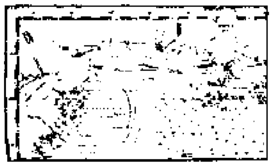
FINAL REPORT
Contract Number MASG-R/EN-1
Grant Number NA81AA-D-00050

HYDRODYNAMICS OF MOBILE BAY AND MISSISSIPPI SOUND



by

Donald C. Raney
Professor of Engineering Mechanics

John N. Youngblood
Professor of Mechanical Engineering

and

Gary C. April
Professor of Chemical Engineering

Prepared for
Mississippi-Alabama Sea Grant Consortium

August 1984

BER Report No. 324-183
MASGP-83-027

The University of Alabama
College of Engineering
Bureau of Engineering Research
P.O. Box 1968
University, Alabama 35486
Telephone: (205) 348-6400

THE UNIVERSITY OF ALABAMA
COLLEGE OF ENGINEERING

The College of Engineering at The University of Alabama has an undergraduate enrollment of more than 2,300 students and a graduate enrollment exceeding 180. There are approximately 100 faculty members, a significant number of whom conduct research in addition to teaching.

Research is an integral part of the educational program, and research interests of the faculty parallel academic specialities. A wide variety of projects are included in the overall research effort of the College, and these projects form a solid base for the graduate program which offers fourteen different master's and five different doctor of philosophy degrees.

Other organizations on the University campus that contribute to particular research needs of the College of Engineering are the Charles L. Seebeck Computer Center, Geological Survey of Alabama, Marine Environmental Sciences Consortium, Mineral Resources Institute—State Mine Experiment Station, Mineral Resources Research Institute, Natural Resources Center, School of Mines and Energy Development, Tuscaloosa Metallurgy Research Center of the U.S. Bureau of Mines, and the Research Grants Committee.

This University community provides opportunities for interdisciplinary work in pursuit of the basic goals of teaching, research, and public service.

BUREAU OF ENGINEERING RESEARCH

The Bureau of Engineering Research (BER) is an integral part of the College of Engineering of The University of Alabama. The primary functions of the BER include: 1) identifying sources of funds and other outside support bases to encourage and promote the research and educational activities within the College of Engineering; 2) organizing and promoting the research interests and accomplishments of the engineering faculty and students; 3) assisting in the preparation, coordination, and execution of proposals, including research, equipment, and instructional proposals; 4) providing engineering faculty, students, and staff with services such as graphics and audiovisual support and typing and editing of proposals and scholarly works; 5) promoting faculty and staff development through travel and seed project support, incentive stipends, and publicity related to engineering faculty, students, and programs; 6) developing innovative methods by which the College of Engineering can increase its effectiveness in providing high quality educational opportunities for those with whom it has contact; and 7) providing a source of timely and accurate data that reflect the variety and depth of contributions made by the faculty, students, and staff of the College of Engineering to the overall success of the University in meeting its mission.

Through these activities, the BER serves as a unit dedicated to assisting the College of Engineering faculty by providing significant and quality service activities.

FINAL REPORT

on

HYDRODYNAMICS OF MOBILE BAY AND MISSISSIPPI SOUND

by

Donald C. Raney
Gary C. April
John N. Youngblood

Prepared for

Mississippi-Alabama Sea Grant Consortium

BER Report No. 324-183

Grant No. NA81AA-D-00050

Contract MASG-R/EN-1

August 1984

TABLE OF CONTENTS

I. INTRODUCTION

The objective of the research project "Hydrodynamics of Mobile Bay and Mississippi Sound" was to establish a baseline of calibrated and verified numerical models capable of providing input data for engineering studies, water-resource management, water-quality assessment and other water related projects in the Mobile Bay - Mississippi Sound region.

The project was funded for five (5) program years (1979-83) although only a minimal maintenance funding was provided in the 1981 program. To a large extent the project objectives were realized. In addition, a number of fringe benefits have resulted directly and indirectly from this project.

A number of numerical model applications have been made in the Mobile Bay - Mississippi Sound region, providing valuable engineering information concerning the hydrodynamics of the coastal regions. The research program interacted with other Mississippi - Alabama Sea Grant principal investigators and outside agencies in several studies. In particular, a number of cooperative studies were conducted with the Mobile District, Corps of Engineers.

The research results from the project have been well documented. A number of theses, technical reports and papers have been published on various components of the project. Nine (9) graduate students have obtained valuable numerical modelling experience working on the project. With the project as a base, the numerical modelling capabilities of the University have been significantly expanded. Additional outside funding and internal grants have allowed the Engineering Mechanics Department to develop an excellent numerical modelling facility with a Hewlett-Packard System 1000 as the basic component. This dedicated facility greatly enhances the numerical modelling capabilities beyond that available from the University mainframe computer system.

A graduate program in Coastal Engineering has been developed and approved in large part due to student interest developed as a result of the numerical modelling research. Graduate courses in Physical Oceanography and Numerical Modelling of Hydrodynamic Systems have been taught. A new course in Water Quality Modelling is currently being developed.

The Engineering Mechanics Department has identified Numerical Modelling of Physical Systems as one of the two primary research areas for the Department. The two primary research areas have first priority on available physical and financial resources in an attempt to develop specialized areas of expertise within the Department.

II. REVIEW OF PROJECT ACTIVITIES

This research project was originally visualized as a three-year program (1979-1981). Due to a shortage of prototype data and expansion of the original scope of work it became a five-year program (1979-83). Most research activities of the project have previously been documented by published technical reports. A brief summary of the yearly project activities provides a general project overview.

A. 1979 Program

The first year of the program was completed essentially as planned. The WIFM model developed at the U. S. Army Engineer Waterways Experiment Station (WES) was selected as the basic hydrodynamic model. WIFM is an implicit finite difference model based on a two-dimensional depth averaged formulation of the governing hydrodynamic equations. For non-stratified estuaries, this model has been shown to yield satisfactory simulation of the hydrodynamics.

The numerical model was made operational at The University of Alabama. Available historical data were collected, and necessary modifications to the model were accomplished. Graphical programs for convenient visual display of model output were also developed. Three basic model applications were initiated: Mobile Bay alone, Mississippi Sound alone, and Mobile Bay-Mississippi Sound combined.

Input data for these model applications were developed and the models applied, producing results which appeared reasonable. The accuracy of the results could not be established due to a lack of prototype data for model calibration and verification.

An interim technical report[4] documents in detail the first year activities. In addition, two technical papers[11, 12] were presented outlining the use of numerical models for planning and management purposes.

B. 1980 Program

The planned second year of the project was almost completely dependent upon having sufficient prototype data available for model calibration and verification. Some limited prototype data for Mobile Bay were obtained from the Corps of Engineers; however, no prototype data for Mississippi Sound became available in 1980. It was necessary, therefore, to modify the second-year program. The available data for Mobile Bay was used to partially calibrate a numerical model for the Bay. An investigation of pass exchange was initiated: Mobile Bay with the Gulf of Mexico and with Mississippi Sound. A request was also received from Dr. Brande at the University of Alabama in Birmingham for some hydrodynamic input to his research efforts in an attempt to explain the apparent spreading pattern of dredge material in Mobile Bay. Modification of the Mobile Bay model was initiated to provide information for Dr. Brande. In addition, some activities planned for the third year of the project (1981 Program) were moved forward into the 1980 program. Investigations were initiated into one-dimensional models (to better handle the river-inflow problem), three-dimensional models and water-quality models. Development work on the basic two-dimensional hydrodynamic model continued, aimed at increasing its flexibility and accuracy.

Work initiated in 1980 ultimately led to publications related to movement of dredge spoil from the channel aprons. In addition, investigations of water quality models developed the foundation for later publications on salinity variations in Mobile Bay as a function of tide, river and wind effects.

C. 1981 Program

The planned third year of the project (1981 program) was significantly modified due to a continuing lack of prototype data for calibrating and verifying the numerical models. The third year's efforts were at a very reduced funding level while awaiting availability of prototype data. Four major activities were initiated: (1) application of the partially verified hydrodynamic model of Mobile Bay to investigate pass exchange, Mobile Bay with the Gulf of Mexico and Mobile Bay with Mississippi Sound; (2) use of a tidal cycle averaged salinity model to determine the effect of river inflow on salinity levels in Mobile Bay; (3) use of the hydrodynamic model of Mobile Bay to investigate east-west currents in the Bay and attempts to correlate these currents with observed sediment movement from the channel aprons; and (4) discussions with Corps of Engineering personnel relative to the establishment of a cooperative research effort between the Corps of Engineers and the Mississippi-Alabama Sea Grant Consortium.

The first two activities became masters theses by Phillip Jarrell[1] and Tyrone Ling[2]. These were published as MASG technical reports. The third activity was in conjunction with Scott Brande from the University of Alabama in Birmingham and later resulted in publication of a technical report[5] and paper[13].

In many ways the fourth activity listed above produced the most significant results. As a result of these discussions a cooperative agreement was negotiated between the Corps of Engineers and the Mississippi-Alabama Sea Grant Consortium. The cooperative agreement: (1) made available the Corps of Engineers calibrated WIFM model for the Gulf of Mexico; (2) insured access to available prototype data for Mobile Bay and Mississippi Sound; (3) provided for The University of Alabama to apply the WIFM model to specific areas in Mississippi Sound and to make the results available to the Mobile District, Corps of Engineers; and (4) provided for other cooperative efforts of mutual benefit.

D. 1982 Program

During the 1982 Sea Grant program, numerical models and data were transferred from the Corps of Engineers to The University of Alabama and made compatible with The University of Alabama computer system. The exchanged information included (1) a current version of the WIFM hydrodynamic model calibrated and verified for the upper portion of the Gulf of Mexico (referred to as a global grid), (2) a version of the WIFM model to which a salinity algorithm has been added, (3) an example application of the WIFM global grid model for the Gulf of Mexico used in conjunction with a fine grid in a local region of interest, and (4) available prototype data for Mississippi Sound.

In exchange, The University of Alabama provided numerical modelling assistance to the Mobile District, Corps of Engineers. Assistance was provided with an environmental impact statement for a proposed breakwater at Eastpoint in Apalachicola Bay. This activity was documented in a technical paper[14] and two technical reports[6,7]. In addition, assistance in generating finite difference grids for local areas in Mississippi Sound was provided to the Mobile District, Corps of Engineers.

E. 1983 Program

1983 was primarily a year of model applications. The WIFM model was applied to local regions in Mississippi Sound and to Mobile Bay. Models were calibrated and verified using available prototype data. This work was in conjunction with and in cooperation with the Mobile District, Corps of Engineers. Some aspects of this work is documented in two technical reports[3,9] and one paper[17]. The local Gulfport and Biloxi areas were investigated. In particular, the effects of deepening navigational channels on the hydrodynamics of the area was explored using the WIFM model.

A paper[15] and technical report[10] were written documenting the water quality model developed by Dr. John Youngblood as a part of this project. The model was applied to investigate variations of salinity patterns in Mobile Bay during a tidal cycle. River inflow and wind conditions were varied in the investigation.

An internal grant from the University allowed the development of a numerical modelling laboratory with a Hewlett Packard System 1000 and 7580A Drafting Plotter as the basic components. During 1983, much of the numerical modelling activity was shifted to this system from the University mainframe computer system. More capability and flexibility are available from the dedicated facility.

III. STUDENT INVOLVEMENT

The following graduate students received financial assistance from the research contract:

Lih Chern
J. Phillip Jarrell
Tyrone Ling
Der-Jang Lou
Chris Roberts
Hasan Urgun
Y. C. Wu

Two other graduate students, Therese Rhodes and Dino Theodorou, were involved in the Sea Grant project but did not receive direct financial assistance from the project.

All of the above-mentioned students except Dino Theodorou have completed requirements for the degree of Master of Science in Engineering Mechanics. Mr. Jarrell and Mr. Ling obtained degrees in Chemical Engineering. The other students received degrees in Engineering Mechanics.

Mr. Jarrell, Mr. Ling and Mr. Urgun wrote theses for the Master of Science degree on aspects of the research project. The other students were enrolled in non-thesis options. All three theses were published as technical reports and are documented elsewhere in this report.

Several undergraduate students received limited financial assistance for short-term work on the project.

IV. SUMMARY OF PUBLICATIONS

A number of theses, technical reports and papers have resulted completely or in part from the research project. A listing and abstract or brief summary of these publications will be tabulated in this section.

A. Theses

1. Jarrell, J. Phillip, "Hydrodynamics of Mobile Bay and Mississippi Sound - Pass Exchange Studies", The University of Alabama Bureau of Engineering Research Report No. 271-112, MASGP-80-023, July 1981.

This study applied the Waterways Experiment Station Implicit Flooding Model (WIFM II) to the Mobile Bay - East Mississippi Sound system. The boundaries of the numerical model are shown in Figure 1. The object was to investigate the exchange of water through the passes; Pass aux Herons from Mobile Bay to East Mississippi Sound and Main Pass, from Mobile Bay to the Gulf of Mexico. The model was calibrated with available prototype data from the Mobile District, Corps of Engineers. Various tidal conditions, river flows and wind conditions were applied to the model and the resulting flow rates through the passes were analyzed. The distribution of flows through Main Pass and Pass aux Herons for various conditions is presented in various graphical formats. A typical circulation pattern, at a specific time and for specific input parameters, is shown in Figure 2.

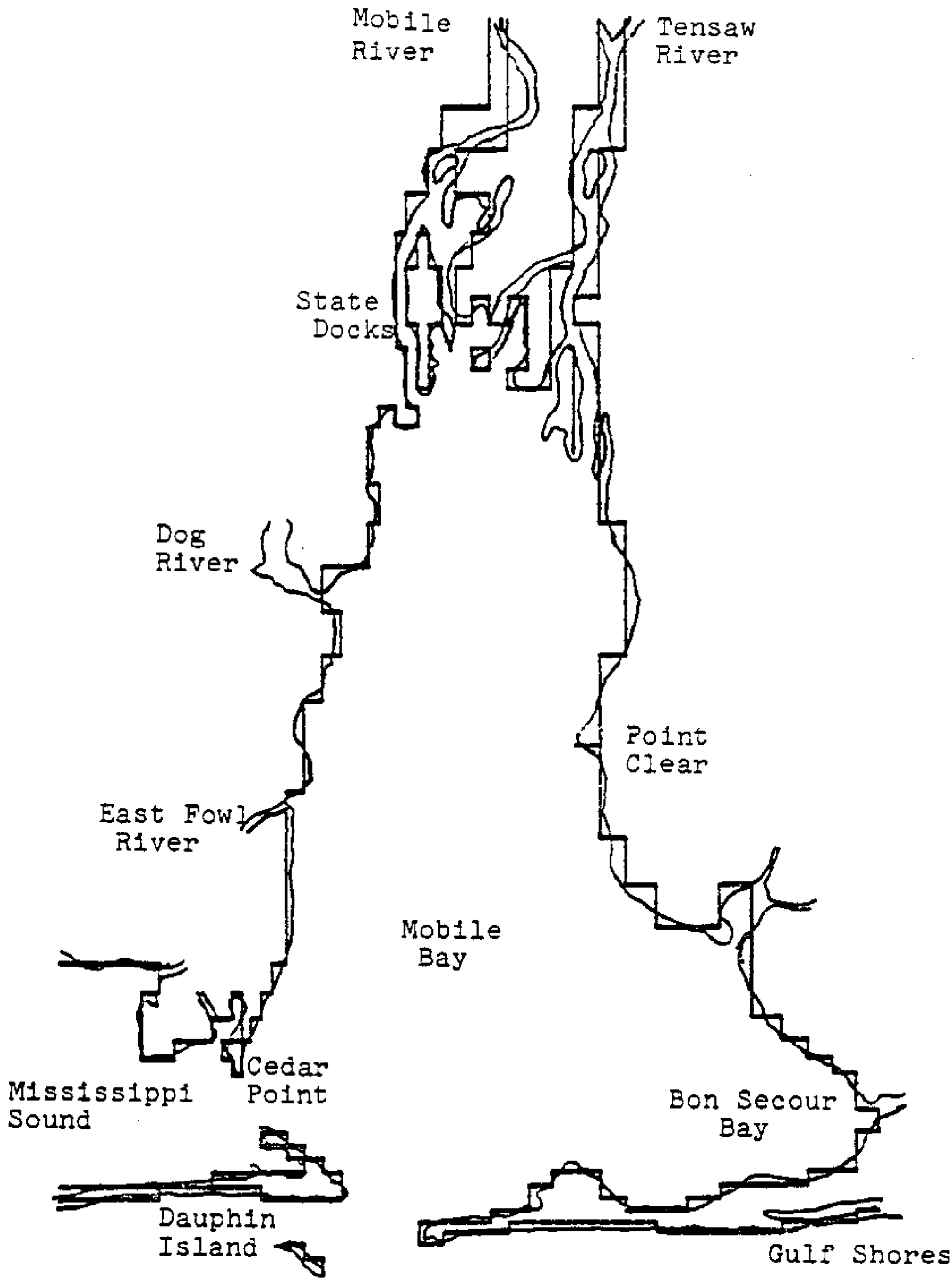


Figure 1. Boundaries of Mobile Bay-East Mississippi Sound Model

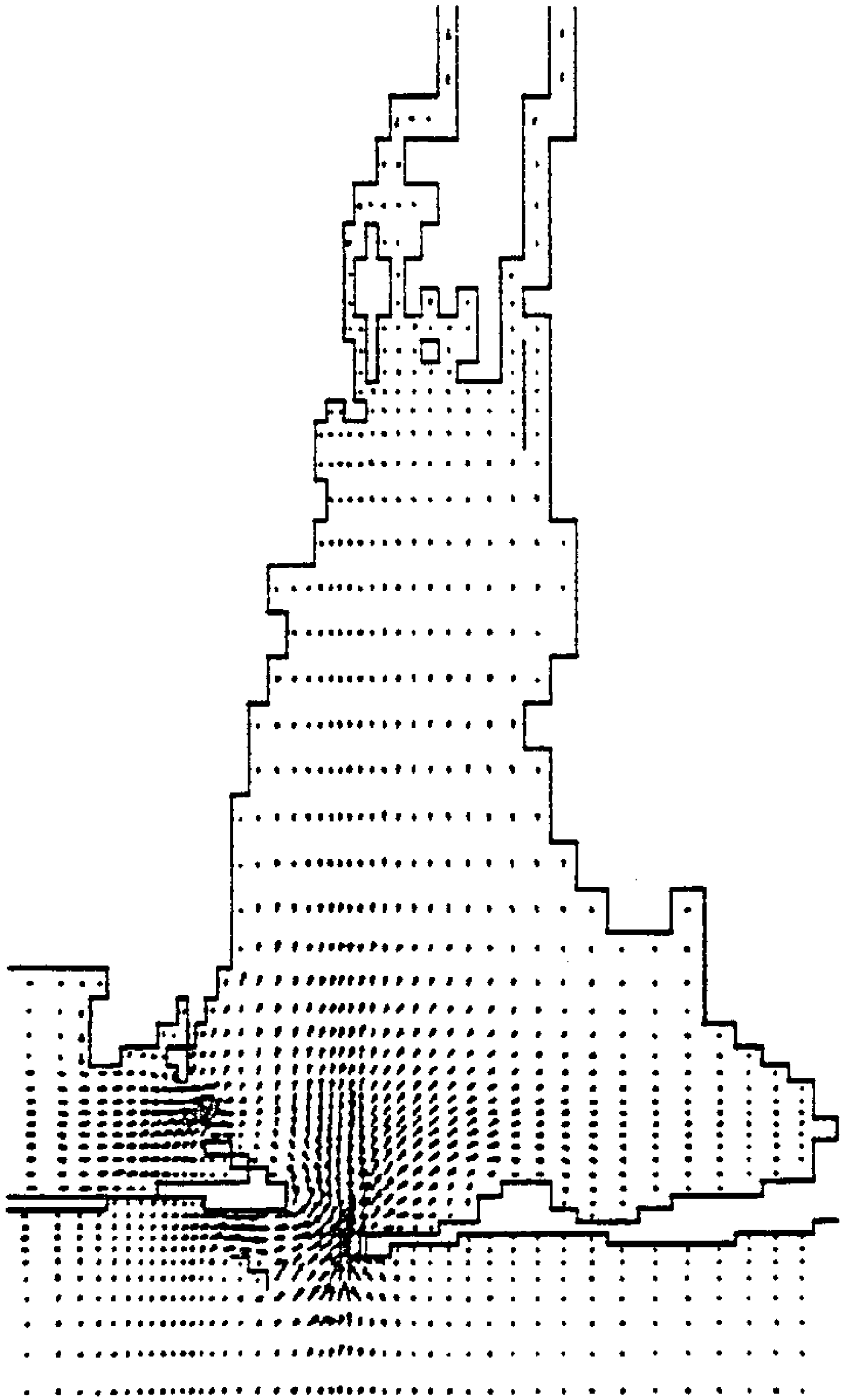


Figure 2. Velocity Vector Plot of Mobile Bay-East Mississippi Sound -- Run 1 (Flood Tide)

2. Ling, Tien-Feng Tyrone, "Hydrodynamic and Salinity Models for Mobile Bay and East Mississippi Sound", The University of Alabama Bureau of Engineering Research Report No. 283-112, MASGP-81-020, December 1981.

Two-dimensional depth averaged finite difference formulations of the hydrodynamic and salinity continuity equation are used to investigate salinity patterns in Mobile Bay and East Mississippi Sound. The Gulf of Mexico, Mobile Bay and Mississippi Sound have different salinity levels so particular attention is devoted to the exchange of water through Main Pass and Pass aux Herons.

The models were calibrated using available prototype data. General agreement to within field data accuracy was obtained for salt concentrations.

Various tide, river inflow and wind conditions are applied as boundary conditions. Salinity profiles are analyzed and operating trends indicated for various system parameters. A typical salinity profile is presented in Figure 3 for a specific set of boundary conditions.

Figure 3. Sample Salinity Profile (Tidal Cycle Average) for Mobile Bay and East Mississippi Sound with a River Flow of 49000 CFS and 30 ft/s Wind from Southwest

3. Urgun, Hasan, "A Hydrodynamic Model for Biloxi Bay and Ship Channels", The University of Alabama Bureau of Engineering Research Report No. 292-183, April 1984.

A finite difference numerical model has been developed for investigating the hydrodynamics of Biloxi Bay and Ship Channels when subjected to various meteorological and tidal conditions. As illustrated in Figure 4, the model represents a sub-grid of a larger model previously developed for Mississippi Sound. The previously calibrated model for Mississippi Sound was used to establish boundary conditions for the smaller sub-grid. The finite difference grid used for this model application is shown in Figure 5. Smaller finite difference cells are used to provide greater resolution of geometry in critical regions. The primary application of the model was to investigate the effects on hydrodynamics of deepening navigation channels in the Biloxi Bay region.

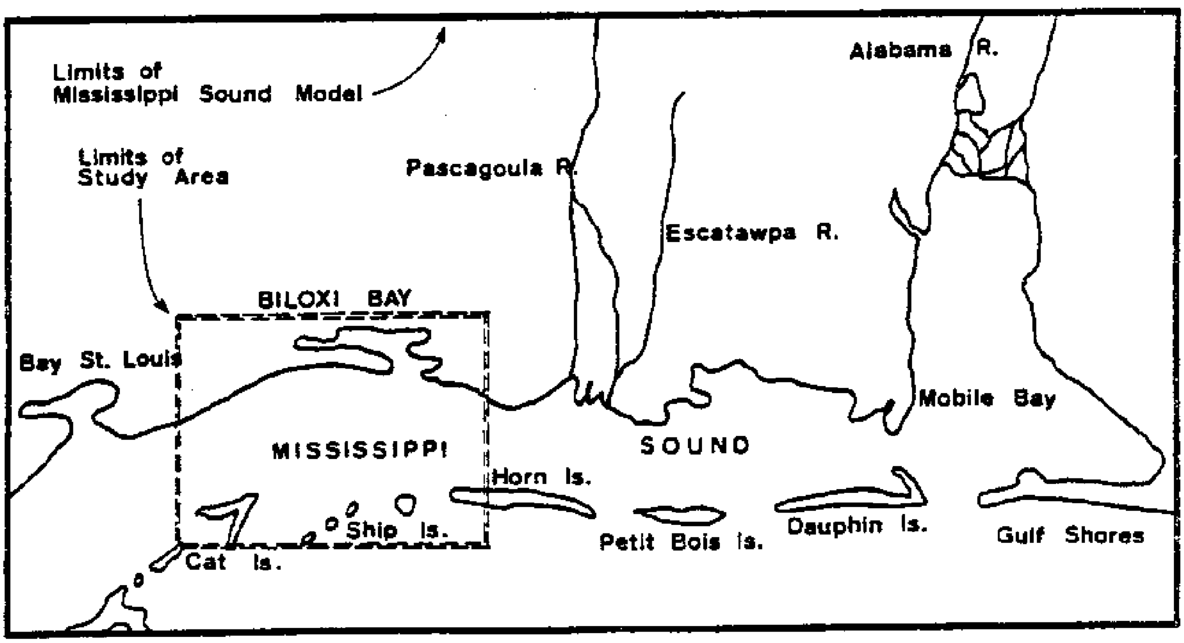


Figure 4. Areas Covered by Mississippi Sound Model and Biloxi Bay Model

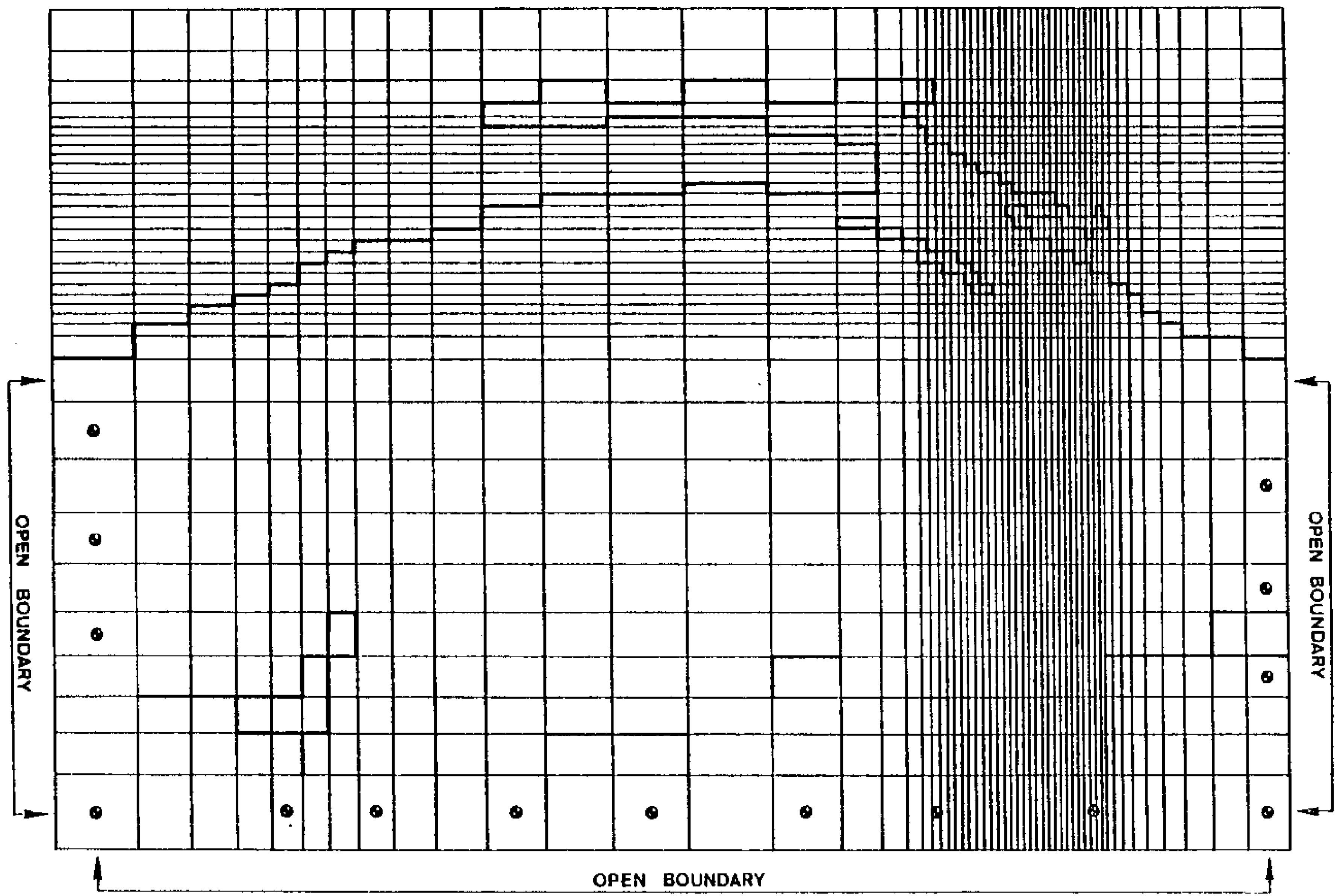


Figure 5. Finite Difference Grid for Study Area and Physical Boundaries

B. Technical Reports

4. Raney, Donald C. and April, G. C., "Hydrodynamics of Mobile Bay and Mississippi Sound", Interim Report on Contract MASG-R/ES4, The University of Alabama Bureau of Engineering Research Report No. 247-112, Interim Report on MASG-R/ES4, March 1980.

Previous work at The University of Alabama dealing with the numerical modeling of Mobile Bay has demonstrated the value of a predictive capability describing water movement and elevation in coastal waters. The extension of that concept to include the Mississippi Sound is both logically and technically correct. Each of these water bodies influences the circulation within the other. That has been demonstrated in field-survey studies during the 1970s. The nature of the coastal zone adjacent to these waters is such that rapid industrial, commercial, residential and recreational development is expected. Major goals of this project are, therefore, directed at providing information responsive to this development.

During 1979, successful adaptation of the WIFM II models to Mississippi Sound and Mobile Bay has been achieved. Trend calibration studies in the Mobile Bay system have been completed using historical field survey data. Results from a Sea Grant-sponsored field survey designed for trend calibration in Mississippi Sound is anticipated during the early period of 1980. In addition, data from a detailed six-month survey program to be conducted by the Corps of Engineers in mid-1980 may be made available for comprehensive calibration and verification of the models.

Preliminary investigations have been initiated into water-quality models, storm-surge models, three-dimensional models and sediment-transport processes. These areas will become of increasing importance once the hydrodynamic model (WIFM II) has been verified and calibrated for Mobile Bay and Mississippi Sound.

5. Raney, Donald C. and Youngblood, J. N., "Hydrodynamics of Mobile Bay and Mississippi Sound - Net Cross-Channel Flows in Mobile Bay", Bureau of Engineering Research Report No. 285-112, June 1982.

Mobile Bay is located on the northeastern shoreline of the Gulf of Mexico east of the Mississippi River delta. The estuary is about 31 miles long and varies in width from 8 to 10 miles in the northern half to about 24 miles wide in the southern portion. The bay is connected by passes to the Gulf of Mexico and also to East Mississippi Sound.

The bay is the terminus of the Mobile River system which consists of more than 43,000 square miles of drainage basin. As a result of the large region drained and the relatively high river flows during the rainy season, suspended sediment loads equivalent to about 5.5 x 10^6 tons/year are carried into the bay. To maintain navigation channels in the bay, it is necessary for the Corps of Engineers to engage in yearly maintenance dredging activities. During the time period 1970-1977 an average of 6.4 million ft^3/year of sediment was dredged from navigation channels, most of which came from the main channel which runs from Main Pass to the Port of Mobile. The sediment dredged from the main channel is placed in disposal areas adjacent to and on both sides of the channel. Current open water disposal of dredge spoil from the main ship channel is by contract limited to about a 2000 ft. wide strip adjacent to the channel center.

Some seismic surveys have indicated a possible redistribution of spoil material far outside the contract disposal areas. This apparent redistribution of spoil material is asymmetric, a considerable eastward spreading is possibly indicated with only a slight westward spreading of the material. If this preliminary seismic information is valid, serious consideration must be given to future dredge spoil disposal practices and locations within Mobile Bay.

The study was initiated to determine whether a numerical hydrodynamic model would indicate any tendency to produce circulation patterns consistent with an asymmetric spreading of the dredged material. The sediment transport problem is extremely complex to model properly. The deposition and resuspension process combined with the generally long time frame associated with sediment movement are difficult to represent in a numerical model. As a first approximation to the problem, sediment transport is considered as being related to net fluid transport. A partially calibrated and verified numerical model of Mobile Bay and East Mississippi Sound is applied and net flow rates across the main channel are evaluated. Net flow rates across the channel are considered for various tide, river and wind conditions. A graphical output of this result is shown in Figure 6.

In order for sediment from the channel aprons to actually be deposited in an area it is not necessary or sufficient that there be net cross-channel flows in the direction of the area under consideration. A more complex flow pattern can exist which results in sediment following a more indirect path before deposition. In addition, if fluid velocities are strong in an area the sediment will move through the area without being deposited. To investigate this aspect of the sediment transport problem, overall circulation patterns at hourly intervals were considered. A representative circulation pattern is shown in Figure 7. In addition, a normalized average hydrodynamic energy level over a tidal cycle was calculated for each finite difference cell. The average hydrodynamic energy level is based upon a mean square of the velocity over the tidal cycle. Regions of low average hydrodynamic energy levels are much more susceptible to sediment deposition than are regions of higher average energy levels. Erosion rather than deposition should occur in regions of very high hydrodynamic energy levels. The result from this analysis is shown in Figure 8.

The numerical hydrodynamic model results do not indicate a tendency for net west to east flows across the main channel which might be directly consistent with the preliminary seismic survey results. Net flows, depending primarily on the wind condition can be either west to east or east to west. Actually, a slight general tendency appears to exist for net east to west flows across the main channel. There does appear to be some correlation between hydrodynamic energy levels predicted by the model and possible deposition patterns identified by the preliminary seismic surveys. Thus, the numerical model results appear to indicate a possible asymmetric deposition pattern rather than net cross-channel flows as the mechanism for any asymmetric spreading of the dredge spoil which may exist. A strong asymmetric spreading of the dredge spoil cannot be established based upon hydrodynamic model results.

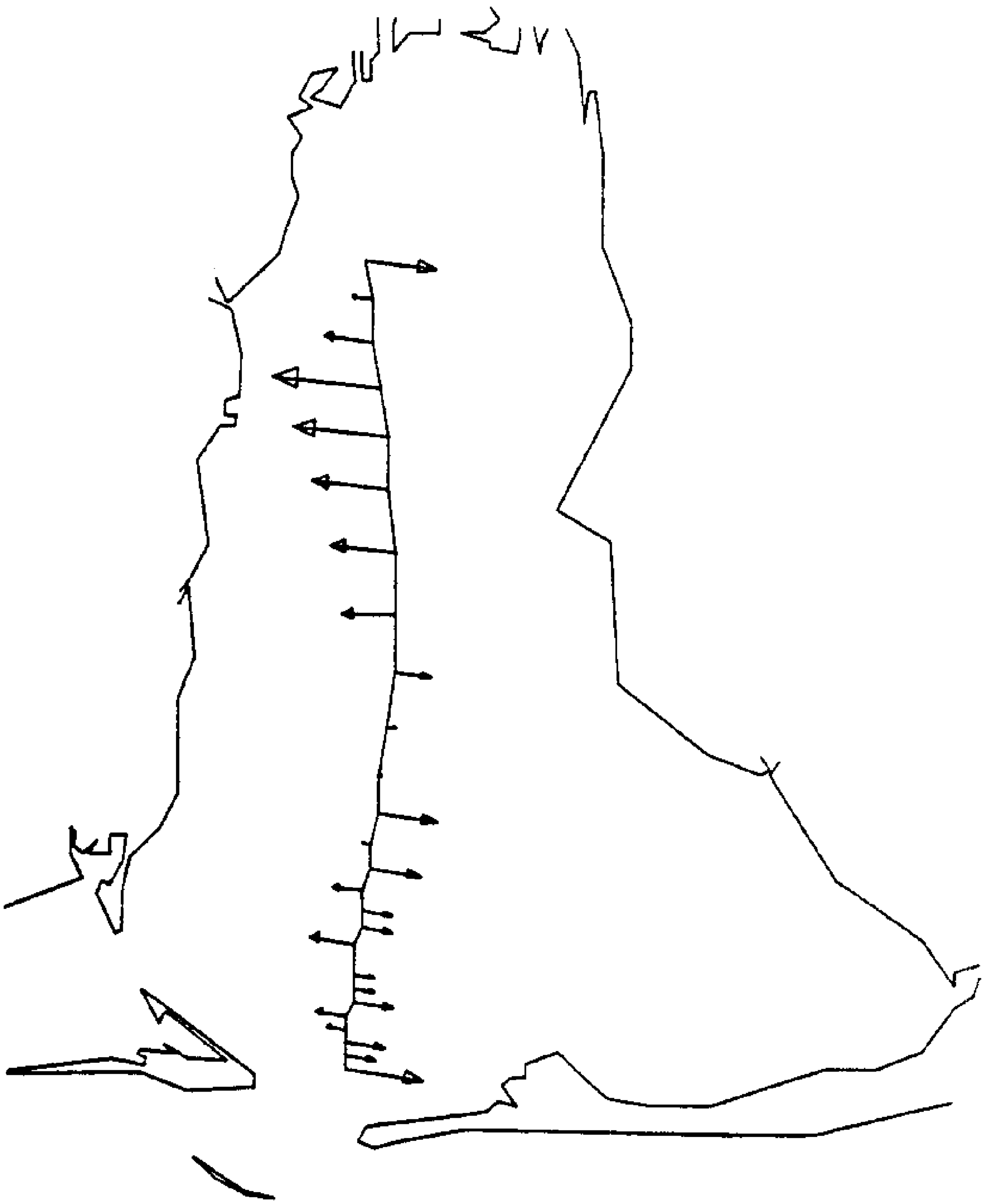


Figure 6. Normalized Net Cross-Channel Flows Over a Tidal Cycle With a 20 MPH Wind from the SW and a Large River Flow Rate

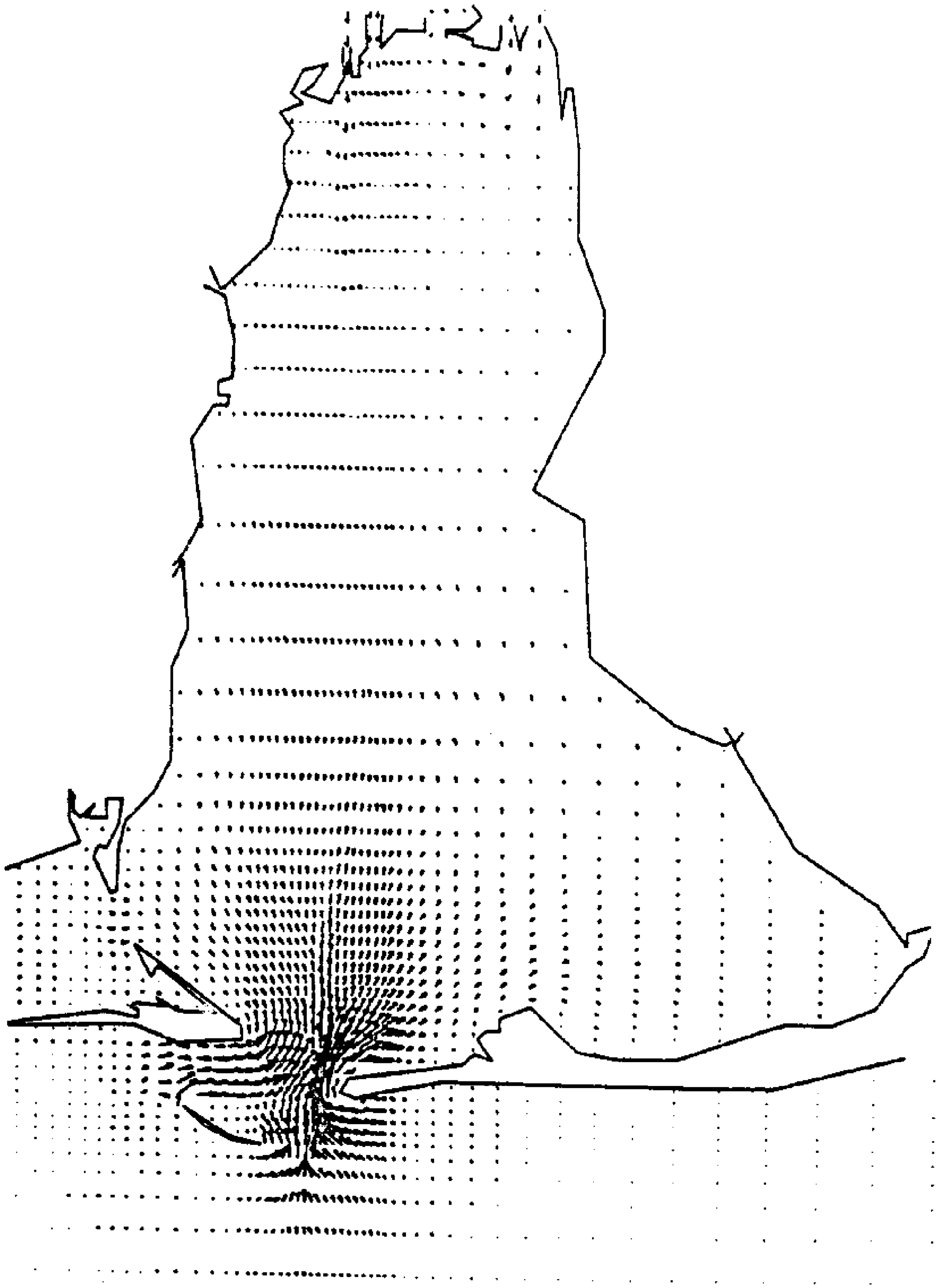
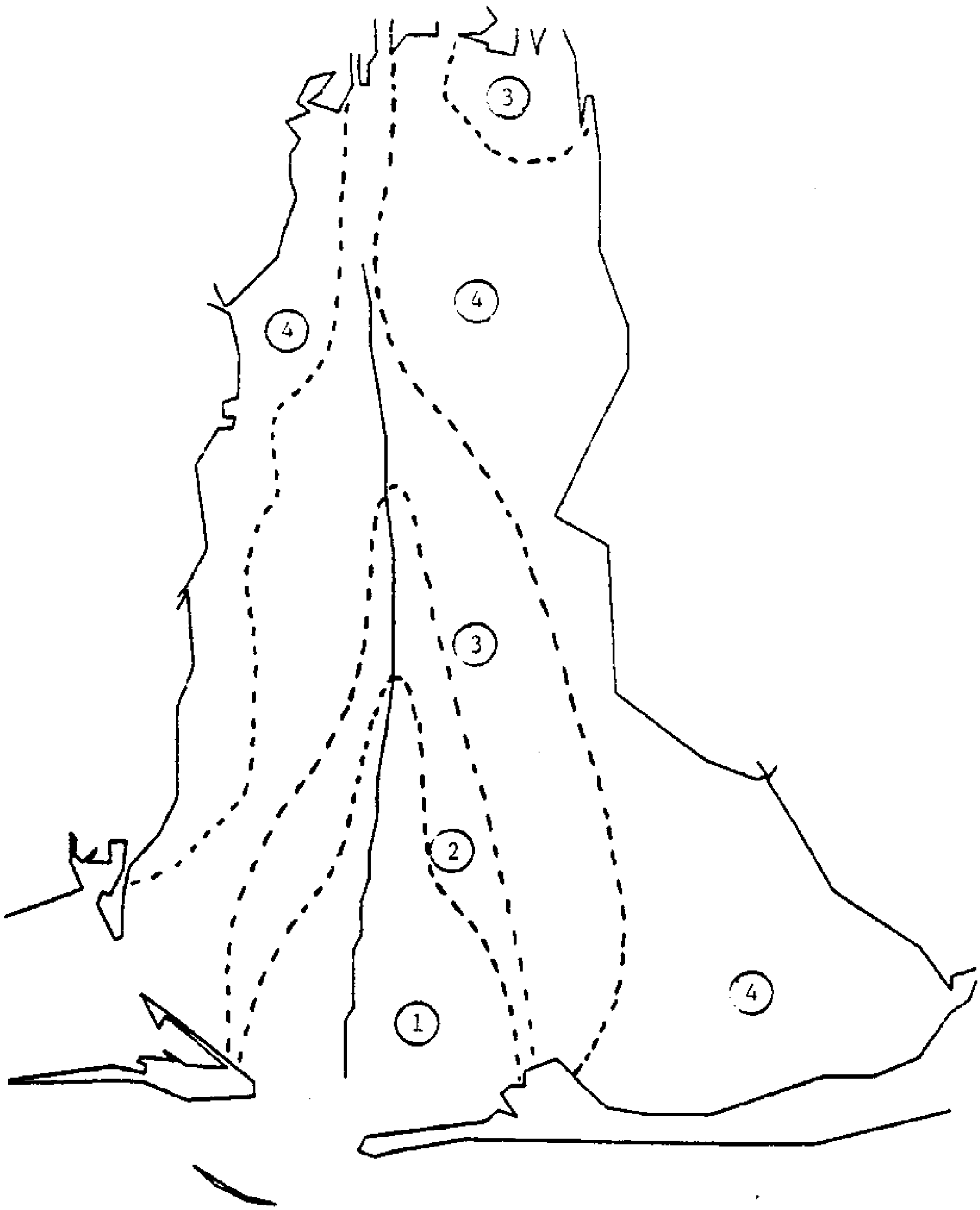


Figure 7. Typical Circulation Pattern in Mobile Bay
Near Maximum Flood Condition



Region 1 - High Hydrodynamic Energy Level
Region 2 - Moderately High Hydrodynamic Energy Level
Region 3 - Medium Hydrodynamic Energy Level
Region 4 - Low Hydrodynamic Energy Level

Figure 8. Average Hydrodynamic Energy Levels in Mobile Bay Over a Typical Tidal Cycle

6. Raney, Donald C., Youngblood, J. N. and Urgun, Hasan, "Establishment of the Influence Zone for Physical Changes to an Estuarine Environment: An Apalachicola Bay Example", The University of Alabama Bureau of Engineering Research Report No. 288-12, February 1983.

7. Raney, Donald C., Youngblood, J. N. and Urgun, Hasan, Appendix B of "Detailed Project and Environmental Impact Statement on Breakwater at Eastpoint, Florida", U. S. Army Corps of Engineers, Mobile District, South Atlantic Division, May 1983.

The Apalachicola Bay estuarine system, shown in Figure 9, is composed of Apalachicola Bay, the principal embayment, St. Vincent Sound to the west, East Bay to the north and St. George Sound to the east. Barrier islands separate the embayments from the Gulf of Mexico. Apalachicola Bay is one of the most important bays in Florida because of the large fresh water inflow and seafood production. The bay contains 80 percent of the natural, public oyster reefs on the Gulf Coast of Florida.

The fishing fleet at Eastpoint, Florida desires construction of a rubble breakwater and relocation of the existing Federal Navigation Channel. A possible configuration of the project is shown in Figure 10. The proposed project would provide the fishing fleet with shelter and protection from storm waves and reduce delays due to congestion in the existing channel.

A two-dimensional depth averaged finite difference model (WIFM) is used to provide a preliminary assessment of hydrodynamic and water quality changes which can result from construction of the project. The model is partially calibrated using available prototype data. Application is then made with a representative tide, an average river inflow and for three wind conditions; no wind, a typical summer wind and a typical winter wind. Comparisons are made between model hydrodynamics results for existing conditions and with the breakwater and channel project installed.

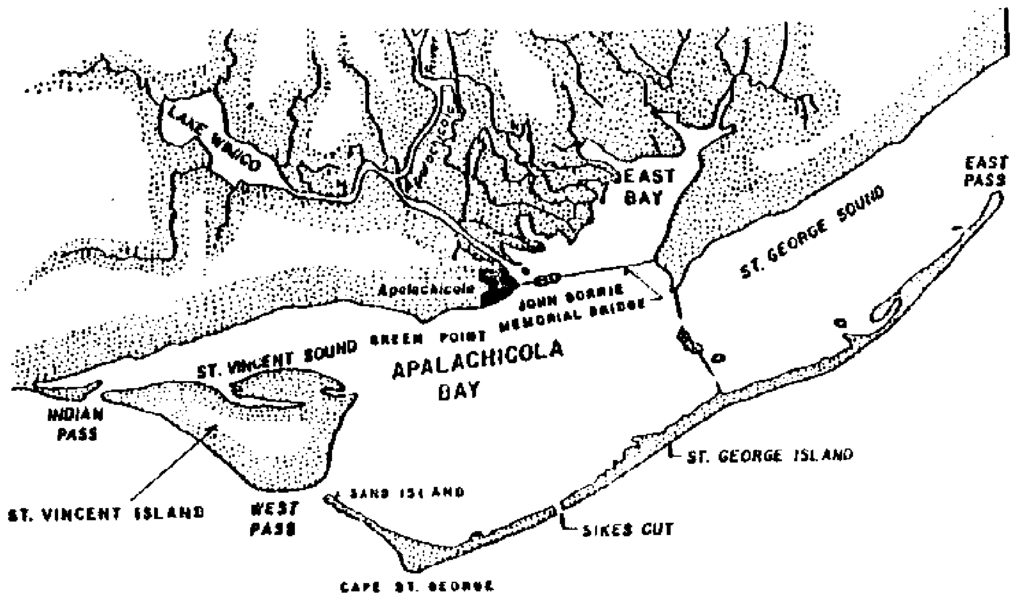


Figure 9. Apalachicola Bay Estuarine System

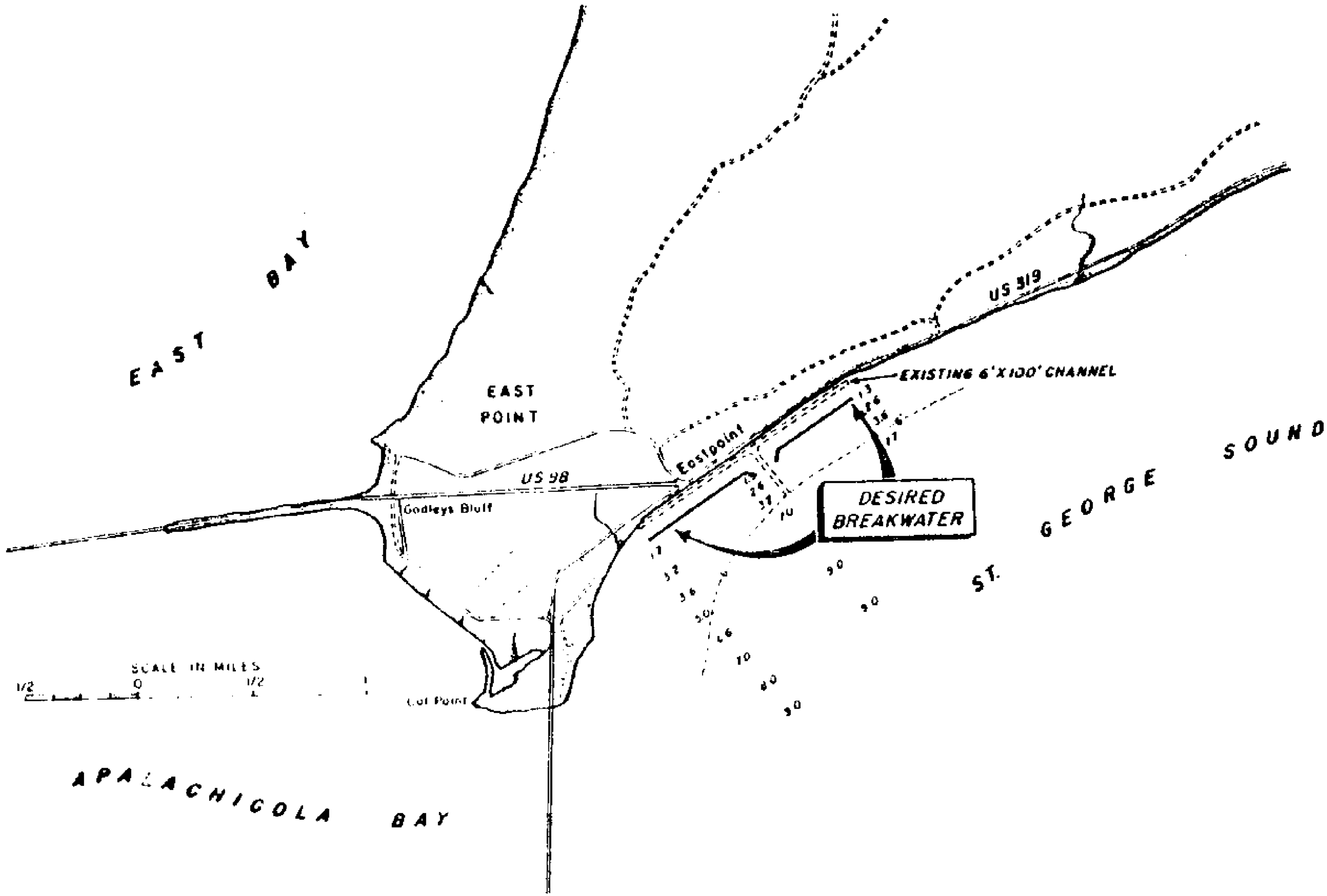


Figure 10. Possible Configuration of the Eastpoint Project in Apalachicola Bay

The model results, for the limited range of parameter considered, indicate that the project will have a very limited range of influence. Measurable changes in water surface and velocities are confined to a two-mile radius from Eastpoint. Even within the Eastpoint area, hydrodynamic changes produced by the breakwater are small.

No water quality parameters have been directly considered in this study. Water quality changes can, to some extent, be inferred from the hydrodynamic changes. Only local changes in water quality parameters would appear likely.

8. Raney, Donald C., Youngblood, J. N. and Urgun, Hasan, "Evaluation of the Effects of L & N Railroad on the Flooding Problems Along Bayou Sara, Alabama", The University of Alabama Bureau of Engineering Research Report No. 291-183, October 1982.

Mobile Bay is the terminus of the fourth largest river system, in terms of discharge, in the contiguous United States. The river flow is highly seasonal. February, March and April are generally the months of high river flow with low flow periods between June and November. Upper Mobile Bay and the river delta region consists of a complex system of channels and flood plains. During times of large river flow the area is subject to significant flooding.

Man's major intrusion into the delta region is the L&N Railroad which crosses the central portion of the delta. This railroad is built on a fill with several relief openings. The railroad generally follows a NE to SW path across the delta. Because of the location of Bayou Sara relative to the railroad, some speculation exists concerning the effect which the railroad may have upon flooding problems which are encountered along Bayou Sara. The purpose of this study was to conduct a preliminary evaluation of the influence which the L&N Railroad exerts on flood stages along Bayou Sara.

A two-dimensional depth averaged finite difference model (BAY) was used to simulate the delta region hydrodynamics. The finite difference grid used in this investigation is shown in Figure 11. The model was partially calibrated and verified using data from known flood events. Various flood events are simulated varying the river flow rate from that representative of the two-year frequency flood event up to a flow rate representative of a 500-year frequency flood event. The model was applied for existing conditions and for a condition where the L&N Railroad fill is removed. Flood stages, flow rates and flow patterns are compared for

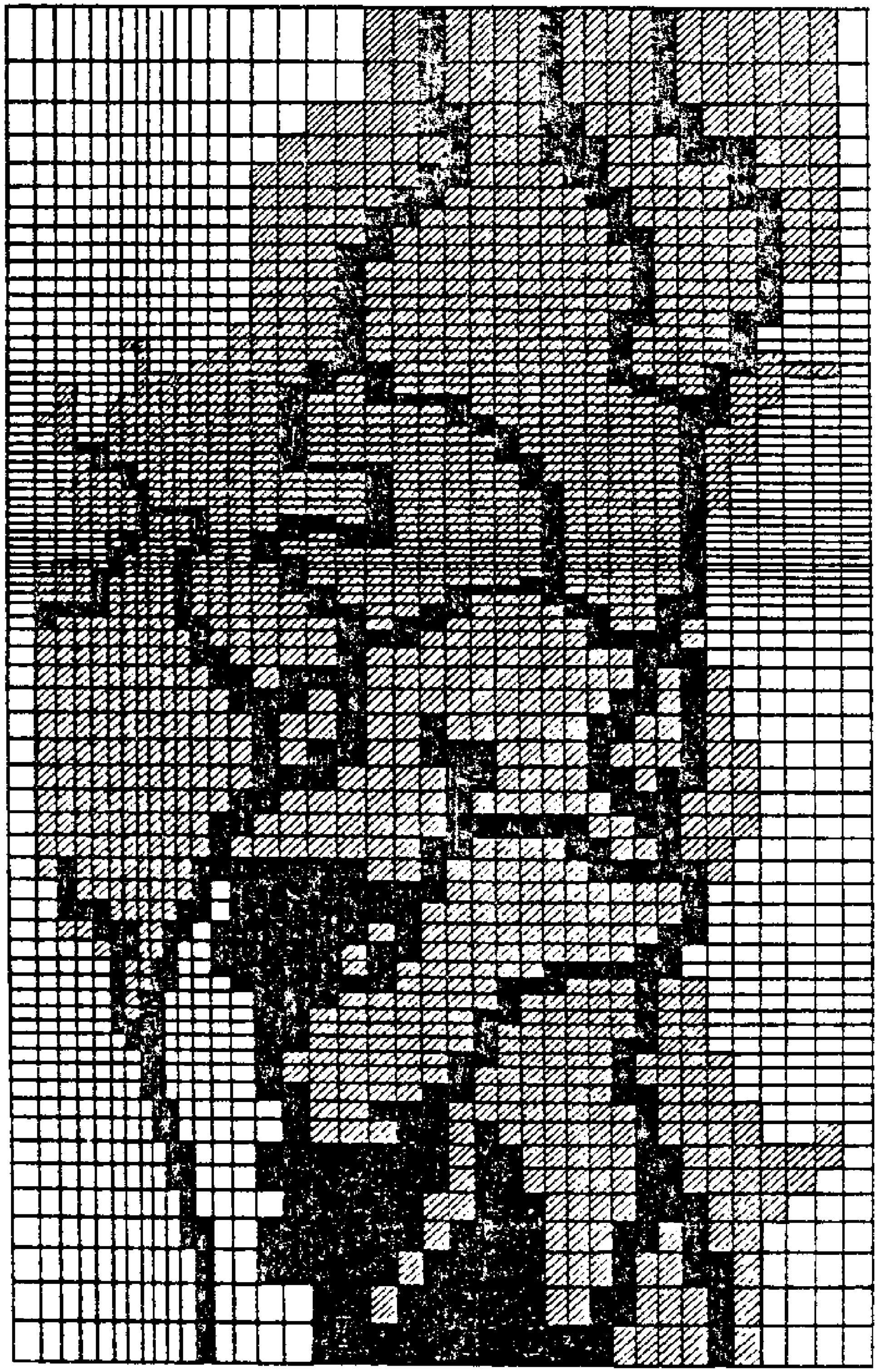


Figure 11. The Variable Size Finite Difference Grid

existing conditions and the condition without the railroad fill. From these results, a preliminary evaluation was made of the influence which the L&N Railroad exerts upon flooding problems in the delta region.

Based upon the preliminary numerical model results, the L&N Railroad does not appear to have a large effect upon flood stages around the boundary of the river delta system. There are some fairly large flood stage elevation differences across the railroad fill within the interior of the delta, but the effects which extend to the boundaries are small. This is illustrated in Figure 12. Although a great deal of water is stored on the flood plains during a given flood event, there is a relatively small amount of actual flow along or across the flood plains. The majority of the flow is still along existing channels. As long as debris does not collect and restrict flow through bridges and other relief openings, the railroad fill appears to reduce overall flows down the delta by a moderate percentage. Bayou Sara does appear to be the portion of the delta region boundary most affected by the railroad fill. However, even here, the effect is not large.

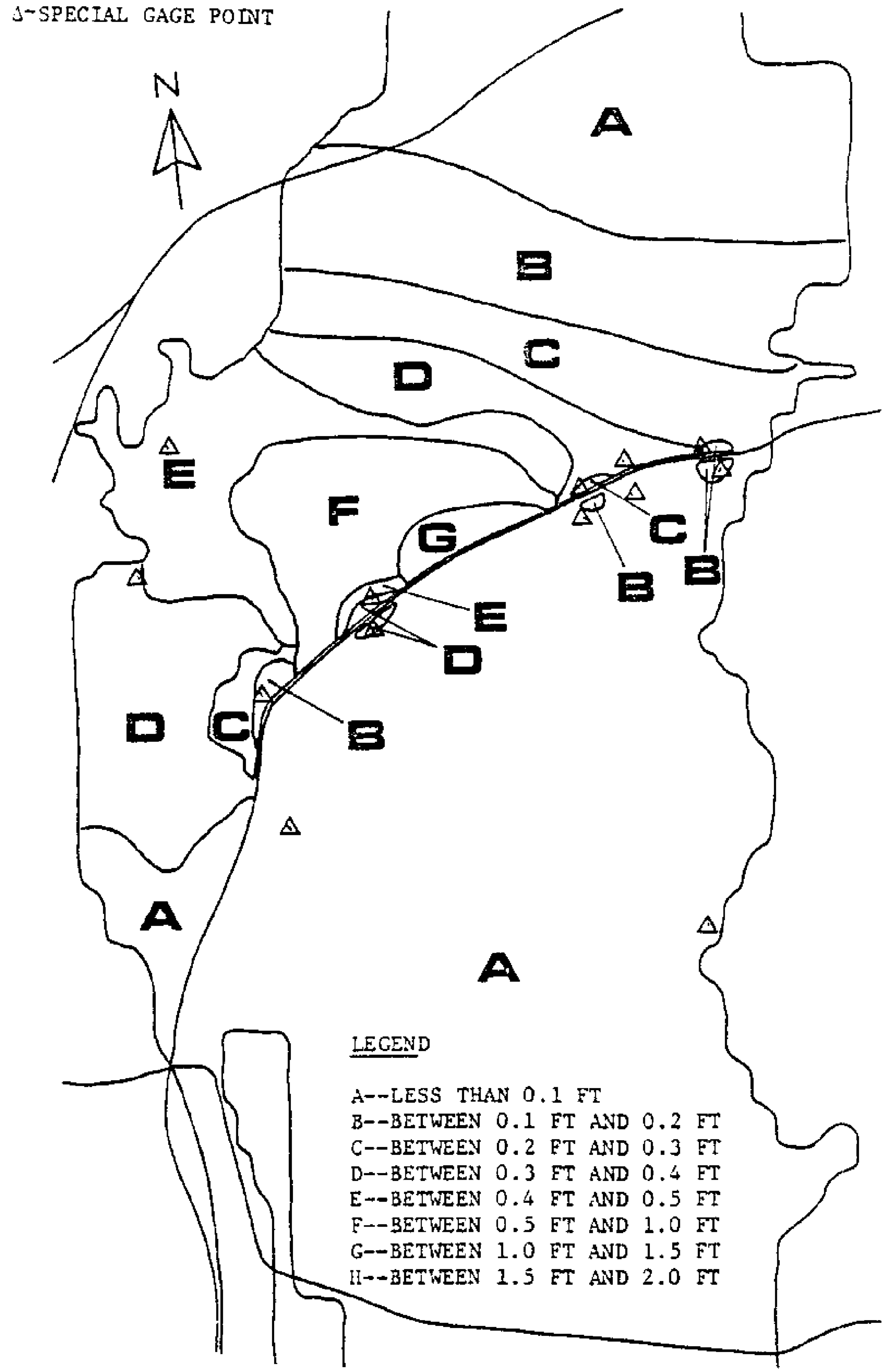


Figure 12. Differences in Flood Stage Elevations in the Mobile Bay Delta Region as a Result of the L&N Railroad for a Flow Rate of Approximately 700,000 cfs

9. Raney, Donald C., Huang, I., and Urgun, Hasan, "A Hydrodynamic Model for Gulfport Harbor and Ship Channels", The University of Alabama Bureau of Engineering Research Report No. 295-183, MASG-R/EN-1, April 1984.

A finite difference numerical model has been developed for investigating the hydrodynamics of Gulfport Harbor and Ship Channel when subjected to various meteorological and tidal conditions. The model represents a sub-grid of a larger model of Mississippi Sound as shown in Figure 13. The previously calibrated model for Mississippi Sound was used to establish boundary conditions for the sub-grid. The finite difference grid used for this model application is shown in Figure 14. The primary application of the model was to investigate the effect on hydrodynamics produced by deepening navigational channels in the Gulfport region.

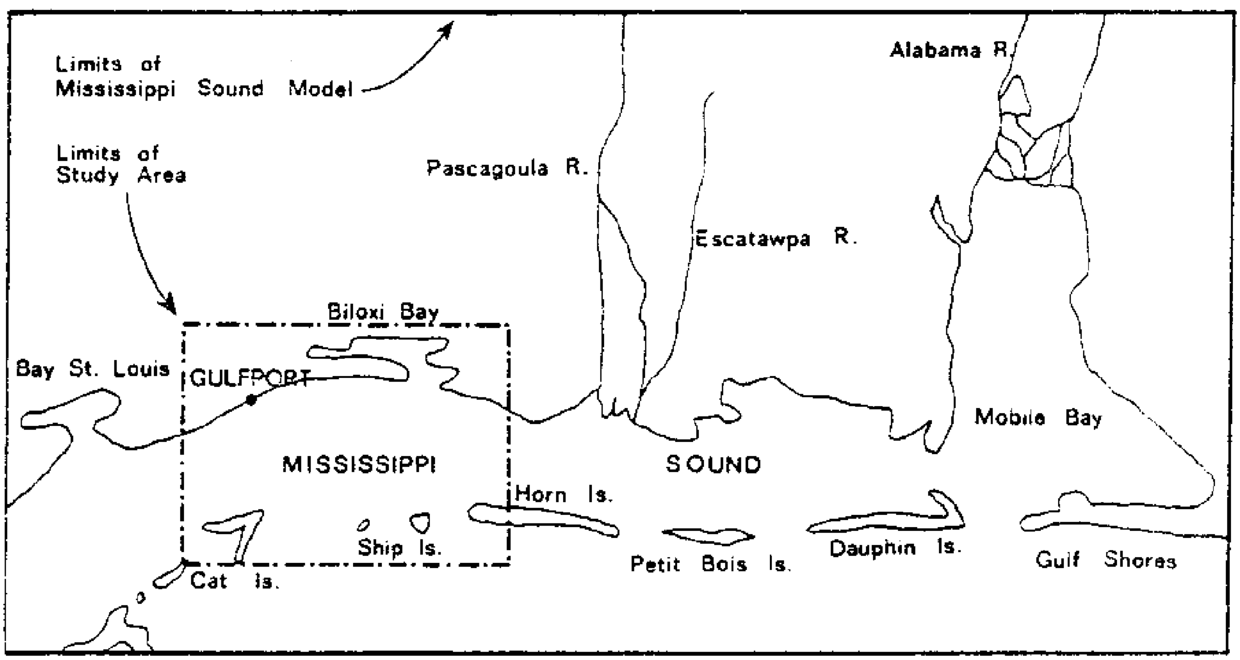


Figure 13. Areas Covered by Mississippi Sound Model and Gulfport Harbor Model

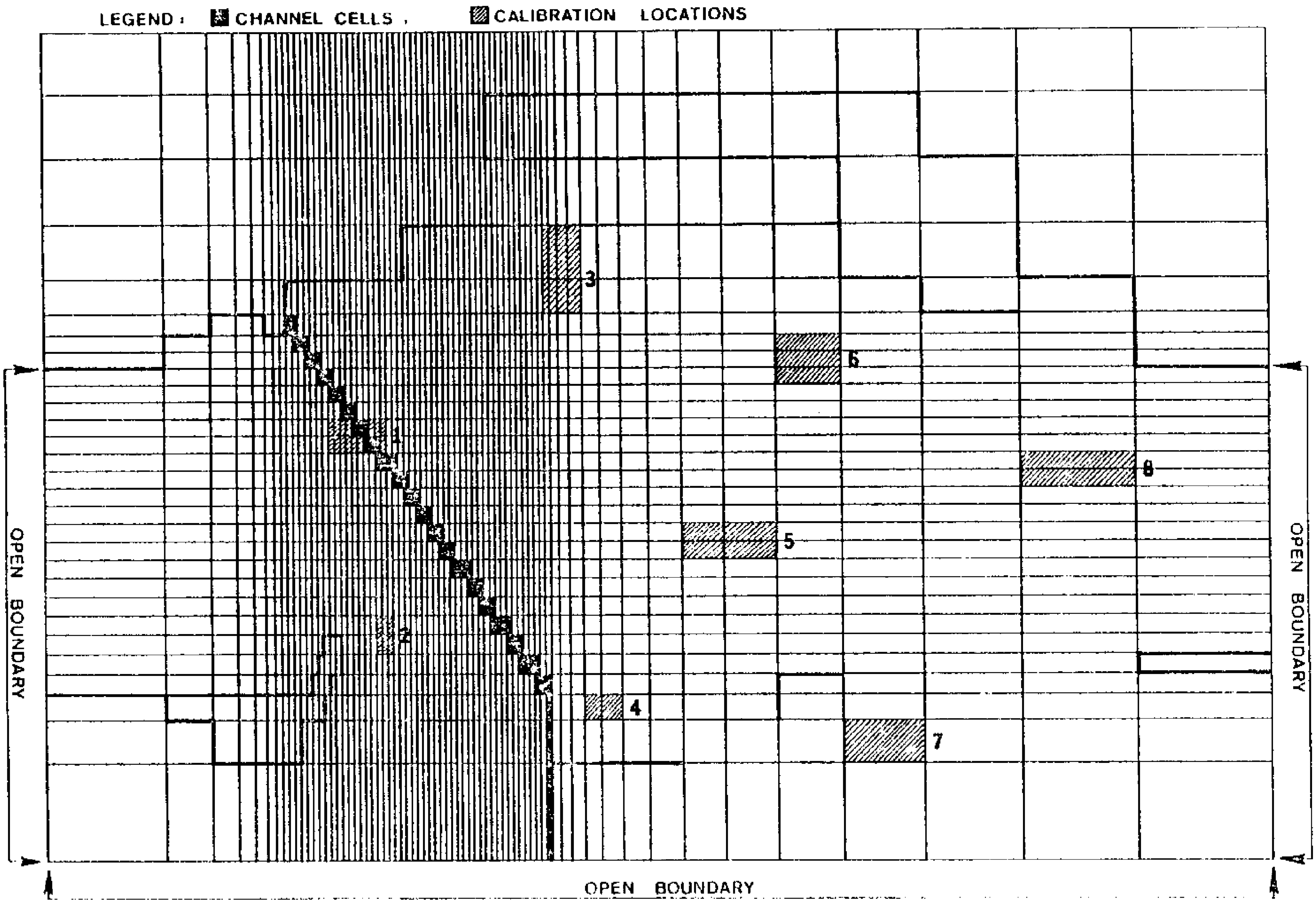


Figure 14. Finite Difference Grid for Study Area and Numerical Model Boundaries

10. Youngblood, John N. and Raney, Donald C., "A Depth-Averaged Water Quality Model and Application to Salinity Propagation in Mobile Bay", The University of Alabama Bureau of Engineering Research Report No. 297-112, July 1984.

The entire effort of this research is to design, develop, verify and document a water quality simulation model for application to current research problems in conjunction with an existing hydrodynamic model. To make meaningful decisions about the discharge of waste material into coastal waters, or the effects of new construction, or the possible consequences of oil spills, it is necessary to have verified numerical models of hydrodynamic motion and water quality variation. The reason for undertaking this work was to provide a comprehensive water quality model which has the stability and accuracy characteristics consistent with high quality simulation and the flexibility to be used with existing hydrodynamic models.

The design of a numerical water quality or transport model is a major undertaking. While the area has been extensively researched, it remains an extremely active area with a number of different approaches. In choosing the particular model type the designer must consider the following items in relation to the features of the particular approach:

a. Accuracy requirements of the application.

b. Stability requirements as a function of efficient step sizes.

c. Time step strategies as constrained by a concurrently operating hydrodynamic model.

d. Spatial grid selection as constrained by the accompanying hydrodynamic model, concurrent or separate.

e. The uncertainty of new development with regard to accuracy, stability and run cost.

f. The time necessary to develop a new approach.

Before starting model development the designer must decide the nature and structure of the model based on a careful assessment of the requirements of the application and the confirmed or expected characteristics of a particular approach.

After the model is selected, the finite-difference approximation of the appropriate transport equation is derived for the particular strategy. This transformation is lengthy, complex, and likely to distort physical properties and processes of the material if care is not exercised. A repetitive solution, either explicit or implicit as required by the chosen structure, is employed to generate the solution.

The water quality model reacts with velocity and elevation data from the hydrodynamic model defined on an identical grid reference frame. The hydrodynamic and water quality models may be organized to operate concurrently with hydrodynamic data coupled directly to the water quality model, or may be run separately by storing the hydrodynamic data for future use.

The final step in the use of the model is a careful and systematic validation process by comparison with observed data in the study area. This process may be used to adjust model parameters to improve the model or to indicate difficulties that render the model ineffective for a particular study.

In this study a number of published approaches have been surveyed and a promising method has been selected, refined to remove physical inconsistencies, formulated and applied.

To verify the model with an application for which measured data exist, a simulation of the dynamic salinity patterns of Mobile Bay was performed. A validated hydrodynamic model of the study area was used to generate a periodic elevation - velocity profile for a complete tidal cycle. The elevation - velocity profile was subsequently used to drive the water quality (salinity) simulation.

The variation in salinity level over a tidal cycle is illustrated in Figures 15, 16, 17 and 18. This particular application is for a moderate river discharge. Low and high river discharge levels produce significantly different results.

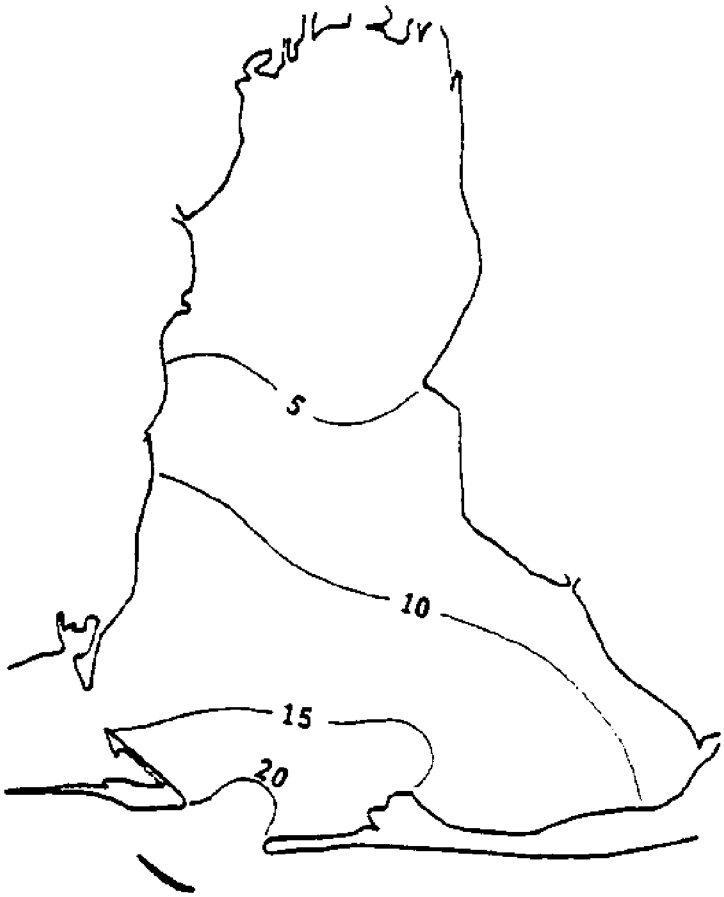


Figure 15. Moderate Rivers Discharge: Incoming Tide

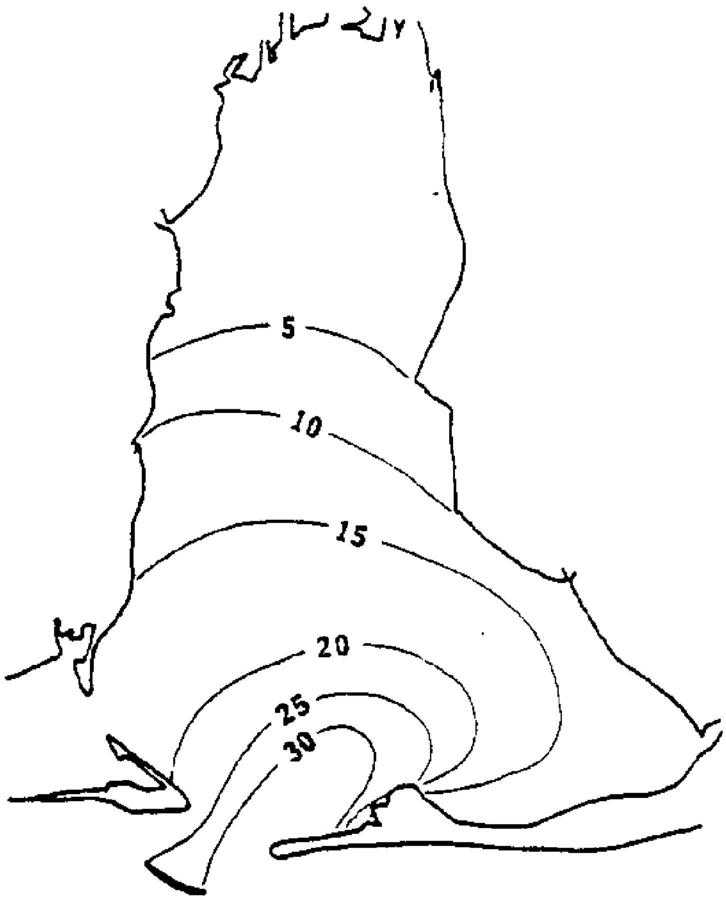


Figure 16. Moderate Rivers Discharge: High Tide

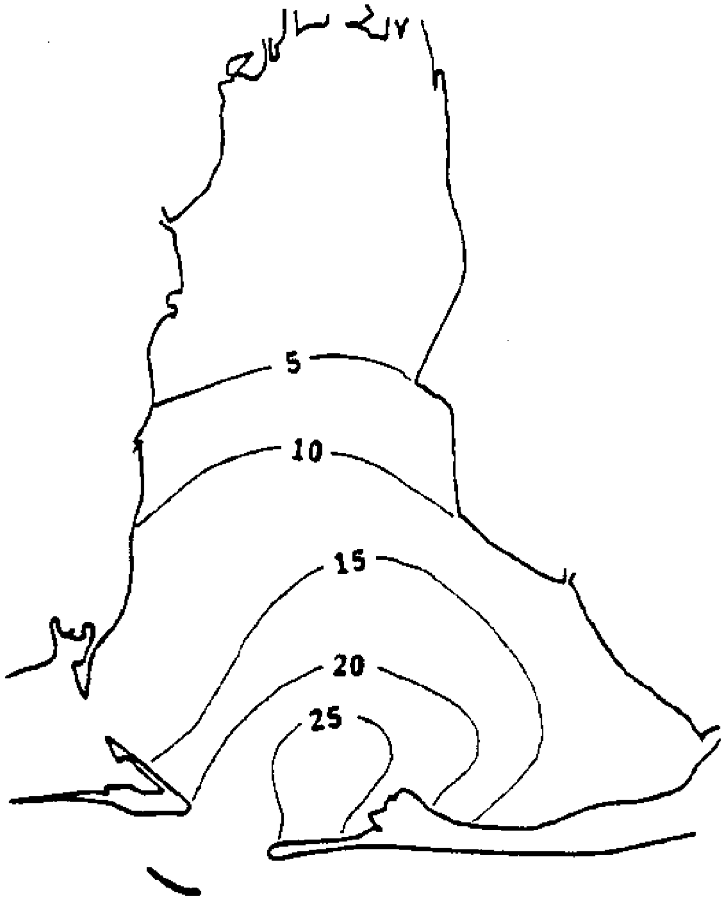


Figure 17. Moderate Rivers Discharge: Outgoing Tide

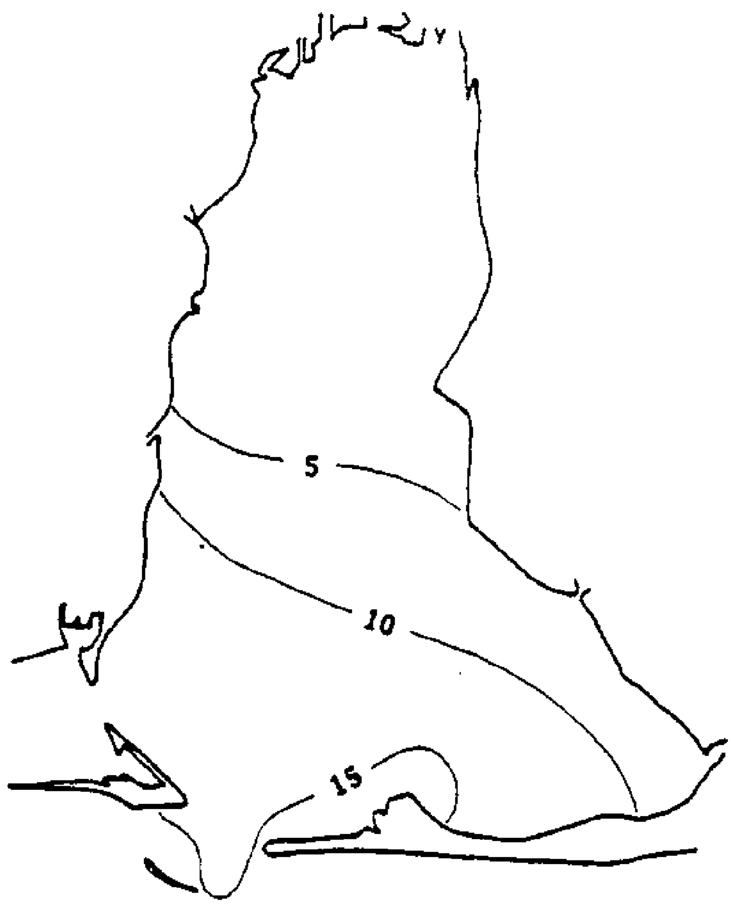


Figure 18. Moderate Rivers Discharge: Low Tide

C. Technical Papers

11. April, G. C. and Raney, Donald C., "Predicting the Effects of Storm Surges and Abnormal River Flow on Flooding and Water Movement in Mobile Bay, Alabama", Proceedings of the Wetland and Estuarine Processes and Water Quality Modeling Workshop, U. S. Corps of Engineers, New Orleans, Louisiana, June 18-20, 1979.

The threat of man-made and natural disturbances to the coastal environment is a continuing and perplexing problem. With the advent of rapid, numerical simulation models describing coastal water behavior, the ability to better understand these regions and to provide data to offset the adverse impacts caused by these disturbances has greatly improved.

This paper discusses the recent numerical modeling activities of the Mobile Bay system under severe conditions. Results are presented in terms of changes that occur in water elevation and movement, and, in salinity distribution patterns when the bay is subjected to river flooding inflows and storm surges.

At a river flood stage of 7000 m^3/s, water behavior in the northern and central portions of the bay is totally governed by the fresh water inflow. A salinity level of 5 ppt is restricted to the lower bay at a point 15 km from the Main Pass. Usual salinity values under normal conditions are in the range of 15 to 20 ppt in this area. A critical river flow rate of 8500 m^3/s is also identified. At or above this flow, saline water intrusion in the lower bay becomes stabilized at 10 ppt on a line 6 km north of the Main Pass.

Conversely, large amounts of saline water enter the bay under storm surge conditions investigated in this study. Conditions typical of those caused by Hurricane Camille in 1969 were used in the modeling exercise. Salinity levels as high as 26 ppt were predicted for the northern bay area. This high saline water intrusion is caused by the development of the surge hydrograph at the gulf-bay interface as the storm approaches the coastline.

In both cases the model results were shown to be representative of bay behavior. Comparisons with existing field observations were made to calibrate and verify the models.

12. April, G. C., and Raney, Donald C., "An Alternate Source of Data for Managers and Researchers", Proceedings of the Symposium on the Natural Resources of the Mobile Estuary, Alabama, U. S. Department of Interior, Fish and Wildlife Service, Mobile, Alabama, May 1-2, 1979.

This paper reviews the results derived from mathematical models used in the description of hydrodynamic and material transport behavior in Mobile Bay. Results of parametric studies are reported as tidal cycle average current and salinity patterns and monthly average coliform bacteria patterns for normal and severe hydrologic and meteorologic conditions in the Bay area. The parameters included are wind direction and speed, river flow rates, coliform bacteria concentrations at the river inlets, bay water temperature and tidal stage at the Bay/Gulf exchange.

Of primary importance are the relationships of the data base used to calibrate and verify the various models and the form of the corresponding model results derived from the study. These comparisons provide a way of integrating mathematical modeling methods with field and remote sensed data collection programs. A recommendation for the development of a statewide, coordinated data collection program providing better support of mathematical modeling efforts is also made.

13. Raney, Donald C. and Youngblood, J. N., "Movement of Dredged Material from Channel Aprons", IASTED International Symposium, ASM '82, Applied Simulation and Modelling, July 1982.

Mobile Bay is the terminus of the Mobile River system which consists of more than 43,000 square miles of drainage basin. As a result of the large region drained and the relatively high river flows during the rainy season, suspended sediment loads equivalent to about 5.5×10^6 tons/year are carried into the bay. To maintain navigation channels in the bay, it is necessary for the Corps of Engineers to engage in yearly maintenance dredging activities. During the time period 1970-1977 an average of 6.4 million ft^3/year of sediment was dredged from navigation channels, most of which came from the main channel which runs from Main Pass to the Port of Mobile. The sediment dredged from the main channel is placed in disposal areas adjacent to and on both sides of the channel. Current open water disposal of dredge spoil from the main ship channel is by contract limited to about a 2000 foot wide strip adjacent to the channel center.

Some preliminary seismic surveys have indicated a possible redistribution of spoil material far outside the contract disposal areas. This redistribution of spoil material appears to be asymmetric, a larger eastward than westward spreading from the channel is indicated. If this preliminary seismic information is valid, serious consideration must be given to future dredge spoil disposal practices and locations within Mobile Bay.

This study was initiated to determine whether a numerical hydrodynamic model would indicate any tendency to produce circulation patterns consistent with an asymmetric spreading of dredge material from the channel aprons. The sediment transport problem is extremely complex to model properly. The erosion, movement and deposition process combined with the generally long time frame associated with sediment movement are difficult to simulate with a numerical model. As a first approximation to the problem, sediment transport from the channel aprons is considered as being related to net fluid transport across the channel. A partially calibrated and verified hydrodynamic model of Mobile Bay and East Mississippi Sound is applied and net flow rates across the main channel are evaluated. Net flow rates across the channel are considered for various tide, river and wind conditions. Velocity patterns in the bay are also examined to determine regions of low energy levels where materials might tend to be deposited.

Numerical model results are examined to determine if general water movement patterns in Mobile Bay are consistent with sediment movement patterns indicated by the preliminary seismic information and other available technical data.

14. Raney, Donald C. and Youngblood, J. N., "Hydrodynamic Models for Minimizing Environmental Damage from Coastal Zone Development", Proceedings of the IASTED International Symposium, ASM '83, Applied Simulation and Modelling, May 1983, pp. 1-5.

Numerical models have great potential for improved environmental impact assessment of development in the coastal zone. In this paper, a two-dimensional depth averaged finite difference hydrodynamic model is used to investigate two examples of construction, or proposed construction, in the coastal zone. The first example is a railroad built on a fill across the flood plains above Mobile Bay, Alabama. The second example is a proposed breakwater and channel relocation at Eastpoint, Florida.

In the Mobile Bay flood plain application, the hydrodynamic model is used to quantify the effect which an existing structure has upon flooding problems which are known to exist along Bayou Sara. The model is applied both with and without the railroad on the flood plains. Changes in flow patterns and flood stage elevation which can be attributed to the railroad are documented.

The fishing fleet at Eastpoint, Florida in Apalachicola Bay desires construction of a rubble breakwater and relocation of the existing Federal Navigation Channel. Apalachicola Bay is one of the most important bays in Florida because of its large freshwater inflow and seafood production. In this case the hydrodynamic model is used to evaluate the potential environmental impact of the proposed project.

15. Youngblood, J. N. and Raney, D. C., "Salinity Propagation in Mobile Bay", Proceedings of the IASTED International Symposium, ASM '83, Applied Simulation and Modelling, May 1983, pp. 16-20.

The purpose of this study is to investigate the general nature of salinity propagation in Mobile Bay, Alabama, as it is affected by river inflow levels and tidal effects. No rigorous effort is made to verify quantitatively the solutions that were generated for several reasons. Primarily, the model was driven by "typical" tidal and river inflow levels not associated with those existing during any collection of prototype data. Secondly, there is a scarcity of prototype data that defines salinity profiles completely over the area and sufficiently in time. Lastly, the two-dimensional spatial model does not allow for known vertical stratification effects, thus allowing for the possibility of misleading results near the passes.

16. Raney, Donald C., Youngblood, J. N. and Urgun, Hasan, "A Hydrodynamic Model for Flood Plain Investigations", Proceedings of Ninth Canadian Congress of Applied Mechanics, May 1983, pp. 435-436.

Mobile Bay is the terminus of the fourth largest river system, in terms of discharge, in the contiguous United States. The river flow is highly seasonal. Upper Mobile Bay and the river delta region is a complex system of channels and flood plains. During times of large river flow the area is subject to significant flooding.

Man's major intrusion into the delta region is the L&N Railroad which crosses the central portion of the delta. This railroad is built on a fill with several relief openings. The railroad generally follows a NE to SW path across the delta. Because of the location of Bayou Sara relative to the railroad, some speculation exists concerning the effect which the railroad may have upon flooding problems which are encountered along Bayou Sara. The purpose of this study is to conduct a preliminary evaluation of the influence which the L&N Railroad exerts on flood stages along Bayou Sara.

A two-dimensional depth averaged finite difference model is used to simulate the delta region hydrodynamics. The model is partially calibrated and verified using data from known flood events. Various flood events are simulated varying the river flow rate from that representative of the two-year frequency flood event up to a flow rate representative of a 500-year frequency flood event. The model is applied for existing conditions and for a condition where the L&N Railroad fill is removed. Flood stages, flow rates and flow patterns are compared for existing conditions and the condition without the railroad fill. From these results, a preliminary evaluation is made of the influence which the L&N Railroad exerts upon flooding problems in the delta region.

17. Raney, Donald C. and Urgun, Hasan, "A Hydrodynamic Model for Biloxi Bay and Ship Channels", Proceedings of the IASTED International Symposium, ASM '84, Applied Simulation and Modelling, June 1984.

A finite difference numerical model has been developed for investigating the hydrodynamics of Biloxi Bay and Ship Channels when subjected to various meteorologic and tidal model previously developed for Mississippi Sound. The previously calibrated model for Mississippi Sound is used to establish boundary conditions for the smaller sub-grid. Smaller finite difference cells in the sub-grid model allows greater resolution of flow patterns in the local region. The primary purpose of the model is to investigate the effects on hydrodynamics of deepening navigational channels.

V. COOPERATIVE PROGRAM WITH MOBILE DISTRICT, CORPS OF ENGINEERS

Over the course of this research project an extremely good cooperative arrangement has been established with the Mobile District, Corps of Engineers. The Mobile District has made available prototype data and computer programs. They have on other occasions obtained special data for our requirements. In return, numerical models have been applied to specific sites with the results provided to the Corps of Engineers for use in accessing environmental impact. Assistance has also been provided to the Mobile District in establishing finite difference grids and input data sets for numerical models which they wished to apply.

These cooperative efforts have advanced to the point where the Corps of Engineers is providing funds to the Mississippi-Alabama Sea Grant Consortium to support research efforts. Research programs in Apalachicola Bay and in the Apalachicola, Chattahoochee and Flint River Drainage Basin are currently underway.

VI. ENHANCEMENT OF COMPUTER FACILITIES

An indirect result of this research project has been a significant upgrading of the numerical modelling capability at The University of Alabama. With the Sea Grant project and the cooperative activities with the Mobile District, Corps of Engineers as a base, the Department of Engineering Mechanics was able to obtain an internal grant to establish a Computer Aided Engineering Laboratory.

The Computer Aided Engineering Laboratory supports the teaching and research focus on numerical modelling within the Department of Engineering Mechanics. This facility includes a Hewlett Packard HP-1000A minicomputer system with two megabytes of core memory and a 28.5 megabyte disk storage system. The HP-1000A minicomputer can support a variety of interactive terminals, plotters and printers. At present the laboratory includes a HP2623 graphics terminal, a HP120 Series 100 terminal, an IBM PC-XT microcomputer, a Victor 9000 microcomputer, an Apple II microcomputer, a Ramtek 6210 terminal, two HP-2617G graphics thermal printers, a HP-7580A drafting plotter, a HP-7470A graphics plotter, a HP-9120 flexible disk drive and a Tektronix 4015 graphics terminal.

The heart of the Computer Aided Engineering Laboratory is the Hewlett Packard HP-1000A minicomputer system. The A700 central processor that bundles a high performance hardware floating point processor with scientific and vector instruction sets performs 200,000 to 400,000 floating point operations per second. The HP-1000A currently contains two megabyte of core memory that can be expanded to four megabytes. The system runs under the RTE-A/VC+ real time, multiuser operating system that supports a powerful editor, data base management, high level programming languages and device independent graphics. The virtual memory capability allows programs to access extremely large data structures. In addition to the RTE-A/VC+ Operating System, the current software includes FORTRAN 77 and the Graphics/1000-II Device Independent Graphics Library. The HP-2623 graphics terminal serves as the system console. It is a monochromatic raster scan terminal with a resolution of 512 horizontal by 390 vertical. An HP-2617G graphics thermal printer is attached to the HP-2623 graphics terminal to allow screen dump. A Talley, Model T-1805 printer provides the primary system printer output. A microbuffer box is connected between the system and the printer for smoother printer operation.

High quality graphic output is provided by the Hewlett Packard HP-7580A drafting plotter. This plotter produces ink drawings or maps of the highest quality. It plots on sheets from 8.5 x 11 inches up to 24.5 x 46.5 inches. The resolution is 0.00012 inch with a repeatability of 0.0002 inch. Maximum plotting speed is 24 inches/second with a maximum acceleration of 4 gs. Pen force, speed and acceleration are all programmable. The plotter can use up to 8 pens and plot on most standard paper, vellum and matte polyester film. In addition a secondary plotting capability is provided by the HP-7470A graphics plotter. This plotter also produces drafting quality plots, but is limited to 8½ x 11 inch paper.

A HP-120 Series 100 terminal provides a secondary complete interactive work station for the HP-1000A. A HP-26176 graphics thermal printer provides screen dump capability. Access to the other system components is provided.

Information can be stored or retrieved using the system tape cartridge or on micro flexible disks in the HP 9121 disk drive.

The IBM PC-XT and the Victor 9000 are used as communication devices between the Hewlett-Packard system and the University mainframe computer, as stand-alone computers or as terminals with access to the Hewlett Packard or University mainframe computer.

The Ramtek 6210 Color Graphics Terminal and the Tektronix 4015 graphics terminals are used primarily to access the Univac mainframe computer. The Apple II microcomputer provides a stand-along capability.

The minicomputer equipment selection process was directed toward the objective of attaining computational speed comparable to that of the UNIVAC Mainframe while simultaneously allowing virtual memory capabilities to permit manipulation of data arrays larger than can now be handled on the UNIVAC 1100/60. Also of prime importance was to have hardware and software carefully integrated to support device independent graphics. Performance for the HP1000A700 computer has exceeded initial expectation. Large finite difference and finite element programs being solved for applications which could not be handled with the UNIVAC 1100/60. Furthermore, turnaround time to get report quality graphic results has changed from a minimum of twenty-four hours to a matter of minutes.

VII. COASTAL ENGINEERING PROGRAM

An educational spinoff from the numerical modelling research activities was the establishment of a Coastal Engineering Program at The University of Alabama. This is significant since no similar programs exist in the Mississippi-Alabama region.

A student in the Coastal Engineering Program would be expected to formulate a program from the courses listed below and within the general requirement of the Masters of Science in Engineering degree.

Major Field Courses

MH 500 Intermediate Fluid Mechanics
* MH 511 Physical Oceanography
MH 567 Statistical Dynamics
* MH 520 Numerical Modeling of Fluid Systems
MH 5XX Tide and Wind Waves
* MH 5XX Estuarine Processes
MH 6XX Sediment Transport
CE 530 Marine and Offshore Structures
CE 670 Open Channel Flow
MH 521 Boundary Layer Theory
MH 5XX Water Quality Modeling

Mathematics

* GES 554 Partial Differential Equations
GES 551 Matrix and Vector Analysis
GES 459 Numerical Analysis
GES 555 Engineering Statistics

Minor Field

Minor allowed in any approved related engineering field.

*Required Courses