would have little if any effect on flow patterns and velocities in the entrance channel. While the model tests indicated some minor cross-current action just off the ends of the jetties, the locations of which would be shifted gulfward as the lengths of jetties were increased, the magnitudes of such currents did not appear to be sufficient for any jetty length to cause problems to navigation.

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For the various jetty lengths mentioned in the previous paragraph, assumed beach accretions were placed in the model east of the east jetty and west of the west jetty to determine if such accretions would appreciably change flow patterns or velocities in the entrance. The most drastic assumed beach accretions extended essentially out to the Gulf ends of the jetties, and even under such conditions there were no indications that flow patterns and velocities in the entrance would be adversely affected.

Tests were also made of dikes, spaced 2400 ft apart, on both sides of the channel extending into Matagorda Bay from the bay side of Matagorda Peninsula. The purpose of these tests was to determine how cross-current action in the channel between Matagorda Peninsula and Port O'Connor would be affected by such dikes. The conditions tested consisted of 1,000-ft-long dikes on both sides of the channel, extension of the west dike to 3000 ft, and further extension of the west dike to 5000 ft. The results of the dike tests indicated that 1,000-ft-long dikes on both sides of the channel would appreciably improve cross-current action in the channel. Extensions to the west dike would decrease the length of channel exposed to cross currents, but the velocities of the cross currents just off the end of the dike would be increased progressively as the length of the west dike is increased. It was concluded that the effects of the 1,000-ft-long dikes on both sides of the channel are entirely beneficial, but that extensions to the west dike should be made only if navigation interests have a definite preference to a lesser length of channel exposed to higher cross-current velocities, as opposed to a greater length of channel exposed to cross currents of moderate velocities.

A one-year salinity test was made in the model to determine the effects of the Route C navigation channel on salinities throughout the bay system. In addition to the deep-draft channel, the plan installed in the model included jetties 2400 feet apart extending into the Gulf of Mexico to the -24 ft contour of depth; 1000-ft-long spoil dikes, also 2400 ft apart, extending into Matagorda Bay from Matagorda Peninsula; and the spoil bank arrangement in Matagorda and Lavaca Bays arrived at in the following discussion of spoil bank location and alignment.

Two tests of approximately one-year's duration were made, one for existing conditions (base test) and the other with the Route C channel and appurtenant works installed in the model. In both tests, the fresh-water discharges of all tributaries to the bay system were controlled in accordance with prototype hydrographs for the

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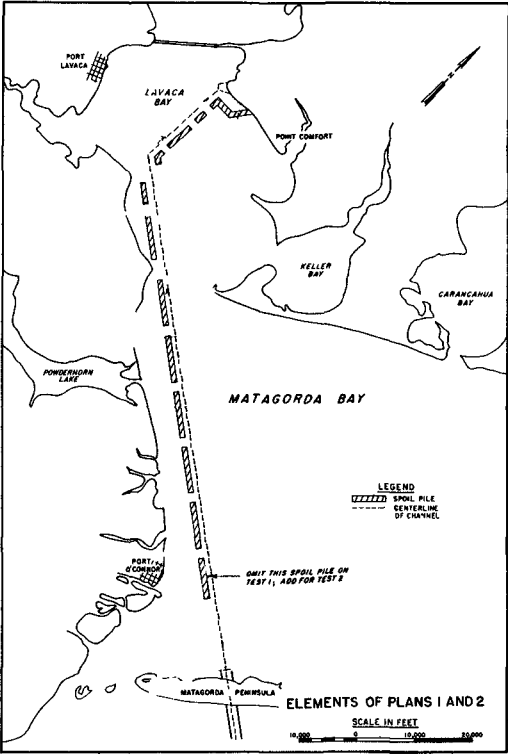


Fig. 8

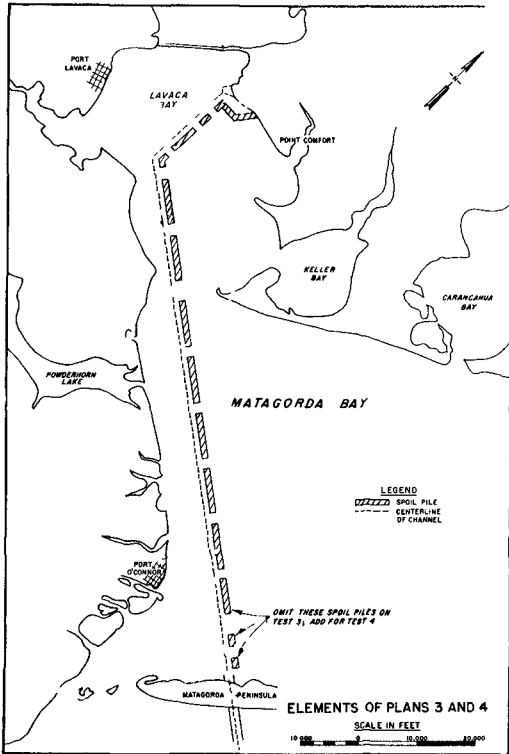


Fig. 9

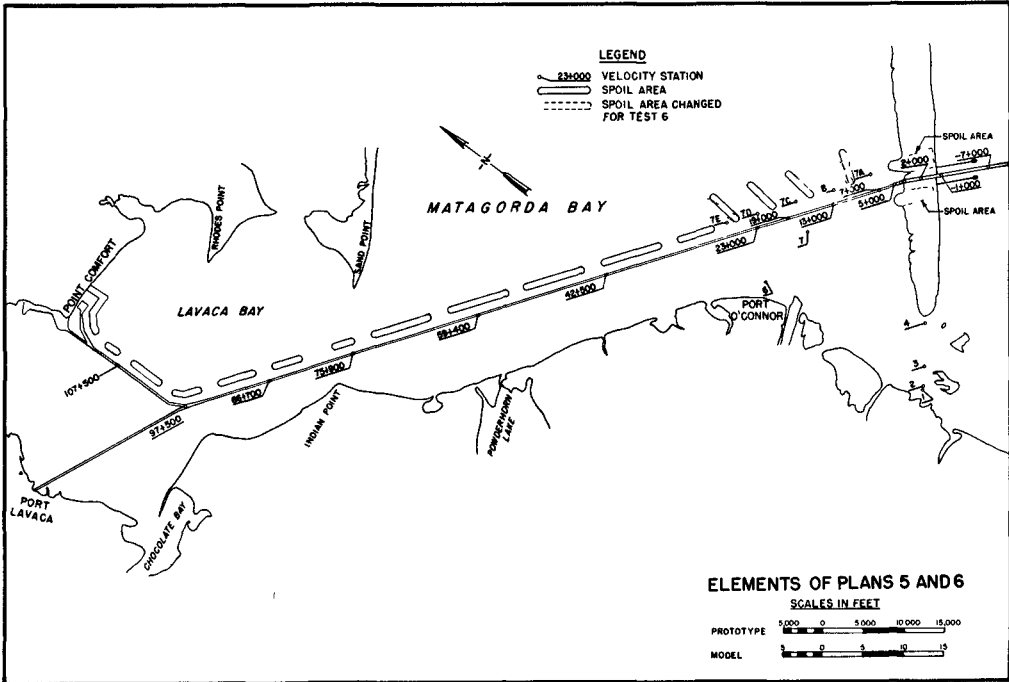


Fig. 10

## CONTRIBUTION OF MATAGORDA BAY MODEL TO DESIGN OF MATAGORDA BAY DEEP DRAFT NAVIGATION PROJECT

period 27 May 1959 through 2 June 1960. Samples for salinity determination were obtained at intervals of about one week at all stations and depths at which samples were obtained in the prototype for model verification purposes.

In general, it appeared that the Route C channel would not effect a major change in the salinity regimen of the bay system. Considering annual average salinities in the major subdivisions of the bay system, the maximum increases (2.0 to 3.8 parts per thousand) occurred in Lavaca Bay system and the east portion of Matagorda Bay. Maximum salinities throughout the test year were increased by the plan at most stations and depths, but in general the increases amounted to one or two parts per thousand; however, minimum salinities at some locations in Lavaca Bay were increased by as much as 8.7 parts per thousand.

### SPOIL BANK LOCATION AND ALIGNMENT

To aid in formulating a spoil disposal plan for disposal of spoil dredged during construction of the deep-draft channel, surface current pattern photographs were taken in the model along the channel alignment from Matagorda Peninsula to Point Comfort. From the above photographs the Galveston District proposed four tentative plans for disposal of the spoil to be tested in the model. Two plans (plans 1 and 2) involved placement of most of the spoil on the west side of the channel, in series of fills parallel to the channel with gaps between fills (see Fig 8), while the other two plans (plans 3 and 4) involved placement of most of the spoil on the east side of the channel in a similar manner (see Fig 3). The two plans involving placement of most of the spoil on the west side of the channel had no measurable effects on tidal prism or mass flow patterns in the bay system. However, it was noted that some cross-current action developed opposite essentially every gap between spoil banks. While the intensities of such current were probably insufficient to affect navigation, it seemed likely that shoaling would be accelerated in the channel opposite each gap.

Plans 1 and 2 were discarded from any further tests when it was learned that there are two oyster reefs on the southwest side of the channel, in the vicinity of Indian Point in Lavaca Bay and Powder Horn Lake in Matagorda Bay. It was agreed that placement of the spoil piles on the west side of the channel would be detrimental to these oyster reefs. It was also agreed that by the placement of the spoils on the east side of the channel they would afford more protection to navigation.



## COASTAL ENGINEERING

In plan 3 the spoil piles were placed on the east side of the channel in a manner similar to that employed in plan 1. The first spoil pile was located east of Port O'Connor approximately four miles from the bay shore of the Peninsula. This plan was subjected to model tests, and the results showed that it had no detrimental effect on conditions in the channel. For plan 4, three additional spoil piles (Fig 9) were added between Matagorda Peninsula and the first spoil pile for plan 3. The addition of the three spoil piles increased cross current velocities in the openings of the added spoil piles. The first cost of dredging the deep-draft channel through lower Matagorda Bay would be greatly reduced by permitting deposition of spoil in the 4-mile reach between Matagorda Peninsula and station 28+000. Plan 5, (Fig 4) which consisted of 4 spoil areas 5,000 ft apart in the 4-mile reach, was then tested in the model. Each spoil pile had bottom dimensions of 900 by 4600 feet, top dimensions of 100 by 3800 feet, and side slopes of about 1 on 20. Observations of surface and subsurface velocities and current directions at the entrance of the ship channel into Matagorda Bay for Plan 5 indicated that the arrangement of spoil banks in this area could be improved. Several trial alignments were installed in the model and tested. It was found that by rotating the first and fourth spoil banks (nearest the entrance) 20 degrees and 10 degrees, respectively, from the plan 5 alignment, closer conformity of the banks with the current patterns could be achieved (plan 6, Fig 10). The intensity of cross-current action for plans 5 and 6 was probably insufficient to affect navigation, except at station 7+000 where current directions departed from normal with the channel alignment by about 90 degrees on flood and about 60 degrees on ebb, with corresponding current velocities of about 2.0 ft per sec. This variance decreased progressively from station 7+000 to station 23+000 where the departure was about 50 degrees on flood and about 30 degrees on ebb, with maximum velocities of 1.8 ft per sec and 1.2 ft per sec, respectively.

### CONCLUSIONS

The project that has been selected for construction in the field is essentially the same as plan C with some minor alterations. The project consists of a 300-ft-wide by 38-ft-deep entrance channel, with 1 on 3 side slopes from deep water in the Gulf of Mexico to the end of the jetties; thence 1 on 5 side slopes from the end of the jetties in the Gulf to about 1000 ft north of the bay shore of Matagorda Peninsula; and thence a 200-ft-wide by 36-ft-deep channel with 1 on 3 side slopes from a point 1000 ft north of the bay shore of Matagorda Peninsula to Point Comfort. The 300-ft-wide channel through Matagorda Peninsula is aligned eight degrees south from the alignment of the 200 ft channel and has twin jetties 2000 ft apart, extending from the Gulf shoreline of Matagorda Peninsula to the 24-ft contour of depth in the Gulf; and twin protective spoil embankments, 25 ft in height at mlw across Matagorda Peninsula, extending about 1000 ft into Matagorda Bay.

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## SUMMARY

In resume, the authors have attempted to emphasize the importance of the Matagorda Bay model as an aid to the design engineers in selection of the optimum route for the deep-draft channel route from the Gulf of Mexico through Matagorda and Lavaca Bays to Point Comfort. With the aid of information provided by the model, the route selected for construction (Route C) will result in substantial savings over the route proposed originally (Route A), because of its shorter length, the lesser requirements for length of entrance jetties, and the fewer number of navigation aids which will be required because of its straighter alignment.

The model also provided a wealth of valuable information as to the optimum arrangement of spoil disposal areas to be used during construction and subsequent maintenance of the channel. The arrangement of spoil disposal areas selected will not cause cross currents in the channel which would be hazardous to navigation, and they will have a minimum effect on tidal circulation and salinity distribution in the bay system so as to preserve existing conditions to the extent possible in the interest of the fish and wildlife resources of the area.

It is further emphasized that the hydraulic model is not capable of providing in a quantitative sense all of the information that design engineers need in selecting the significant features of a major navigation project such as the Matagorda Bay project. However, in the hands of experienced hydraulic laboratory personnel who are thoroughly familiar with the capabilities and limitations of hydraulic models, the cost and effort invested in a model is usually returned with dividends in terms of lower cost of construction in the field as well as in terms of more efficient performance of the final project.