TECHNICAL BULLETIN NO. 18

HISTORY OF THE CORPS OF ENGINEERS COMMITTEE ON TIDAL HYDRAULICS

(JANUARY 1949 TO JUNE 1971)

by

John B. Luckett

June 1972

Committee on Tidal Hydraulics
CORPS OF ENGINEERS, U. S. ARMY

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REPORTS OF COMMITTEE ON TIDAL HYDRAULICS

Report No.	Title	Date
1	Evaluation of Present State of Knowledge of Factors Affecting Tidal Hydraulics and Related Phenomena	Feb. 1950
2	Bibliography on Tidal Hydraulics	Feb. 1954
	Supplement No 1, Material Compiled Through May 1955	June 1955
	Supplement No. 2, Material Compiled from May 1955 to May 1957	May 1957
	Supplement No 3 Material Compiled from May 1957 to May 1959	May 1959
	Supplement No. 4, Material Compiled from may 1959 to May 1965	May 1965
	Supplement No 5, Material Compiled from May 1965 to May 1968	Aug. 1968
	Supplement No. 6, Material Compiled from May 1968 to May 1971	July 1971
3	Evaluation of Present State of Knowledge of Factors Affecting Tidal Hydraulics and Related Phenomena (revised edition of Report No. 1)	May 1965

Technical Bulletin No.	Title	Date
1	Sediment Discharge Measurements in Tidal Waterways	May 1954
2	Fresh Water-Salt Water Density Currents, a Major Cause of Siltation in Estuaries	April 1957
3	Tidal Flow in Entrances	Jan. 1960
4	Soil as a Factor in Shoaling Processes, a Literature Review	June 1960
5	One-Dimensional Analysis of Salinity Intrusion in Estuaries	June 1961
6	Typical Major Tidal Hydraulic Problems in United States and Research Sponsored by the Corps of Engineers Committee on Tidal Hydraulics	June 1963
7	A Study of Rheologic Properties of Estuarial Sediments	Sept. 1963
8	Channel Depth as a Factor in Estuarine Sedimentation	Mar. 1965
9	A Comparison of an Estuary Tide Calculation by Hydraulic Model and Computer	June 1965
10	Significance of Clay Minerals in Shoaling Problems	Sept. 1966
11	Extracts from The Manual of Tides	Sept 1966
12	Unpublished Consultation Reports on Corps of Engineers Tidal Projects	Dec. 1966
13	Two-Dimensional Aspects of Salinity Intrusion in Estuaries: Analysis of Salinity and Velocity Distributions	June 1967
14	Tidal Flow in Entrances; Water-Level Fluctuations of Basins in Communication with Seas	July 1967
15	Special Analytic Study of Methods for Estuarine Water Resources Planning	Mar. 1969
16	The Computation of Tides and Currents in Estuaries and Canals	Sept. 1969
17	Estuarine Navigation Projects	Jan. 1971
18	History of the Corps of Engineers Committee on Tidal Hydraulics	June 1972
19	A Field Study of Flocculation as a Factor in Estuarial Shoaling Processes	June 1972

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The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

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CORPS OF ENGINEERS, U. S. ARMY

ARMY MRC VICKSBURG MISS

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PRESENT MEMBERSHIP OF
COMMITTEE ON TIDAL HYDRAULICS

Members	
P. A. [illegible]nel, Jr.	New Orleans District
E. B. [illegible]mner	Office, Chief of Engineers
A. B. [illegible]avis, Jr.	Galveston District
J. W [illegible]rris	Savannah District
F. A [illegible]errmann, Jr.	Waterways Experiment Station
D [illegible]logan	Seattle District
J. [illegible]. McAleer	Office, Chief of Engineers
J. [illegible] Phillips	Philadelphia District
T [illegible]oville, Jr.	Coastal Engineering Research Center
[illegible] A. Schultz	San Francisco District
[illegible]. B. Simmons	Waterways Experiment Station
Liaison	
J. H. Douma	Office, Chief of Engineers
Consultants	
J. B. Tiffany	Chairman
J. B. Lockett	Recorder
Dr. Arthur T. Ippen	Massachusetts Institute of Technology
Dr. G. H. Keulegan	Waterways Experiment Station
Dr. D. W. Pritchard	Johns Hopkins University
C. F. Wicker	Consulting Engineer, Philadelphia

FOREWORD

Army Regulation 870-5 provides, in part, as follows:

> Organizational history is the entire body of events concerned with specific military organization, its participation as part of, and its contribution to the objectives of the larger military forces to which it has belonged. Unit history is the written narrative record of a specific military organization. Commanders of all organizations subordinate to Headquarters, Department of the Army, are responsible for preparing a unit history for their organization.

The U. S. Army Engineer Committee on Tidal Hydraulics, staffed by civilians, is under the supervision of the Department of the Army through the Chief of Engineers, Corps of Engineers, U. S. Army, Washington, D. C.

Significant to the history of that Committee are the circumstances which led to its establishment in 1948. These circumstances developed through a series of events that are deemed worthy of record.

Early in the 1940's, engineers at the U. S. Army Engineer Waterways Experiment Station at Vicksburg, Mississippi, had completed construction of the then largest hydraulic model of a coastal estuary—the Savannah Harbor Model. This model had been molded in concrete with the hope of learning how to reduce or prevent the heavy shoaling prevailing in the authorized navigation channel of that harbor. The late Mr. Ralph E. Rhodes, U. S. Army Engineer District, Savannah, held high hopes that the model would verify the field measurements of current velocity and direction which, he recognized, appeared contradictive in several aspects, including the fact that surface and bottom currents often were in opposite directions.

The great day eventually arrived when the model was filled with fresh water, upland discharge was simulated, and the tide generators were placed in operation. Current directions and velocities were measured in the model for verification with field observations. These verification efforts, however, were completely disappointing, for no matter how the model was operated, it was not possible to correlate the model velocities and surface and bottom current directions with prototype measurements. This was a matter of great concern as it meant that years of planning, field work, and model construction had come to naught. In desperation, all possible expedients were employed by the Waterways Experiment Station model staff and Mr. Rhodes, but the problem could not be readily resolved.

Finally, Mr. Joseph B. Tiffany, Technical Director of the Waterways Experiment Station, suggested to Messrs. G. B. Fenwick and H. B. Simmons, engineers in charge of the model, that water with salinity comparable to that of the prototype ocean be used in the model ocean in lieu of fresh water. This suggestion was followed and the model immediately and accurately reproduced the field observations, even though these measurements revealed that flows vary considerably in the vertical throughout the estuary, and that bottom currents do not necessarily flow in the same direction or with the same strength as surface currents. This fortunate discovery led to the initial recognition in the United States that density

currents constitute one of the major forces controlling estuarine hydraulics and shoaling, and indirectly was responsible for the establishment of the Committee on Tidal Hydraulics.

During the late 1940's, information being developed in the Savannah hydraulic model was discussed many times by Mr. Tiffany, Mr. Rhodes, and Mr. Clarence F. Wicker of the U. S. Army Engineer District, Philadelphia, who was then planning a very large hydraulic model of the Delaware River. Recognizing that there should be some means of disseminating to Corps estuary engineers the fundamental type data and information being derived from the Savannah River model and likely to be developed in the soon-to-be Delaware River model, they conceived the idea of a Corps-wide civilian committee for this purpose. Mr. Wicker agreed to write a letter for his District Engineer to sign, so proposing to the Office, Chief of Engineers. The latter office approved the suggestion and established the Committee on Tidal Hydraulics in October 1948. Thus, from this unusual beginning the Committee has been functioning for more than 22 years at the time of writing of this history.

This History of the Committee on Tidal Hydraulics was compiled and prepared by Mr. John B. Lockett, Recorder of the Committee, with the assistance and counsel of all members and consultants of the Committee.

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HISTORY
OF THE
CORPS OF ENGINEERS
COMMITTEE ON TIDAL HYDRAULICS

ESTABLISHMENT OF THE COMMITTEE

The need for research by the Corps of Engineers in the field of tidal hydraulics was first recognized by Messrs. Joseph B. Tiffany of the U. S. Army Engineer Waterways Experiment Station, Ralph F. Rhodes of the U. S. Army Engineer District, Savannah, and Clarence F. Wicker of the U. S. Army Engineer District, Philadelphia, during the course of hydraulic model studies of the Savannah and Delaware Rivers, conducted at the Waterways Experiment Station in Vicksburg, Mississippi, during the 1940's. From this recognition, this need was formally outlined in a letter, dated 18 February 1947, from the Director, Waterways Experiment Station, to the Chief of Engineers, subject "Funds for General Investigations and Research for F.Y. 1948." Almost concurrently, concern over this need was also expressed by the District Engineers, Savannah and Jacksonville. As the result, Item No. 16, entitled "Tidal Flow in Rivers and Channels," was included in the 1948 Civil Works Investigation Program, but no work was authorized at that time. On 22 September 1948, the District Engineer, Philadelphia District, in a letter to the Chief of Engineers, subject "Civil Works Investigations," recommended the establishment of the Committee on Tidal Hydraulics. In response thereto, the Chief of Engineers, by letter dated 20 October 1948, to the Division Engineer, U. S. Army Engineer Division, North Atlantic, subject "Establishment of Committee on Tidal Hydraulics," stated:

> At the suggestion of the Philadelphia District and the North Atlantic Division, this office is establishing a committee to be known as the "Committee on Tidal Hydraulics," the function of which will be to study the available theory on tidal hydraulics and the tidal hydraulic problems of the Corps and determine whether a program of general experimentation on this subject is needed. If such an experimental program is found desirable, it will also be the function of the Committee to prepare an outline of such a program for submission to this office for approval as an item in the Civil Works Investigation program and, if approved by this office, to exercise general supervision over this item of the Civil Works Investigation program. ...Expenses of the Committee will be charged to the 1949 Civil Works program. For this purpose, Hydraulic (Type B) Item No. 16 entitled "Tidal Flow in Rivers and Channels" of the 1948 program will be reestablished as Hydraulic item No. CW 816 of the 1949 program with the same title. Funds in the amount of $5,000 will be set aside to cover expenses incurred during the present fiscal year.

At the first meeting of the Committee, held in the offices of the Beach Erosion Board, Washington, D. C., on 12-13 January 1949, an exhaustive discussion of the subject assigned led to the definite conclusion that a comprehensive program of research in tidal hydraulics and related fields was urgently needed within the Corps of Engineers. It was recognized that adequate information was notably lacking to determine the correct relation between width, depth, cross section, and alignment of tidal waterways in order to obtain the most favorable design for maintaining or increasing the tidal prism, for securing or maintaining desired project channels, for determining in advance the changes in the tidal regimen of a river or estuary as a result of the proposed major physical changes, for predicting the tides and currents in a tidal canal to be built or improved, for designing the regulatory works for the control

of tidal inlets, for obtaining the most favorable resultants from the action of saltwater wedge movements, etc. It was noted that coastal districts frequently are responsible for planning improvements necessary to secure and maintain an increased width or depth of project channel, or to extend upstream the limits of an existing navigation channel. However, available technical information on this subject was not sufficient to enable the design engineer to plan regulatory works with any assurance that they would secure the desired results; specifically, in the case of the desired extension upstream of a navigation channel in a tidal river, the extent of improvements required in the lower reaches of the river necessary to improve its tidal characteristics was not known. The Committee held that the comprehensive investigations contemplated should cover not only the hydraulics of tidal rivers and estuaries but also the salinity conditions in such rivers and estuaries as related to tidal phenomena, and shoaling processes as related to both tidal and salinity phenomena. The Committee believed that salinity currents in most tidal rivers were so closely related to tidal phenomena that a comprehensive study of the one was impossible without considering the other. Moreover, it was believed that the processes whereby material is moved to and deposited in the navigation channels of tidal waterways, while not problems of tidal hydraulics in the strictest sense of the term, are closely related to the hydraulic and salinity phenomena. In view of the above, it was the considered opinion of the Committee that a program of research on these subjects was essential to a better understanding of the natural processes involved and offered the likelihood of high dividends from the cost of such investigations in the form of reduced maintenance cost. It was agreed by the Committee that its activities, in order to be worthwhile, should be comprehensive in scope, including not only tidal hydraulics as such but also the related processes which contribute to channel shoaling. Also, these investigations should not be confined to any restricted localities, but rather should include all the tidal areas for which the Corps of Engineers is responsible.

At this initial meeting, the following objectives of the Committee were formulated.

a. To evaluate the present state of knowledge of tidal phenomena of interest to the Corps of Engineers.

b. To recommend programs of study, investigation, and research designed to provide the knowledge necessary to arrive at adequate solutions for the engineering problems associated with tidal waterways.

c. To exercise technical supervision of the prosecution of the recommended programs.

Subsequently, through the years, these objectives were modified in the light of known needs and now, as stipulated in Engineer Regulation 15-2-5, dated 19 April 1971 (see Appendix A), are:

a. To maintain a continuing evaluation of the state of knowledge required for the improvement and maintenance of tidal waterways.

b. To recommend studies, investigations, and research designed to provide the knowledge necessary to arrive at adequate solutions for the engineering problems associated with tidal waterways.

c. To exercise advisory technical supervision of assigned programs.

d. To publish and disseminate pertinent information.

e. To render such consulting service on specific problems in tidal waterways as may be requested by various organizations of the Corps of Engineers.

MEMBERSHIP OF THE COMMITTEE

The directive which established the Committee required that membership be contingent on extensive knowledge and wide experience in the field of tidal hydraulics and related phenomena, and these

considerations were paramount in selection of the original charter and all subsequent Committee members from the civilian component of the Corps of Engineers. Members of the Committee are appointed by the Director of Civil Works, OCE. Pertinent information regarding employees so appointed as members of the Committee is shown in the following tabulation:

Name	Home Office	Tenure[1]	Reason for Leaving
James R. Johnston[2]	North Atlantic Division	12 Jan 49 to 31 Dec 65	3
Joseph B. Tiffany[4]	Waterways Experiment Station	12 Jan 49 to 31 Oct 69	3
Berkeley Blackman	South Atlantic Division	12 Jan 49 to 10 Aug 51	3
Martin A. Mason	Beach Erosion Board	12 Jan 49 to 1 Sep 51	5
Ralph F. Rhodes	Savannah District	12 Jan 49 to 30 Nov 49	3,6
Oscar Rosenzweig	Philadelphia District	12 Jan 49 to 4 Mar 52	Deceased
Jacob H. Douma[7]	Office, Chief of Engineers	12 Jan 49 to Present	
Clarence F. Wicker[8]	Philadelphia District	1 Mar 49 to 31 Dec 61	3,6
Richard O. Eaton	Beach Erosion Board	1 Mar 49 to 31 Dec 63	3
Edward A. Schultz	San Francisco District	12 Nov 51 to Present	
Robert E. Hickson	North Pacific Division	29 Jan 52 to 30 Apr 54	3
Joseph M. Caldwell	Coastal Engineering Research Center	19 Oct 54 to ? Mar 71	9
Harold W. Feldt	Southwestern Division	19 Oct 54 to 14 Sep 57	5
Henry B. Simmons[10]	Waterways Experiment Station	19 Oct 54 to Present	
John C. Marcroft	South Pacific Division	19 Oct 54 to 31 Jul 63	3
John B. Lockett[11]	North Pacific Division	28 Oct 58 to 30 Jul 70	3
Clement P. Lindner	South Atlantic Division	28 Oct 58 to 30 Dec 66	3
Albert B. Davis, Jr.	Galveston District	2 Oct 62 to Present	
John B. McAleer	Office, Chief of Engineers	2 Oct 62 to Present	
P. Alfred Beenel, Jr.	New Orleans District	28 Jan 64 to Present	
Thorndike Saville, Jr.	Coastal Engineering Research Center	30 Jun 64 to Present	
Joseph F. Phillips	Philadelphia District	20 Jun 66 to Present	
John W. Harris	Savannah District	13 Jun 67 to Present	
Eugene B. Conner	Office, Chief of Engineers	17 Oct 67 to Present	
Frank A. Herrmann, Jr.	Waterways Experiment Station	9 Mar 71 to Present	
Dwain F. Hogan	Seattle District	9 Mar 71 to Present	

[1] As determined from date of meeting first attended as member and date of leaving.
[2] Temporary Chairman, 1st Meeting.
[3] Retired from Federal service.
[4] Recorder, 12 Jan 49 to 30 Jan 58, Acting Chairman, 30th Meeting, Chairman, 1 Jan 62 to 31 Oct 69, subsequently employed as Chairman-Consultant 16 Jun 70 to present.
[5] Resigned from Corps of Engineers.
[6] Subsequently employed as Consultant to the Committee.
[7] OCE liaison member.
[8] Chairman, 1 Mar 49 to 31 Dec 61.
[9] Resigned and transferred to OCE.
[10] Acting Recorder, 30th Meeting; Recorder, 1 Jul 58 to 30 Jun 62.
[11] Recorder, 1 Jul 62 to 30 Jul 70; subsequently employed as Recorder-Consultant, 18 Nov 70 to present.

CONSULTANTS

The Committee has also made use of recognized experts in the field of tidal hydraulics, both outside and within the Federal Government, as consultants in connection with its activities. Its consultants, so employed, are listed in the following tabulation:

Name	Home Office	Tenure[1]	Reason for Leaving
Dr. Boris A. Bakhmeteff	Columbia University	1 Jul 49 to 21 Jul 51	Deceased
Dr. Lorenz G. Straub	University of Minnesota	1 Jul 49 to 27 Oct 63	Deceased
Mr. Ralph F. Rhodes	Savannah, Ga.	23 May 50 to 30 Nov 54	Retired
Dr. Martin A. Mason	George Washington University	29 Jun 52 to 30 Jun 57	Task completed
Dr. Hans A. Einstein	University of California	21 Apr 53 to 30 Jun 61	Task completed
Dr. Arthur T. Ippen[2]	Massachusetts Institute of Technology	24 Feb 54 to Present	
Dr. Donald W. Pritchard	Johns Hopkins University	10 May 55 to Present	
Dr. Garbis H. Keulegan	Bureau of Standards and WES	2 Oct 57 to Present	
Mr. Clarence F. Wicker	Philadelphia, Pa.	6 Mar 62 to Present	
Mr. Joseph B. Tiffany[3]	Vicksburg, Miss.	16 Jun 70 to Present	
Mr. John B. Lockett[3]	Portland, Oreg.	18 Nov 70 to Present	

1 As determined from date of meeting first attended as consultant and date of leaving.
2 On sabbatical leave for approximately one year beginning in the Fall of 1964, during which time Dr. D R. F. Harleman, Massachusetts Institute of Technology, served as consultant to the Committee in Dr. Ippen's absence.
3 Although employed as consultants, these former employees of the Corps of Engineers are considered members of the Committee pursuant to the provisions of ER 15-2-5, dated 19 April 1971.

MEETING REGISTER

Meetings of the Committee are called by the Chairman whenever the problems for Committee consideration warrant such action. At least two and not more than four meetings have been held annually by the Committee throughout its existence. These meetings have generally been held in the offices of the coastal Corps of Engineers Divisions and Districts, the Coastal Engineering Research Center, and the Waterways Experiment Station, at the invitation of the Officers in Charge of these installations. A listing of the dates and location of each meeting of the Committee is contained in Appendix B. Group photographs of the Committee, its consultants, and guests taken at some of these meetings are shown in Appendix H.

MEETING PROCEDURES

Meetings of the Committee are either open or closed meetings. The open meetings are generally divided into technical sessions, at which interested representatives of the Federal Government and state

and local agencies as well as private enterprise are invited to attend; followed by executive sessions at which only members and consultants attend. Closed meetings are usually held for administrative purposes and are generally executive in nature. The technical sessions of open meetings are normally opened with a note of welcome by the Officer in Charge of the installation at which the meeting is held, or under whose auspices the meeting is held. Following this, the Chairman leads in the introduction of Committee members, consultants, and guests. Thereupon, in accordance with prearranged agenda, the technical sessions consist of presentations before the Committee of tidal hydraulics problems, generally in the locale of the meeting site, by informed Corps of Engineers representatives, during which open discussions on the pertinent details of the problems normally ensue. Upon the completion of these presentations and discussions, the balance of the technical sessions are devoted to presentations of generalized reports by members concerned on the status of preparation of Committee reports, Committee research programs, and items of general interest to Corps field personnel engaged in the field of tidal hydraulics. At meetings where such would assist the Committee in its understanding of the problem or problems at hand, the technical sessions may be preceded by a field inspection by the Committee of the problem area. Following adjournment of the technical sessions, the Committee goes into executive sessions generally on the last day of the meeting. At the executive sessions, the first order of business usually involves discussions of the problems presented during the technical sessions, the development of plans for resolution of these problems, and the assignment of tasks necessary to develop and transmit the views of the Committee on these problems to the Corps field office concerned. A large part of each executive meeting is devoted to the monitoring of the status of Committee research programs, analyzing the findings of this research, exploring the need for further research, and developing the means for dissemination of new knowledge gained through these research activities. Also coming under close purview of the Committee during these sessions are the status of its publications, its budget, and new policies and procedures essential to the fulfillment of the mission of the Committee. The Recorder of the Committee prepares detailed minutes of each meeting, which are reproduced and distributed to interested Corps of Engineers offices and employees, research laboratories and institutions, as well as to concerned parties throughout the world.

ACCOMPLISHMENTS OF THE COMMITTEE

Accomplishments of the Committee can be categorized into (a) investigations and scientific research of tidal hydraulics phenomena, (b) the furnishing of consultation and advice to Corps of Engineers field offices in the planning, construction, and maintenance of improvements in tidal waterways, (c) the publication and distribution of appropriate Committee reports and papers to foster development and dissemination of knowledge in the field of tidal hydraulics, (d) special missions, and (e) savings enjoyed by application of new knowledge gained through Committee research.

Investigation and Scientific Research

The investigation and research activities of the Committee are geared to the accumulation and development of new knowledge for specific use by the average coastal engineer of the Corps in the securing and maintenance of adequate navigation facilities in the tidal waterways of the Nation at minimum cost. The Committee commenced its effort in this direction in 1949 by making a careful appraisal of the then existing field of knowledge of tidal hydraulics phenomena and the effect of these phenomena on the planning, construction, and maintenance activities of the Corps in tidal waterways. This appraisal

revealed serious gaps in the knowledge of the engineering profession in this field at that time, and as a consequence, the Committee launched a program of investigation and research designed to fill these gaps in knowledge. This program, modestly initiated by the Committee in 1951, now includes or contemplates work of research in the following subjects:

a. *Hydraulics*
   (1) Tides and Currents in Tidal Waterways
   (2) Salinity Intrusion and Related Phenomena
   (3) Velocities, Directions, and Distributions of Currents in Tidal Waterways
   (4) Pollution and Flushing
b. *Ecology*
c. *Sedimentation Processes*
   (1) Sources of Sediment
   (2) Characteristics of Sediment
   (3) Mechanics of Sediment Scour, Transport, and Deposition
   (4) Flocculation Processes
   (5) Stability of Deposited Sediments
d. *Design of Channels and Stabilization of Inlets*
   (1) Design of Channels for Safe and Economic Navigation
   (2) Design of Channels for Least Annual Cost
   (3) Design and Layout of Channels and Structures for Stabilizing and Improving Inlets
e. *Maintenance and Improvement Practices*
   (1) Dredging Methods
   (2) Spoil Disposal
   (3) Regulatory Measures
f. *Field, Analytical, and Laboratory Procedures*
   (1) Measurement Methods and Instrumentation
   (2) Sampling and Analysis of Suspended and Bottom Sediments
   (3) Use of Models
   (4) Use of Analogs
   (5) Use of Computers
   (6) Tracer Techniques for Investigation and Study of Pollution and Shoaling
   (7) Data Assembly and Analysis

A resume' of research sponsored, cosponsored, encouraged, or proposed by the Committee in the above subject areas is contained in Appendix C hereto.

Consultation and Advice

The Committee has rendered professional consulting service and advice on a large number of navigation and related problems developing in the tidal waterways of the Nation in response to requests of different organizations of the Corps of Engineers. This service has been extensively used by District and Division Engineers in connection with the resolution of many problems, and the advice tendered to the requesting offices has been recorded in the Minutes of the Committee's meetings or in letters and formal reports. As of 30 June 1971, the Committee has considered problems and rendered consulting services on 69 Corps projects throughout the Nation, much of the service being on a continuing basis

from the initial stages of planning through the construction and maintenance stages. A list of projects on which the Committee has given consultation service is shown in Appendix D.

Committee Reports

From time to time, the Committee publishes and disseminates reports and related data on tidal hydraulics phenomena with the view to fulfilling these responsibilities and objectives. As shown in Appendix F, these publications have taken the form of (a) Committee Reports, (b) Committee Technical Bulletins, and (c) Reports on Specific Tidal Hydraulics Problems throughout the Nation. The Committee Report Series is reserved for those documents of general value to all coastal offices of the Corps of Engineers, irrespective of location or type of tidal hydraulics problem involved. This series was inaugurated in February 1950, less than two years after establishment of the Committee, by publication of Report 1, "Evaluation of Present State of Knowledge of Factors Affecting Tidal Hydraulics and Related Phenomena." This report was revised and brought up to date by the Committee in May 1965 to incorporate the advances made during the intervening 15 years by publication of Report 3, bearing the same title. Like the original report, the revised publication consists of chapters prepared by members and consultants of the Committee, each dealing with a phenomenon affecting the solution of tidal hydraulics problems and their related aspects. Committee Report 2 and its supplements constitute a readily usable bibliography on the different phases of the tidal hydraulics field which is continually being brought up to date as new publications are prepared and disseminated.

The results of special technical investigations of tidal hydraulics phenomena sponsored by the Committee, as well as other outstanding studies in this field, have been published by the Committee in the form of technical bulletins. A total of 17 such bulletins, covering important research endeavors, has been published as of 30 June 1971.

As mentioned above, the Committee, in response to requests from field offices of the Corps, has reviewed and recommended courses of action to be taken toward solution of many tidal hydraulics problems throughout the United States. The results of Committee deliberations of these problems were, for many years, furnished the field offices by means of letters addressed by the Chairman to the Division Engineer concerned. These letters contained valuable information and findings of general interest; but as they were merely letters, they were retired to the files after their original purpose was served. As a consequence, these valuable findings and information were not normally available to the average coastal engineer when confronted with a similar tidal hydraulics problem in a different area. In an effort to avoid this situation and to establish a more permanent and readily available record of these deliberations, the Committee in December 1960 adopted the practice of publishing significant findings in report form with an appropriate binding to distinguish them from the usual routine publication. A total of 34 such reports has been published to date. Committee Technical Bulletin 12, published in 1966, assembled and presented the most significant of the previously unpublished letter reports.

Although as indicated in Appendix E several of the Committee publications are now out of print, copies of available publications may be secured upon application to the Recorder, Committee on Tidal Hydraulics, c/o U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Mississippi 39180.

Special Missions

During the course of its existence, the Committee imposed upon itself certain additional tasks or

was called upon to perform special assignments designed to further increase the state of knowledge of tidal hydraulics phenomena. A description of such missions and the accomplishments thereof are contained in Appendix F.

Application of New Knowledge

Perhaps the most significant accomplishments of the Committee on Tidal Hydraulics, which were shared in their fulfillment by the field offices of the Corps of Engineers, were savings in construction costs and subsequent maintenance costs of tidewater improvements made possible by the application of new knowledge gained through Committee research endeavors. These accomplishments represented savings of many millions of dollars to the Corps of Engineers through the proper design of these improvements; utilization of improved dredging and spoil disposal techniques, by not undertaking proposed work, which might otherwise have been completed, were it not for hydraulic model studies that demonstrated the work to be ineffective or detrimental; and office or field studies undertaken at the recommendation of the Committee.

BUDGET HISTORY

Funds supporting Committee activities have been derived through the years from allotments made from the former Civil Works Investigations Program and the present Engineering Studies Program of the Corps of Engineers. These yearly allotments have always been quite modest in magnitude but the achievements made by the Committee with these limited funds are quite remarkable. It is doubted that any funded Corps activity has ever yielded the monetary and other benefits made possible through the acquisition and application of new knowledge gained through Committee use of these funds. A listing of funds expended by the Committee for each fiscal year of its existence under the different ES research programs is shown in Appendix G.

PROPOSED FUTURE RESEARCH

It is anticipated that the Committee will continue to completion its present program of investigation and research, and will recommend and prosecute new and additional research as the need arises until all basic information required for the achievement of adequate engineering solutions to those problems in tidal waterways of concern to the Corps of Engineers has been developed. As guidance in this task, the Committee, beginning in 1964, developed its own program document, which is continually being revised to reflect current research needs.

At the present time, fulfillment of the Committee's current program of research is visualized to require additional work in the following areas:

a. *ES 843, Salinity Intrusion and Related Phenomena.* Phase IV of this research program requires advancement to determine the effects of vertical velocity distribution on the transportation and deposition of sediments as mentioned in Appendix C. Some of the matters to be investigated include:

   (1) Unsteady-state salinity distributions with a view to determining the time required for a system to adjust itself to a change in conditions that are factors in salinity intrusion.

   (2) Relations between sediment motions and a steady-state salinity distribution to determine whether sediment forms a shoal in equilibrium and, if so, the distribution thereof.

   (3) The effectiveness of bubble curtains in an estuarine and saline environment.

(4) Distribution of pollutants in a tidal waterway with a view to determining whether such distribution diverges from the normal salinity distribution.

(5) Characteristics of lateral distribution of salinity (Z direction) and the effects of such distribution on the transportation and deposition of sediments.

b. *ES 844, Office Investigation of Existing Data on Tidal Entrances.* Further correlation of existing data on tidal entrances to develop empirical relationships of inlet characteristics will be required as new data become available.

c. *ES 845, Tides and Currents in Tidal Waterways.* With regard to estuaries open to the ocean at one end and canals or waterways connecting two independent tidal waterways, areas for additional research include (1) extension of the one-dimensional, finite difference formulation to include tidal problems with multiple channel junctions as in the case of tidal delta networks, and (2) an extension of the nonlinear, finite difference formulation to two-dimensional tidal motion, including the Coriolis term, for application to wide estuaries and tidal embayments. With respect to canals or waterways extending from one tidal body to a bay or lagoon not having an independent tide, further study envisions definition of the effects of geometric parameters of the inlet on the head loss through the inlet, flow patterns throughout the inlet, and the effects of more than one inlet connecting the ocean with a single bay or sound.

d. *ES 856, Shoaling Processes.* Although some breakthrough in the securing of new knowledge regarding the mechanisms associated with the processes involved in shoaling has been achieved as discussed in Appendix C, much more intensive research will be necessary before the goal of developing sound methods for making an analytical determination of prospective channel shoaling rates and for design of corrective measures for shoaling of existing projects is achieved. Further work is also required to determine the mechanics of slip and tributary shoaling. In the area of sampling and packaging of estuarine sediments it is anticipated that a modest program to formulate recommendations for improvements in existing equipment and procedures and/or the development of new equipment and procedures will be launched in the near future.

e. *ES 860, General Coastal Inlet Studies.* This research program will be vigorously prosecuted in general accordance with the proposed plans outlined in Appendix C.

In the sphere of new research, it is anticipated that the Committee will soon be involved in the formulation and prosecution of a 5-year program of research leading to engineering design of navigation channels in tidal waterways, now under consideration in the Office, Chief of Engineers. While the design of such channels in the past has been based largely on rule-of-thumb considerations, the Committee believes that safer and more economical design can be effected through engineering analyses of factors involved including the increasing size of commercial vessels, effect of vessel squat, vessel clearance above channel bottom, horizontal clearance between channel banks, minimum channel curvature, effects of restricted channels, and effects of waves and winds on navigation. The Committee is of the opinion that the 5-year program should concentrate on areas of deficient knowledge such as (a) behavior of vessels in wide and shallow waterways, as well as in restricted waterways, (b) effect of vessel squat on passing, (c) vessel motion due to waves, (d) handling characteristics of vessels when passing, (e) effects of winds, currents, and waves on heading of vessels, (f) optimum channel alignment, and (g) appropriate depth and width considerations.

Other presently visualized areas of needed new research and development include other areas and subjects mentioned in the project document, with particular emphasis to:

a. Determine the effects of engineering improvements on prevailing estuarine ecology.

b. Follow-up on completed projects to ascertain how functioning of these projects has conformed to past predictions of their performance.

c. Expand electronic computer techniques, including the development of automatic data gathering and rapid display of prototype measurement results.

APPENDIX A
ER-15-5

DEPARTMENT OF THE ARMY
Office of the Chief of Engineers
Washington, D.C. 20314

ER 15-2-5

ENGCW-EH

Regulation
No. 15-2-5

19 April 1971

BOARDS, COMMISSIONS AND COMMITTEES
Committee on Tidal Hydraulics

1. Purpose. This regulation prescribes the composition of the Corps of Engineers Committee on Tidal Hydraulics and the objectives of its work.

2. Applicability. This regulation is applicable to the committee members as well as to all installations concerned with the various aspects of tidal hydraulics.

3. Objectives. The objectives of the Committee are:

a. To maintain a continuing evaluation of the state of knowledge required for the improvement and maintenance of tidal waterways.

b. To recommend studies, investigations, and research designed to provide the knowledge necessary to arrive at adequate solutions for the engineering problems associated with tidal waterways.

c. To exercise advisory technical supervision of assigned programs.

d. To publish and disseminate pertinent information.

e. To render such consulting service on specific problems in tidal waterways as may be requested by various organizations of the Corps of Engineers.

4. Composition. The Committee on Tidal Hydraulics is a continuing committee of which the members are civilian or former civilian engineers of the Corps of Engineers having expert knowledge of tidal theories and tidal problems. Members of the Committee are appointed by the Director of Civil Works, OCE. The Committee designates two of its members to serve as Chairman and Recorder, respectively. The current membership of the Committee is shown in Appendix A to this regulation.

5. Responsibilities. The Committee functions under the direction of the Chief of Engineers and is responsible for:

This Regulation supersedes ER 15-2-5, 8 June 1964

a. Annual review of existing and proposed programs of research, studies and investigations designed to provide knowledge for the more efficient improvement of tidal waterways for which the Committee has been assigned advisory technical supervision.

b. Recommendations to Chief of Engineers in regard to type, scope and funding of assigned tidal hydraulic investigations.

c. Continuous advisory technical supervision and guidance of assigned research studies and investigations in the tidal hydraulics field.

d. Providing upon request consulting services on specific tidal hydraulic problems to officers in charge of Corps of Engineers' organizations and to the Chief of Engineers. In order to maintain a proper balance of Committee advisory service, the following procedures will apply:

(1) Beach erosion control projects and specific coastal engineering projects which have no questionable tidal hydraulic features should be referred for review through normal channels and not to the Committee on Tidal Hydraulics.

(2) Coastal engineering projects which are not unduly complex but would be of interest to the Committee and for which the Committee's advice on some aspects may be helpful should be presented to the Committee at one of its meetings. The Committee's advice will be confined to discussion at the meeting and a recording of the discussion in the Committee minutes.

(3) Major coastal engineering projects for which the Committee's advice is desired on project formulation or complex tidal hydraulic features should be presented and thoroughly considered at a Committee meeting, after which the Committee will give further consideration to the problems in executive session and later individual reviews by Committee members, as required. The Committee will prepare and submit to the office concerned, with copies furnished to OCE, a brief letter report containing its views and recommendations.

(4) OCE will review Committee minutes and advisory reports, and make such comments thereon as are required to coordinate the Committee's views with the engineering, advance planning, and funding considerations of OCE.

In order to improve coordination of the Committee's advisory service, requests for such service should be made to the Committee Chairman through OCE. Normally, requests should be made at least four months

prior to the desired assistance so that the Committee may properly schedule its meetings.

6. General. The Committee will carry out its responsibilities in accordance with the following:

a. The Chairman of the Committee will call Committee meetings whenever the problems for Committee consideration warrant such action. Advance notices and minutes of Committee meetings will be furnished the Chief of Engineers, attention ENGCW-E, ENGCW-O and ENGCW-P.

b. Administrative and funds support for Committee activities will be provided, as appropriate, by the field organizations accomplishing general investigations in the tidal hydraulics field and by the organizations to which Committee members are normally assigned. Salaries of Committee members while engaged in Committee activities will be chargeable to home offices. Per diem and travel expenses will be chargeable to Engineering Studies, Civil Works Investigations.

c. Committee recommendations for work to be performed by field organizations will be submitted to the Chief of Engineers, attention ENGCW-E, for authorization through normal channels.

d. Committee activities will require that members accomplish some Committee work at home offices.

e. Direct correspondence is authorized among Committee members, and between the Chairman and officers in charge of Corps of Engineers field organizations. Information copies of Committee actions having important bearing on project planning or investigations programs will be furnished to the Chief of Engineers, attention ENGCW-E.

f. The Committee will arrange for publication and distribution of appropriate committee reports and papers to foster development of knowledge of tidal phenomena.

g. The Committee may arrange through cooperating Corps of Engineers field organizations for engagement of staff assistance, expert services and consultants.

FOR THE CHIEF OF ENGINEERS:

Richard F. McAdoo

RICHARD F. McADOO
Colonel, Corps of Engineers
Executive

1 Appendix
List of Designated Members
of the Corps of Engineers
Committee on Tidal Hydraulics

APPENDIX A

The following Corps of Engineers personnel and former employees now retired are currently designated members of the Corps of Engineers Committee on Tidal Hydraulics:

Member	Installation
Joseph B. Tiffany, Chairman	U. S. Army Engineers Waterways Experiment Station (Retired)
John B. Lockett, Recorder	U. S. Army Engineer Division, North Pacific (Retired)
Jacob H. Douma, Liaison	Office, Chief of Engineers
Alfred P Becnel, Jr.	U. S. Army Engineer District, New Orleans
Eugene B. Conner	Office, Chief of Engineers
Albert B. Davis, Jr.	U. S. Army Engineer District, Galveston
John W. Harris	U. S. Army Engineer District, Savannah
Frank A. Herrmann, Jr.	U. S. Army Engineers Waterways Experiment Station
Dwain F. Hogan	U. S. Army Engineer District, Seattle
John B. McAleer	Office, Chief of Engineers
Joseph F. Phillips	U. S. Army Engineer District, Philadelphia
Thorndike Saville, Jr.	U. S. Army Coastal Engineering Research Center
Edward R. Schultz	U. S. Army Engineer District, San Francisco
Henry B. Simmons	U. S. Army Engineers Waterways Experiment Station

APPENDIX B

MEETINGS OF THE COMMITTEE

MEETINGS

Meeting	Dates	Host Office and Location
1	12-13 Jan 1949	Beach Erosion Board, Washington, D. C
2	1-2 Mar 1949	Waterways Experiment Station, Vicksburg, Miss.
3	3-5 May 1949	Savannah District, Savannah, Ga.
4	14-16 Sep 1949	Philadelphia District, Philadelphia, Pa.
5	27-28 Feb 1950	South Pacific Division, Oakland, Calif.
6	23-25 May 1950	New Orleans District, New Orleans, La.
7	15-17 Nov 1950	Beach Erosion Board, Washington, D. C.
8	14-16 Feb 1951	Waterways Experiment Station, Vicksburg, Miss.
9	6-8 Jun 1951	North Atlantic Division, New York, N. Y.
Special	26 Sep 1951	Philadelphia District, Philadelphia, Pa.
10	12-14 Nov 1951	Galveston District, Galveston, Tex.
11	29-31 Jan 1952	Charleston District, Charleston, S. C.
12	24-28 Mar 1952	Philadelphia District, Philadelphia, Pa.
13	5-8 Aug 1952	North Pacific Division, Portland, Oreg.
14	20-21 Oct 1952	New England Division, Boston, Mass.
15	21-23 Apr 1953	Waterways Experiment Station, Vicksburg, Miss.
16	4-6 Aug 1953	South Pacific Division, San Francisco, Calif.
17	17-19 Nov 1953	Waterways Experiment Station, Vicksburg, Miss.
18	24-26 Feb 1954	Beach Erosion Board, Washington, D. C.
19	28-30 Jun 1954	Philadelphia District, Philadelphia, Pa.
20	19-22 Oct 1954	North Atlantic Division, New York, N. Y.
21	25-27 Jan 1955	Waterways Experiment Station, Vicksburg, Miss.
22	10-12 May 1955	Beach Erosion Board, Washington, D. C.
23	26-27 Oct 1955	North Atlantic Division, New York, N. Y.
24	28 Feb-1 Mar 1956	Waterways Experiment Station, Vicksburg, Miss.
25	27-29 Jun 1956	Providence Field Office, New England Division, Providence, R. I.
26	10-12 Dec 1956	Philadelphia District, Atlantic City, N. J.
27	13-15 Feb 1957	Waterways Experiment Station, Vicksburg, Miss.
28	17-19 Jun 1957	South Pacific Division, San Francisco, Calif.
29	2-4 Oct 1957	St. Paul District, St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minn.
30	11-13 Feb 1958	Savannah District, Savannah, Ga.
31	10-12 Jun 1958	Waterways Experiment Station, Vicksburg, Miss.
32	28-30 Oct 1958	New England Division, Boston, Mass.
33	3-5 Feb 1959	Galveston District, Galveston, Tex.
34	10-12 Jun 1959	Wilmington District, Wilmington, N. C.
35	6-8 Oct 1959	San Francisco District, San Francisco, Calif.
36	1-3 Mar 1960	Waterways Experiment Station, Vicksburg, Miss.

MEETINGS (continued)

Meeting	Dates	Host Office and Location
37	25-28 Oct 1960	Portland District, Portland, Oreg.
38	28 Feb-2 Mar 1961	Charleston District, Charleston, S. C.
39	6-8 Jun 1961	New York District, New York, N. Y.
40	28-30 Nov 1961	Waterways Experiment Station, Vicksburg, Miss.
41	6-8 Mar 1962	Beach Erosion Board, Washington, D. C.
42	1-3 May 1962	North Atlantic Division, New York, N. Y.
43	4-8 Jun 1962	Alaska District, Anchorage, Alaska
44	2-5 Oct 1962	Seattle District, Seattle, Wash.
45	15-18 Jan 1963	Mobile District, Mobile, Ala.
46	18-20 Jun 1963	Beach Erosion Board, Washington, D. C.
47	15-17 Oct 1963	New England Division, Boston and Hyannis, Mass.
48	28-30 Jan 1964	Galveston District, Brownsville, Tex.
49	21-23 Apr 1964	North Atlantic Division, New York, N. Y.
50	30 Jun-2 Jul 1964	Jacksonville District, Fort Lauderdale, Fla.
51	20-22 Oct 1964	New Orleans District, New Orleans, La.
52	26-28 Jan 1965	Waterways Experiment Station, Vicksburg, Miss.
53	24-27 May 1965	San Francisco District, San Francisco, Calif.
54	13-14 Jul 1965	Philadelphia District, Philadelphia, Pa.
55	16-18 Nov 1965	Charleston District, Charleston, S. C.
56	15-17 Feb 1966	Coastal Engineering Research Center, Washington, D. C.
57	20-23 Jun 1966	Waterways Experiment Station, Vicksburg, Miss.
58	25-26 Oct 1966	Jacksonville District, Jacksonville, Fla.
59	14-16 Feb 1967	Seattle District, Seattle, Wash.
60	13-14 Jun 1967	Baltimore District, Baltimore, Md.
61	17-19 Oct 1967	North Atlantic Division, New York, N. Y.
62	13-15 Feb 1968	Galveston District, Galveston, Tex.
63	26-28 Jun 1968	Philadelphia District, Philadelphia, Pa.
64	22-24 Oct 1968	Waterways Experiment Station, Vicksburg, Miss.
65	8-10 Apr 1969	Los Angeles District, San Diego, Calif.
66	15-16 Jul 1969	New Orleans District, New Orleans, La.
67	21-23 Oct 1969	San Francisco District, San Francisco, Calif.
68	18-20 Nov 1969	North Pacific Division, Portland, Oreg.
69	16-18 Jun 1970	Charleston District, Charleston, S. C.
70	18-20 Nov 1970	Philadelphia District, Philadelphia, Pa.
71	9-10 Mar 1971	Coastal Engineering Research Center, Washington, D. C.
72	23-25 Jun 1971	Seattle District, Seattle, Wash.

APPENDIX C

COMMITTEE INVESTIGATION AND SCIENTIFIC RESEARCH

The activities of the Committee on Tidal Hydraulics were originally established as an item of the Civil Works Investigations Program of the Corps of Engineers, and all subsequent programs of study, investigation, and research were assigned as separate items under this basic program. Over the years some of the research programs blended into other programs when such action was indicated. In recent years the title of the basic program was changed to "Engineering Studies Program" and in the discussion that follows the present designation of items under the new program is used to distinguish the different fields of research.

ES 816, Tidal Flows in Rivers and Harbors

This item provides for regular meetings of the Committee, the reproduction and distribution of reports, employment of Consultants, and all general activities not directly related to one of the following specific investigations sponsored by the Committee.

ES 823, Effects of Adjacent Beaches on Tidal Inlets

This item of research was proposed by the Committee in 1949 in recognition of the effects of littoral transport, as influenced by waves, alongshore currents, and tidal currents on sedimentation of bar channels, entrance channels, and tidal inlets. Work on this item was initiated in 1954 and subsequent efforts were devoted to the following three subprojects:

a. Tests in appropriate test basins at the Waterways Experiment Station to determine the factors which influence the migration and/or stability of tidal entrances having erodible banks, and the relative importance of the different factors involved.

b. The securing and analyzing of prototype hydraulic and hydrographic data following construction of a new inlet on the Texas coast.

c. The acquisition and calibration of instruments required for measurement of the rate of littoral transport at prototype inlets equipped with sand bypassing installations.

In connection with subproject a., the Committee has cooperated with the Waterways Experiment Station in having six tests conducted in one test basin and two tests performed in a second test basin. The results of these tests in the first basin were analyzed jointly by the Committee, the Beach Erosion Board, and the Waterways Experiment Station and a report thereon was published in May 1957 as Technical Memorandum 94 of the Beach Erosion Board, "Laboratory Study of Effects of an Uncontrolled Inlet on Adjacent Beaches." The results of tests in the second test basin were subjected to preliminary analysis by the Waterways Experiment Station and forwarded for complete study by the Beach Erosion Board.

Under subproject b., the Committee cooperated with the Beach Erosion Board and the Galveston District in obtaining and analyzing hydraulic and hydrographic data following construction by Willacy County Navigation District of the Port Mansfield, Texas, entrance channel which connects the Gulf of Mexico with Laguna Madre. This channel was dredged to a controlling depth of 10 ft across Laguna Madre and Padre Island, thence 16 ft to deep water in the Gulf of Mexico in 1957, about halfway between Aransas Pass and Port Isabel. The hydraulic and hydrographic measurements were continued until 1959, at which time the inlet was essentially closed and the data obtained were analyzed by the Beach Erosion Board. After completion of a Federal project providing a jettied entrance, a series of measurements of tides and currents through the channel was undertaken under the direction of the Committee to provide prototype data for mathematical analyses of flow through a tidal entrance. Due to the complexities of the Port Mansfield flows created by wind setup, this study was deferred. A less

complex entrance, Indian River Inlet, Delaware, was selected as the subject of mathematical analyses, which analyses were presented in Committee Technical Bulletin 14.

Following studies of the Port Mansfield project, the Committee, in 1962, recognized the need for suitable testing facilities for general and specific inlet studies, which recognition led to authorization of a new research item, ES 860, General Coastal Inlet Studies, subsequently discussed hereafter.

ES 843, Salinity Intrusion and Related Phenomena

This investigation was proposed by the Committee in 1949 in recognition of the knowledge that salinity intrusion into estuaries (and the density currents and other phenomena associated with salinity intrusion) plays a major role in estuarine shoaling processes. Although work on this investigation began as an effort to understand the phenomenon of the saltwater wedge in estuaries having stratified flows, it was later expanded to embrace all aspects of salinity intrusion including the mechanics of the phenomenon in well-mixed and partly mixed estuaries. Further refinement of the objectives of this study divided the experimental and analytical portion into four distinct phases as follows:

Phase I – Definition of the extent of salinity intrusion into open channels and the resulting mean salinity distribution as a function of the intrusion length and phase of tide.

Phase II – The vertical distribution of salinity as a function of the intrusion length and phase of tide.

Phase III – The effects of vertical salinity intrusion on the vertical distribution of current velocities.

Phase IV – The effects of vertical velocity distribution on the transportation and deposition of sediments.

Work on this study was initiated in 1951 at the Waterways Experiment Station by the construction of a transparent plastic salinity flume 140 ft long, 9 in. wide, and 18 in. deep, with facilities in a 20- by 20-ft basin for producing tide phases in salt water at one end and the introduction of fresh water at the other end. The initial testing program in the salinity flume, completed in 1952, consisted of performance tests to determine the usable range of tide, range of time scale, range of freshwater flow, basic movements of water-surface slopes, and current velocities with fresh water only. Later this program used salt water in the tidal basin to show the behavior of the saltwater wedge at different tidal ranges and depths of water in the flume. Dr. Garbis H. Keulegan of the Bureau of Standards was called upon later that year to provide guidance in the interpretation of the results of these tests. He recommended further tests to determine the range of usefulness of this pilot apparatus. Mr. H. B. Simmons of the Waterways Experiment Station, who was in immediate charge of the flume tests and who subsequently became a member of the Committee, proposed a testing program designed to provide data on the longitudinal and vertical distribution of velocities and salinities for the range of saltwater intrusion types capable of being reproduced in the flume without resort to artificial roughness. This program demonstrated the effect of tidal range, freshwater discharge, and salinity differences on intrusion length and vertical distribution, as well as trends for movement and deposition of sediments of different specific gravities for the different types of intrusion studied.

Late in 1953 the salinity flume was extended to its full length of 327 ft. The flume, however, was unable to achieve sufficient mixing of the two waters without the installation of artificial roughness. This roughness was provided and the subsequent tests appeared to conform with conditions noted in Savannah Harbor. In view thereof, the Committee agreed on a program of testing to determine the vertical distribution of current velocities using fresh water only in the flume against the vertical distribution of velocities using salt water in the tidal basin, and to make similar measurements of horizontal and

vertical distribution of current velocities, with both fresh and salt water in the tidal basin. These tests were completed early in 1954 and Dr. A. T. Ippen of the Massachusetts Institute of Technology was employed as a consultant to the Committee to review and analyze the results of these tests.

As the result of his analyses of the test data, Dr. Ippen recommended the undertaking of additional tests to provide data from which the isolated effect on salinity movement of freshwater discharge, tidal period, and tidal range could be determined. These tests were completed late in 1954, and operating procedures were developed which permitted a close reproduction of a highly stratified salinity condition and which enabled a reasonably close reproduction of a partly mixed condition. However, it appeared that the flume was incapable of setting up conditions for reproduction of a completely mixed condition. Mr. Simmons suggested, as means for overcoming this deficiency, that the flume be modified to provide a trapezoidal cross section with net cross-sectional area decreasing from the ocean end to the head of tide. While the merits of this suggestion were recognized, it was decided to continue tests in the rectangular flume. Dr. Ippen continued his work of analyses of this tests.

Early in 1957, the flume was modified to incorporate a mixing device which permitted constant salinity conditions to be maintained at the entrance to the flume, and further tests were made to determine tidal amplitudes and phases for a variety of controlled conditions to correlate salinity and velocity data obtained from previous tests. In February 1959, Dr. Ippen was of the opinion that completion of his report on Phase I of the investigation would be possible in the reasonably near future, but he was doubtful regarding the achievement of satisfactory treatment of vertical salinity and velocity distributions. Later that same year, as the result of additional studies, Dr. Ippen and his colleague, Dr. Donald R. F. Harleman, stated that it appeared that worthwhile results could be obtained in Phases II and III of the investigation, if analytical data completed could be applied to the prototype. Work on these two phases was started in the fall of 1960; and in June 1961, the report by Drs. Ippen and Harleman on Phase I was published as Committee Technical Bulletin 5, "One Dimensional Analysis of Salinity Intrusion in Estuaries."

During the ensuing three years numerous tests essential to the completion of Phases II and III of this investigation, which were combined as a single endeavor, were made involving the extent of dye diffusion throughout the flume for selected conditions of tide and freshwater discharge and also of diffusion coefficients in distorted models. Following this, a draft report on these phases was distributed to the Committee in October 1964, but it was believed that the findings of this report should be verified by prototype observations before they could be accepted. Work of such verification was undertaken, and in June 1967, following satisfactory correlation with prototype observations, the report by Drs. Ippen and Harleman was published and distributed as Committee Technical Bulletin 13, "Two-Dimensional Aspects of Salinity Intrusion in Estuaries: Analysis of Salinity and Velocity Distribution."

Work on Phase IV of the investigation began in 1969 through modification of the salinity flume to show (a) unsteady salinity distribution, (b) mechanics of salinity and sediment motion, (c) longitudinal distribution of pollutants, and (d) use of air-bubble curtains as salinity barriers in estuaries. These modifications of the flume were completed in 1970, and as of this writing, these tests should be completed in Fiscal Year 1972.

ES 844, Office Investigation of Existing Data on Tidal Entrances

This study was proposed by the Committee in 1949 in recognition of a need for collation of data collected and studies made of the characteristics of tidal entrances over an extended period of years by numerous offices of the Corps of Engineers. This collation was believed capable of revealing empirical

relationships between tidal prism, entrance cross-sectional area, flow velocities, bar location and geometry, and other pertinent physical elements of the entrance region that might be of great value in the planning and prosecution of tidal inlet improvements. Work on this project was undertaken in 1955 under terms of a contract between the Beach Erosion Board and the University of Florida with studies performed by Dr. Per Bruun and Mr. F. Gerritson of the Coastal Engineering Laboratory of that University. A report on the results of the data analysis was submitted to the Committee by the contractor in May 1957. Subsequently, the data analysis was used by Dr. Bruun in preparation of an ASCE paper on tidal inlets. Accordingly, the Committee decided that no good purpose would be served by publication of the data analysis as a separate Committee document. This research endeavor was thereupon terminated by the Committee in 1962, pending the further collection of inlet data.

ES 845, Tides and Currents in Tidal Waterways

In consideration of the knowledge that there were in use at least three widely divergent methods for computing tides and currents in tidal waterways, the Committee in 1949 proposed this investigation. All three methods were fairly complicated and laborious, and none of the methods had been evaluated by comparison to selected actual cases to show conclusively the degree of accuracy obtained. The work was initiated in 1952 under terms of a contract with Dr. Hans A. Einstein of the University of California which provided for:

a. Review of the three methods in use for computing tides and currents in tidal waterways (the method proposed by Colonel Earl L. Brown, that proposed by General George B. Pillsbury, and the method of characteristics developed by Dutch engineers in connection with tidal problems in the Netherlands).

b. Application of each method to a sufficient variety of specific tidal waterways to permit evaluation of the advantages, disadvantages, and the degree of accuracy obtained by each.

c. Development of a new method for use in predicting tides and currents in tidal waterways if all of the existing methods were too complicated or laborious, or if none produced satisfactory results.

Work performed by Dr. Einstein on the first two phases of this investigation indicated that the method of characteristics is superior to the other two methods and will yield satisfactory answers to problems involving the prediction of tidal elevations, tidal phases, and mean current velocities in tidal waterways. This work also revealed that the method of characteristics is very laborious in actual problems and that electric analogs and high-speed computers may be used to advantage. Although the contractor submitted a final report on his studies, which may ultimately be a valuable addition to literature, it failed to achieve its primary objective, as the computations were not sufficiently well organized to permit comparisons of the three methods. Also, the computations were applied to different canals under each method; hence, no comparison of the three methods was possible. In addition, no effort was made to study a natural estuary. As a consequence, the report of the contractor was not published as a Committee document.

In 1959, a comparison of tidal computation by hydraulic model and by electronic computer using the tidal harmonic method was jointly sponsored by the Committee and by the Corps Hurricane Study Coordinating Committee. This comparison of tidal conditions involved studies of tides in Narragansett Bay and was made possible in connection with studies of hurricane barriers proposed for construction in the lower portions of this bay. The computer program part of this study was conducted at the Texas A&M University Research Foundation, College Station, Texas, and the hydraulic model tests were conducted at the Waterways Experiment Station. This comparison indicated that the two methods of

prediction give results that are in close agreement. A report on this study is contained in Committee Technical Bulletin 9, "A Comparison of an Estuary Tide Calculation by Hydraulic Model and Computer," by J. M. Caldwell, June 1965.

In further recognition of the need for procedures permitting the average coastal engineer to predict tides and currents in tidal waterways, the Committee in 1965 approved work under a contract with the Massachusetts Institute of Technology which had as its objective the development of methods of computing such tides and currents by the different procedures available in a readily understandable manner. Following a thorough review of the literature on tidal computations and the development of a method of classification of tidal problems, work was directed to the development and application of a general computer program for tidal computations of actual prototype estuaries. These programs considered the explicit scheme which seemed to be superior to both the implicit scheme and the method of characteristics. As a result, an explicit, finite difference method was developed. This method deals with the basic continuity and momentum equations and has the advantage of being able to treat both the simple and complex tidal problems within the same general framework. This method is outlined in Committee Technical Bulletin 16, "The Computation of Tides and Currents in Estuaries and Canals," by D. R. F. Harleman and Chok-hung Lee, September 1969. In 1971, Dr. Harleman was authorized to develop data supplementing this report to provide for comprehensive explanation of using the program outlined therein together with revision of the user manual which will be published separately.

ES 855, Mathematics of Flow in Tidal Channels

This research item was also proposed by the Committee in 1949 in recognition of the need for dependable methods for calculating flow patterns and current velocity distributions in tidal entrances. Work was initiated in 1950 by Drs. Garbis H. Keulegan and John L. French of the National Bureau of Standards. Work by Dr. French related to flow and velocity patterns developing from the ocean into an inlet as well as from an inlet into the ocean. Under Committee sponsorship, Dr. French's report on these studies was published as Committee Technical Bulletin 3, "Tidal Flow in Entrances," January 1960. Although Dr. Keulegan had made some concurrent studies of an analytical approach to the problem of defining changes in the water level of a basin connected to the ocean by a channel or channels, this approach, providing the means of predicting flows through entrances by use of simple techniques, was not perfected until considerably later. Dr. Keulegan's report on his studies was published as Committee Technical Bulletin 14, "Tidal Flow in Entrances - Water Level Fluctuations of Basins in Communication with Seas," July 1967.

ES 856, Shoaling Processes

At the time of its formation, the Committee found that a better understanding of the natural processes involved in the phenomenon of shoaling presented the likelihood of high dividends from the cost of research in the form of reduced channel maintenance expenditures. Although all of the investigative items sponsored by the Committee are related to this matter, it was decided that certain of the more important items should be carried forward to completion before a concerted investigation of shoaling processes was initiated. In 1957 the Committee recommended a program of additional studies considered necessary to develop essential knowledge of shoaling processes. The work planned or accomplished to date under the different subfeatures of the program is outlined in the following paragraphs.

Flume Studies of Muds. As most estuarine shoals in the Unites States are composed of muds rather

than sands, it was recommended that flume studies be made to establish the basic laws which govern the transportation and deposition of muddy sediments. Soon after this recommendation was made, a need for similar information developed in connection with prototype and model studies of the San Francisco Bay system. A contract was arranged between the San Francisco District and the University of California for a study, by means of tests in laboratory flumes, of the dynamic characteristics of various flows and suspensions which determine and influence sediment transport behavior and deposition in shoals. While the Committee did not actively support the work performed under this contract, Committee members gave advice and consultation to those in charge of its prosecution. Work under the contract involved study of San Francisco Bay sediments only; and on the basis of tests conducted, the following conclusions were reached:

a. Deposition of San Francisco Bay sediments occurs when the mean current velocity is reduced to about 0.6 fps.

b. A somewhat higher velocity is required to resuspend the deposited material.

c. There is little or no evidence of "bottom layer" movement of the sediment.

d. The viscous layer at the surface of the bed is resistant to scour, and scour of this layer is relatively slow.

e. The consolidation rate of the deposited material varies widely with concentration of the suspended matter.

A final report on the tests leading to the above conclusions was published by the University of California in June 1962, "Flume Studies of the Transport of Sediment in Estuarial Shoaling Processes."

Effects of Repetitive Scour and Deposition on Sedimentation. The Committee is of the opinion that successive scour and deposition of sediments may play an important role in shoaling processes, and therefore, flume studies to determine the significance of these factors should be made. However, due to the lack of funds which could be devoted to this research endeavor, the desired flume studies have not been made to date.

Techniques for Radioactive Tracing of Sediment Movement and Deposition. The Committee is also cognizant of the fact that radioactive tracing of sediment movement and deposition offers a great potential in the development of knowledge in shoaling processes. However, since its limited funds and time preclude active participation in such research, the Committee elected to keep informed of the work of others in this field, to encourage use of this technique in connection with specific investigations where it is applicable, and to offer such consultation and advice to those engaged in this work as may be required. The Committee worked closely with the San Francisco District and the University of California in connection with efforts of that District to develop suitable techniques and equipment for radioactive tracing of muddy sediment movements in the San Francisco Bay system. Pursuant to contracts by the District with the University of California, the University accomplished the research and published its findings in the following reports:

a. Report, dated 15 July 1960, "An Underwater Scintillation Detector for Gamma Emitters."

b. Final Report of October 1960, "Methods for Tracing Estuarial Sediment Transport Processes."

Concurrently with the final phases of the above work, the Committee recommended that the San Francisco District prepare a brief report describing the techniques and capabilities of this method for tracing the movement and deposition of sediments for the information of all Corps Division and District Offices. This action was approved and the report, which indicated that a nucleus of experts in the Corps had been trained to perform tracer studies for Districts, was published and distributed in April 1960

as "Radioactive Tracer Techniques as an Aid in Resolving Sedimentation Problems."

Later, in 1970, the Coastal Engineering Research Center developed techniques to trace the movements of sands in the nearshore ocean areas, using specially designed and equipped vessels capable of operating in the surf zone, as well as a monitoring drum dragged by these vessels over the ocean floor to detect the presence of radioactive sand.

Development of In-Place Turbidity Meter. The Committee believes that the development and use of a suitable in-place turbidity meter will greatly advance the understanding of shoaling processes. In view of the large areas involved in most estuaries, and the constantly changing conditions of tide and freshwater inflow, the Committee is of the opinion that complete and simultaneous coverage of such systems for measurements of suspended sediment concentrations, with only approximately accurate results, will yield more valuable information than will long-term coverage and highly accurate results. To accomplish such coverage, it is believed that direct-reading, in-place meters must be developed. Available evidence indicated that an instrument operating on the basis of light extinction as a measure of turbidity will fulfill this requirement. The Committee has learned that the Chesapeake Bay Institute of the Johns Hopkins University has developed and perfected an instrument of this type, and the Committee has elected to keep informed of and to encourage work of this nature without active Committee participation unless required.

Stabilization of Deposits. Early in its establishment, the Committee recognized that physical and chemical changes which occur in sediments after deposition are significant to an understanding of the subject of shoaling processes. A literature review to determine the state of knowledge of these changes was initiated under Committee sponsorship in 1958 by the Soils Division of the Waterways Experiment Station. This review revealed that salinity appears to be the most significant factor controlling the deposition of suspended sediments in tidal waterways. The results of this study were published in June 1960 as Committee Technical Bulletin 4, "Soil as a Factor in Shoaling Processes, a Literature Review."

In December 1960, the Waterways Experiment Station, acting for the Committee, entered into a contract with the University of California, providing for the University to study the rheological properties of consolidating sediments involving analyses of cation-exchange capacity, grain-size distribution, and X-ray diffraction. The results of this study were published in September 1963 in Committee Technical Bulletin 7, "A Study of Rheologic Properties of Estuarial Sediments," by Dr. R. B. Krone.

Flocculation. The Committee early recognized the fact that flocculation of suspended and dissolved solids plays an important role in shoaling processes, particularly as sea water is an efficient flocculating agent. Under Committee sponsorship, the Soils Division of the Waterways Experiment Station conducted a literature review on flocculation, in combination with that of stabilization of deposits described under the preceding research item, the results of which were also published in 1960 in Committee Technical Bulletin 4.

In consideration of the need for further research on the flocculation phenomenon, the Committee gave considerable study to the formulation of a research program designed to provide knowledge of the mechanics of flocculation, recognizing that a cautious probe into matter would undoubtedly be more productive than an ill-planned "all-out" effort. In 1963, the Chairman met with Dr. Krone of the University of California and interested Waterways Experiment Station personnel and developed a program providing for sampling of flocculated materials and velocity observations, study of the development of shoals and their characteristics, and laboratory analyses. Later, it was decided that this flocculation research program would be applied initially to the Savannah Estuary, followed by application to the Delaware Estuary.

Field work under the program, however, was delayed due to lack of funds until September 1963 when work was initiated in the Savannah Estuary. During the next year, the field program for the Delaware Estuary was initiated. At this writing, all field measurements on both estuaries have been furnished to Dr. Krone and it is expected that his report outlining his findings on the flocculation phenomenon will be published in 1972 as a Committee Technical Bulletin.

Analysis of Prototype Data. The Committee is of the opinion that proper analysis and correlation of existing prototype hydraulic and other data will reveal certain relationships between estuaries which should lead to a better understanding of the overall subject of shoaling processes. Consequently, the Committee in 1958 arranged for the Hydraulics Division of the Waterways Experiment Station to assemble and analyze all pertinent prototype data in their files on important estuaries. Following this, in 1963, selected field offices of the Corps of Engineers were asked to review and expand upon the data developed by the Waterways Experiment Station to the end that direct comparisons and correlations could be made for numerous estuaries. To date, considerable work has been accomplished with data from Savannah and Brunswick Estuaries and Grays Harbor; but the study is, as a whole, largely inactive at the present time, due to lack of funds and qualified personnel. The work, however, is being carried forward as time and funds permit, and it is probable that several years will be required to complete this study.

Classification of Sediments. The Committee believes that proper classification of the sediments which contribute to the shoaling of the different tidal waterways of the United States is of importance from the viewpoint of a comprehensive understanding of shoaling processes. This effort is being carried out concurrently with analysis and correlation of prototype data described above.

Sampling and Packaging of Estuarine Sediments. The Committee believes that the importance of the methods employed in the sampling and packaging of estuarine sediments, as related to the proper interpretation of the results of field sampling operations, should be investigated. In 1962, the Committee sponsored a program, undertaken by the Waterways Experiment Station, to survey and evaluate current methods and equipment for on-site testing. Coastal Corps of Engineers field offices were invited to provide information on methods and equipment employed. Analysis of replies received and visits to certain offices oriented the research program to a determination of the effect of highly controlled and careful sampling and packaging, as compared with a careless conduct of the sampling and packaging program. It was decided in 1967 to confine the research program initially to the Savannah Estuary where it could be conducted at minimum cost in connection with the investigation of the flocculation phenomenon. In cooperation with the Skidaway Institute of Oceanography, sediments of the Savannah Estuary were analyzed as part of this research program. Tentative conclusions reached to date indicate that the degree of care exercised in sampling and packaging of sediments makes no difference with respect to the percentage of dry solids, wet density, or grain-size distribution. This research program is continuing and it may be some time before it is completed.

Mechanics of Slip and Tributary Shoaling. The Committee in 1962 adopted a program of research of the Hydraulics Division of the Waterways Experiment Station designed to develop knowledge of the mechanics of slip and tributary shoaling. This program envisioned tests in the Hudson River hydraulic model as well as in the Delaware Estuary model. Although some tests were completed in 1964, the results have not been analyzed or published; and this research program is inactive at this time.

Correlative Investigations. Significant studies are made in Corps of Engineers field offices of various aspects of the shoaling phenomenon which substantially contribute o the field of knowledge in this matter. Examples of such are contained in Committee Technical Bulletin 8, "Channel Depth as a Factor

in Estuarine Sedimentation," by H. B. Simmons, dated March 1960; and Committee Technical Bulletin 10, "Significance of Clay Minerals in Shoaling Problems," by J. Neiheisel, dated September 1966.

ES 860, General Coastal Inlet Studies

As early as 1950, the Committee recognized the need for research in the complex field of inlet behavior. Studies since that date confirmed the pressing need for additional knowledge to solve inlet problems, and as the result of a Committee recommendation in 1962, a research program was funded beginning in Fiscal Year 1963.

Initial consideration of the research program indicated that the problem could be logically separated into two basic aspects, i.e., the hydraulic characteristics of the inlet complex and the dynamic changes in bed configuration associated with the inlet complex. Each of these two aspects was then further subdivided into two problem areas. The hydraulic characteristics aspect of the inlet complex was separated into (a) the definition of the hydraulic characteristics of the inlet proper and (b) the understanding of the interaction of the inlet (including multiple inlets) with the ocean approach and bay. The dynamic aspect of the study was separated into (c) the definition of the littoral transport approaching the inlet and (d) the movement of bed material within the area of influence of the inlet. Each of these four basic areas is being investigated by complementary use of field investigations, laboratory investigations, theoretical approaches, and empirical approaches.

The study of hydraulic characteristics of the inlet (a) includes the definition of the effects of the geometry and bed form of the inlet on the energy losses, flow, and wave patterns in the inlet. A significant portion of the study is being conducted in laboratory facilities constructed specifically for the investigation. Physical models are constructed in one of these facilities in accordance with typical geometries developed from analyses of prototype inlets. Prototype confirmation of the laboratory results will be obtained. The end results of these efforts will provide a basis for determination of the tidal flow through an inlet, and flow patterns as well as wave climates throughout the inlet. Each of these hydraulic characteristics will be defined for normal tide conditions as well as hurricane surge conditions. The model tests for this phase are conducted in Facility A, a 50- by 150-ft basin in which fixed-bed models of undistorted scale inlets are constructed.

The second part of the hydraulic characteristics aspect (b) of the study will be similar in approach with laboratory tests being conducted to augment field data. The main result of this effort will be the development of a basis for predicting the resulting normal tides and hurricane surge amplitudes within the lagoon resulting from flow through various single and multiple inlets generated by tidal and hurricane surge conditions in the ocean. This phase of the study will include necessary prototype confirmation. The model tests for this phase are conducted in Facility B, a 50- by 150-ft basin in which fixed-bed models of distorted scale inlets are constructed. This facility is equipped with a variable-size lagoon or embayment.

The dynamic aspect of the study is directed to concurrent investigations of (c) the distribution and rate of alongshore littoral transport of material approaching the inlet as a function of littoral current and wave climate and (d) the movement of material approaching and within the inlet as a function of inlet geometry, inlet hydraulics, and wave climate. Field data, simplified laboratory tests, and complex laboratory tests are the basic means utilized to resolve these problems. Major efforts in this portion of the study include the development of the relationship of laboratory movable-bed test results to prototype results and evaluation of the effects of model scales on various movable-bed materials. The

end result of this aspect of the study will be the definition of methods for predicting the material movements that can be expected in tidal inlets. The tests for this phase are conducted in Facility C, a 150- by 350-ft basin in which movable-bed models of distorted scale inlets are constructed.

The laboratory facilities required for the study were constructed during the period 1964-1966 and were used initially for studies of specific inlet problems at Galveston Bay, Jamaica Bay, and Moriches Inlet; however, full-time efforts in the facilities have been directed to the general investigation of tidal inlets since 1970.

Initially, it was visualized that this research program would require some 10 years for completion at the then anticipated rate of funding. However, the Coastal Engineering Research Board, in recognition of the urgent need for further knowledge of inlet behavior, recommended that the program be modified to provide for completion in five years. Accordingly, increased funding has been scheduled for the expedited program now visualized for completion in Fiscal Year 1974. Under the modified program, the different facilities are scheduled to be used for tests outlined below:

Program	Testing Scope
Inlet Dynamics	Effects of geometric variations for straight inlets, including gorges; effect of curvature, effect of entrance and exits; effect of artificial structures, and prototype confirmation with natural inlets and artificial structures.
Tidal Relationship and Fixed-Bed Correlation	Fixed-bed hydraulic correlation tests of Masonboro Inlet; tidal relationships, ocean to bay, for single inlets to the bay; tidal relationships, ocean to bay, for multiple inlets to the bay; prototype confirmation.
Inlet Dynamics and Movable-Bed Correlation	Specific study of Moriches Inlet; movable-bed correlation tests of Masonboro Inlet; basic inlet response with bypassing, without structures including prototype confirmation; basic inlet response with channel maintenance including prototype confirmation; basic inlet response with natural environment including prototype confirmation.
Scale Effects and Bed Materials	Basic inlet response to waves from a single direction; prediction tests, small model to large model; prediction tests, model to prototype.
Littoral Transport	Littoral drift for inlets with weir-type jetty and sand bypassing; littoral drift for inlet with jetties and no sand bypassing; littoral drift for inlet with channel maintenance only; littoral drift for natural inlet. These tests may be conducted in an existing facility at CERC.
Prototype	Data from prototype inlet with weir-type jetty and sand bypassing; data from prototype inlet with jetties and no sand bypassing; data from prototype inlet with channel maintenance only; data from natural prototype inlet.

APPENDIX D
PROJECTS ON WHICH THE COMMITTEE ON TIDAL HYDRAULICS HAS RENDERED CONSULTATIVE SERVICES

PROJECTS

(February 1949 to June 1971)

Project	Location in C of TH Minutes[1]	Letter Report Dated	Published Report Dated
Anchorage, Alaska, Small Boat Harbor			Apr 1964
Brazos River, Tex., Crossing of Intracoastal Waterway	57/24		
Brunswick Harbor, Ga.		Apr 1964[2]	
Calcasieu River, La.	45/8		
Charleston Harbor, S. C.		Feb 1965[3]	Jul 1961 Apr 1966
Charleston Harbor Navigation Study		Sep 1970[3]	
Charleston Naval Yard Shoaling		Sep 1970[3]	
Chatham (Stage) Harbor, Mass.			Dec 1963
Chesapeake Bay, Del. and Md., Proposed Model	53/18		
Chesapeake and Delaware Canal, Del. and Md.			Aug 1965
Chincoteague Inlet, Va.			Sep 1970
Colorado River, Tex.	62/8		Nov 1964
Columbia River, Oreg. and Wash.		Apr 1956[4]	Dec 1960
Corpus Christi, Tex., Turning Basin			Aug 1965
Cuttyhunk Harbor, Mass.		Apr 1964[5]	
Delaware River, N. J., Pa., and Del.			Jan 1964
Delaware Estuary—Long-Range Dredge Spoil Disposal Problem			May 1968
Dillingham Harbor, Alaska			Apr 1964
Dry Straits, Alaska	43/47		
Duwamish Waterway, Washington Proposed East Channel Closure			May 1967
East Pass, Choctawhatchee Bay, Fla.	45/5-7		
Echo Sounding Equipment versus Lead Line Soundings		Apr 1952[4]	
Ediz Hook, Wash.	72/29 e		
Galveston Bay Comprehensive Hurricane Protection—West Bay Secondary Protection	62/11		
Galveston Harbor, Tex.			Dec 1964
Gastineau Harbor, Alaska			Aug 1961 Dec 1962
Georgetown Harbor, S. C.			Aug 1961
Grays Harbor, Wash.	72/29 a		Jul 1963
Gulfport Harbor, Miss.		May 1960[4]	
Hillsboro Inlet, Fla.	50/12		
Homer Harbor, Alaska	43/21		
Hudson River, N. Y. and N. J.			Jul 1961

1 The numeral to the left of the virgule designates the meeting number, while the numeral to the right of the virgule designates the paragraph number in the minutes of that meeting containing the Committee views.
2 Available from U. S. Army Engineer District, Savannah, P. O. Box 889, Savannah, Ga. 31402.
3 Available from U. S. Army Engineer District, Charleston, P. O. Box 919, Charleston, S. C. 29402.
4 See Committee Technical Bulletin No. 12, Dec 1966.
5 Available from U. S. Army Engineer Division, New England, 424 Trapelo Road, Waltham, Mass. 02154.

PROJECTS (continued)

Project	Location in C of TH Minutes	Letter Report Dated	Published Report Dated
Hurricane Surge on Texas Coast and in Galveston Bay	62/13		
Interoceanic Sea-Level Canal Studies			Dec 1966
Intracoastal Waterway, Columbia River to Puget Sound, Wash.			Apr 1967
Jacksonville Harbor, Fla.	50/16		
James River, Va.	41/11		
Juneau-Douglas Harbor, Alaska	43/9		
Knik Arm Causeway, Alaska			Jan 1963
Lake Washington Ship Canal, Wash.		Jan 1960[6]	Jan 1963
Lake Washington Ship Canal—Saltwater Barrier	72/29 d		
Matagorda Ship Channel, Tex.		Nov 1958[4] Dec 1958[4]	
Mississippi River-Gulf Outlet La.			Oct 1965
Mississippi River Passes, La.		Apr 1957[4]	
Morro Bay, Calif.	65/25 b		
Narragansett Bay, R. I.		Oct 1963[5]	
Ninilchik Harbor, Alaska			Apr 1964
Nuclear Excavation of Sea Level Canal	53/14		
Oregon Inlet, N. C.		Jul 1959[4]	
Passamaquoddy Tidal Power Project, Maine	32/35	Dec 1958[4]	
Ponce de Leon Inlet, Fla.			Oct 1964
Quillayute Spit, Wash.	72/29 b		
Raritan River, N. J.	7/5		
Rogue River, Oreg.			Mar 1970
Sabine Lake, La., Spoil Disposal	62/16		
Sacramento—San Joaquin Delta, Calif.	53/33		
St. Lucie Estuary, Fla.	45/13		
San Diego Harbor, Calif.	65/25 a		
San Francisco Bay, Calif.			Dec 1965
Savannah Harbor, Ga.		Apr 1958[4]	
Seldovia Harbor, Alaska	43/22		
Tillamook Bay, Oreg.	44/44	Jun 1971[7]	Jan 1970
Turnagain Arm Causeway, Alaska			Jan 1963
Umpqua River, Oreg.	44/43		
Wells Harbor, Maine			Feb 1964
Willapa Harbor, Wash.			Jun 1967
Wilmington Harbor, N. C.	37/45		
Wilmington Harbor, Del.	46/30		
Wrangell Narrows, Alaska	43/8		

[4] See Committee Technical Bulletin No. 12, Dec 1966.
[5] Available from U. S. Army Engineer Division, New England, 424 Trapelo Road, Waltham, Mass. 02154.
[6] Available from U. S. Army Engineer District, Seattle, 1519 Alaskan Way, South, Seattle, Wash. 98134.
[7] Available from U. S. Army Engineer District, Portland, P. O. Box 2946, Portland, Oreg. 97208.

APPENDIX E

PUBLICATIONS OF THE CORPS OF ENGINEERS COMMITTEE ON TIDAL HYDRAULICS

Committee Reports

No. 1 – Evaluation of Present State of Knowledge of Factors Affecting Tidal Hydraulics and Related Phenomena – February 1950[1]

No. 2 – Bibliography on Tidal Hydraulics – February 1954[1]

Supplement No. 1 – June 1955[1]

Supplement No. 2 – May 1957[1]

Supplement No. 3 – May 1959

Supplement No. 4 – May 1965

Supplement No. 5 – August 1968

Supplement No. 6 – July 1971

No. 3 – Evaluation of Present State of Knowledge of Factors Affecting Tidal Hydraulics and Related Phenomena (Revision of Report No. 1) – May 1965

Committee Technical Bulletins

No. 1 – Sediment Discharge Measurements in Tidal Waterways, by C. F. Wicker – May 1954[1]

No. 2 – Fresh Water-Salt Water Density Currents, a Major Cause of Siltation in Estuaries, by E. A. Schultz and H. B. Simmons – April 1957[1]

No. 3 – Tidal Flow in Entrances, by John L. French – January 1960[1]

No. 4 – Soil as a Factor in Shoaling Processes, a Literature Review – June 1960

No. 5 – One-Dimensional Analysis of Salinity Intrusion in Estuaries, by Drs. A. T. Ippen and Donald R. F. Harleman – June 1961[1]

No. 6 – Typical Major Tidal Hydraulic Problems in United States and Research Sponsored by the Corps of Engineers Committee on Tidal Hydraulics – June 1963[1]

No. 7 – A Study of Rheologic Properties of Estuarial Sediments, by Dr. R. B. Krone – September 1963

No. 8 – Channel Depth as a Factor in Estuarine Sedimentation, by H. B. Simmons – March 1965

No. 9 – A Comparison of an Estuary Tide Calculation by Hydraulic Model and Computer, by J. M. Caldwell – June 1965

No. 10 – Significance of Clay Minerals in Shoaling Problems, by J. Neiheisel – September 1966

No. 11 – Extracts from the Manual of Tides, by R. A. Harris, edited by C. F. Wicker – September 1966

No. 12 – Unpublished Consultation Reports on Corps of Engineers Tidal Projects – December 1966

No. 13 – Two-Dimensional Aspects of Salinity Intrusion in Estuaries: Analysis of Salinity and Velocity Distributions, by Drs. D. R. F. Harleman and A. T. Ippen – June 1967

No. 14 – Tidal Flow in Entrances; Water-Level Fluctuations of Basins in Communication with Seas, by G. H. Keulegan – July 1967

No. 15 – Special Analytic Study of Methods for Estuarine Water Resources Planning – March 1969

No. 16 – The Computation of Tides and Currents in Estuaries and Canals, by D. R. F. Harleman and C. H. Lee – September 1969

No. 17 – Estuarine Navigation Projects – January 1971

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[1] Out of print.

Committee Reports on Special Tidal Hydraulics Problems

December 1960 – Present and Potential Channel Maintenance Problems in Lower Columbia Estuary
July 1961 – Review of Shoaling Problems in Hudson River, New York Harbor
July 1961 – Charleston Harbor Shoaling Problem[1]
August 1961 – Georgetown Harbor Shoaling Problem
August 1961 – Shoaling of Gastineau Channel, Alaska
December 1962 – Navigation Project in Gastineau Channel, Alaska
January 1963 – Saltwater Intrusion, Lake Washington Ship Canal, Seattle, Washington[1]
January 1963 – Improvement Plans for Knik Arms and Turnagain Arm, Portions of Cook Inlet, Alaska
April 1963 – Saltwater Intrusion, Lake Washington Ship Canal, Seattle, Washington (Revised)
July 1963 – Review of Improvements Recommended at Grays Harbor, Washington
December 1963 – Channel Maintenance Problem, Chatham (Stage) Harbor, Massachusetts[1]
January 1964 – Comments on Plan for Comprehensive Study of the Delaware Estuary, Pennsylvania, New Jersey and Delaware
February 1964 – Wells Harbor Navigation Project, Wells Harbor, Maine
April 1964 – Plan of Study and Methods for Reducing Shoaling in Small Boat Basin, Dillingham, Alaska
April 1964 – Plan of Study of the Small Boat Basin, Ninilchik, Alaska
April 1964 – Proposed Plan and Studies for Small Boat Basin, Anchorage, Alaska
October 1964 – Shoaling and Beach Stability Problem, Ponce de Leon Inlet, Florida
November 1964 – Tie Channel in the Mouth of the Colorado River, Texas
December 1964 – Channel Deepening Problems, Galveston Harbor, Texas
December 1964 – Problems in Connection with Matagorda Ship Channel Project
August 1965 – Inland Waterway Between Delaware River and Chesapeake Bay — Problem of Disposal of Material to be Removed from Section of Channel in Chesapeake Bay[1]
August 1965 – Sedimentation Problems in Entrance of Turning Basin, Corpus Christi, Texas
October 1965 – Shoaling Problems on the Mississippi River — Gulf Outlet
December 1965 – San Francisco Bay, California — Disposal of Dredge Spoil[1]
April 1966 – Charleston Harbor, South Carolina — A Review of Certain Aspects of Plans for Rediverting Santee-Cooper Power Plant Discharges from Cooper River
December 1966 – Tides and Currents in the Proposed Sea-Level Canal Between the Atlantic and Pacific Oceans
April 1967 – Intracoastal Waterway, Columbia River to Puget Sound, Washington
May 1967 – Duwamish River, Washington, Proposed East Channel Closure
June 1967 Willapa Bay, Washington[1]
June 1967 – Grays Harbor, Washington
May 1968 – Delaware Estuary, Pennsylvania, New Jersey and Delaware — Long-Range Dredged Spoil Disposal Problem
January 1970 – Tillamook Bay, Oregon
March 1970 – Rogue River, Oregon
September 1970 – Navigation Problems at Chincoteague Inlet, Virginia

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[1] Out of print.

Although, as indicated, some publications may be out of print, copies of available publications listed above may be secured by writing to:

The Recorder
Committee on Tidal Hydraulics
c/o U. S. Army Engineer Waterways Experiment Station
Corps of Engineers
P. O. Box 631
Vicksburg, Mississippi 39180

APPENDIX F
SPECIAL MISSIONS OF THE COMMITTEE

Echo Sounding Equipment Versus Lead-Line Soundings

In response to a request of the Chief of Engineers, the Committee at its 12th Meeting in March 1952 gave consideration to the differences in soundings obtained by high-speed echo sounding equipment as compared with those obtained by the traditional lead-line procedures, with particular reference to the use of these two expedients in waterways having a "fluff" line several feet above the consolidated bottom. The views and recommendations of the Committee in this matter were reported in a letter from the Chairman to the Chief of Engineers, dated 22 April 1952, subject "Echo Sounding Equipment Versus Lead-Line Soundings," which is printed in full in Committee Technical Bulletin 12, "Unpublished Consultation Reports on Corps of Engineers Tidal Projects," dated December 1966.

Engineer Manual Chapter on Tidal Hydraulics

The Corps of Engineers in the prosecution of its civil works mission is confronted with many aspects of tidal hydraulics problems such as (a) design and layout of tidewater channels, anchorages, and harbors, (b) analysis of maintenance problems, (c) design and layout of training works, (d) analysis of salinity intrusion problems as they affect water quality, and (e) analysis of diffusion and flushing of pollutants as these factors affect water quality. The Corps, as part of its official civil works engineering and design program, issues to its field offices an Engineer Manual as guidance in the development of this program. The Committee, as a Corps element, has the responsibility of providing technical guidance to Corps offices on the above aspects in the field of tidal hydraulics. In fulfillment of that responsibility, the Committee developed the guidelines contained in and prepared the EM Chapter on Tidal Hydraulics, EM 1110-2-1607, dated January 1953. This chapter was completely revised by the Committee to incorporate new knowledge gained in the 2 August 1965 issue of this publication. This EM Chapter outlines the factors involved in tidal hydraulics problems; outlines the state of knowledge in this field; outlines procedures for channel and harbor design, as well as control works; discusses observational procedures, hydraulic and electric analog models; and explores problems associated with tidal waterway maintenance practices.

Sediment Discharge Measurements in Tidal Waterways

Although procedures were well established for obtaining sediment discharge measurements in waterways having a sensibly constant discharge, unidirectional flow, and homogeneous water density, the Committee early in its existence recognized that use of these procedures in salt or brackish water presented problems due to corrosion of measuring instruments and other factors. A full discussion of these problems with Committee conclusions thereon is contained in Committee Technical Bulletin 1, "Sediment Discharge Measurements in Tidal Waterways," by C. F. Wicker, Chairman, dated May 1954.

Revision of General Pillsbury's Publication on Tidal Hydraulics

In early 1955, the Chief of Engineers furnished the Committee documents, papers, notes, etc., that had been assembled and compiled by the late Brigadier General George B. Pillsbury for revision of his book, "Tidal Hydraulics," with the request that the Committee give its views as to whether the revised edition should be completed and published by the Corps of Engineers. The Committee, following review of these papers considered the revised edition to be of value to the Corps. Prior to its publication, the manuscript was subject to editorial review by members of the Committee, as well as by Dr. Garbis H. Keulegan of the National Bureau of Standards, for the purpose of completing any parts of the text

or figures that had been left partially incomplete by the death of General Pillsbury. The intent of the reviewers was to preserve the original wording insofar as possible. the changes were few in number and minor in nature. General Pillsbury's revised edition, "Tidal Hydraulics," was published in May 1956 under the auspices of the Chief of Engineers, U. S. Army.

Fresh Water-Salt Water Density Currents, a Major Cause of Siltation in Estuaries

At the XIXth International Navigation Congress held in London in July 1957, Messrs. E. A. Schultz and H. B. Simmons of the Committee presented a paper which (a) described the character, movement, and deposition of sediments, and the sources of shoaling materials in tidal waterways, (b) illustrated the role of upland discharge in establishing estuary mixing type, described a simplified method for determining the most significant hydraulic characteristic of estuaries, and demonstrated the effects of changing the upland discharge into estuaries on their hydraulic characteristics, (c) cited specific examples of estuaries, rivers, and harbors where the fresh water-salt water density currents are present in some degree, and in some cases are the major cause of siltation, and (d) described remedial measures undertaken, proposed, or being considered by various agencies of the U. S. Army Corps of Engineers. In consideration of the excellence of this paper and with the concurrence of the American Section, Permanent International Association of Navigation Congresses, this paper was published as Committee Technical Bulletin 2, "Fresh Water-Salt Water Density Currents, a Major Cause of Siltation in Estuaries," by E. A. Schultz and H. B. Simmons, Members, Committee on Tidal Hydraulics, April 1957.

Special Report on Tidal Hydraulics Problems and Research

In March 1962, the Committee presented a special report to the Chief of Engineers on tidal hydraulics problems and research. This report consisted of presentations by a number of Committee members which summarized the typical major tidal hydraulics problems throughout the United States encountered by the Corps of Engineers, together with a discussion of research activities sponsored by the Committee to develop engineering solutions to these problems. Although these problems, by their very nature, are usually extremely complex, considerable progress had been made in the prior 15 years in understanding the mechanisms responsible for the shoaling and flushing characteristics of estuaries. In spite of that progress, however much remains to be learned regarding the interrelation of the several phenomena controlling the estuarine regime. Research sponsored by the Committee has been directed to that end with the view of providing new tools of understanding to those charged with tasks of developing and maintaining estuarine waterways. With such new tools, large savings in the costs of estuarine improvements may be realized. A review of these presentations is contained in Committee Technical Bulletin 6, "Typical Major Tidal Hydraulic Problems in United States and Research Sponsored by the Corps of Engineers Committee on Tidal Hydraulics," dated June 1963.

Sump Rehandling Technique

During maintenance dredging operations on the Delaware Estuary project, engineers in charge were cognizant of the fact that the quantities of material dredged often exceeded the amount of material brought into the estuary from upland sources. This led to the conclusion that as the result of the then approved practice of disposing dredge spoil into the estuarine waters, much of the maintenance dredging constituted in effect redredging of the same material. Using sump rehandler facilities developed by the Philadelphia District, maintenance dredging operations were modified to dispose all dredging onshore

where it was prevented from reentering the system. This practice, which was monitored by the Committee, resulted in the achievement of greater depths with lesser maintenance dredging requirements. A full report on this practice, as well as a modified practice permitting direct pump-out to shore, is contained in a report presented by the Chairman, Mr. C. F. Wicker, at the XXI Congress of the Permanent International Association of Navigation Congresses in Stockholm in June 1965.

Harris Manual of Tides

The "Manual of Tides," by Dr Roland A. Harris, has been considered by students of tidal phenomena as an extraordinary contribution to the fund of knowledge in that domain of science. The Dictionary of American Biography (American Council of Learned Societies) describes the Manual as "...the most exhaustive treatise on the subject to the present time (1931)." It was originally published as parts of series of appendixes to the Annual Report of the Superintendent of the U. S. Coast and Geodetic Survey for Fiscal Years 1894, 1897, 1900, 1904, and 1907 but had never been republished in one binding. The Annual Reports, including the appendixes, are published in quarto size and each contains nearly 1000 pages. All of these reports are out of print. Thus, the Manual was hidden in its intimate association with the official records of the Coast and Geodetic Survey, and it therefore did not receive the attention it deserved from other scholars, particularly those who were delving into the different aspects of tidal hydraulics. Despite inherent difficulties involved in perusal of the Manual due to its sheer volume, a number of members of the Committee on Tidal Hydraulics were aware of the fact that it contained much information of value to the mission of the Committee. Following careful review of the complete Manual, certain of its chapters were selected on the basis that their content is of historic or current interest to the Committee. It was decided that with the approval of the Coast and Geodetic Survey these chapters would be republished in one binding. Such approval was graciously given and these particular chapters were published as Committee Technical Bulletin 11, "Extracts from the Manual of Tides," by R. A. Harris, dated September 1966.

Unpublished Consultation Reports on Corps of Engineers Tidal Projects

One of the functions of the Committee consists of rendering consulting service on specific problems in tidal waterways as may be requested by different organizations of the Corps of Engineers. This service has been extensively utilized by District and Division Engineers in connection with a wide variety of problems, and the results have been recorded in the minutes of Committee meetings or in letters or formal reports to the requesting office. While a few of the problems considered by the Committee are unique, most have elements of general interest. However, the discussions in the minutes and those in the letter-type reports are not readily available for review when the projects concerned are the subjects of further consideration, or in cases where similar problems arise concerning other projects. For this reason, it was believed desirable by the Committee to index the minutes by projects and to reproduce the more significant letter-type reports. This information is contained in Committee Technical Bulletin 12, "Unpublished Consultation Reports on Corps of Engineers Tidal Projects," dated December 1966.

Special Analytic Study of Methods for Estuarine Water Resources Planning

Pursuant to a request of the Bureau of the Budget, the Secretary of the Army in September 1968 requested the Chief of Engineers to initiate a special analytic study to (a) develop the methodology for the comparison of alternative study methods for complete investigation and study of water utilization

and control in estuaries, (b) consider the appropriate role of the various Federal agencies in a complete investigation and study of water utilization and control in estuaries, and (c) determine the appropriate sharing of costs of complete investigations and study of water utilization and control in estuaries between the Federal Government and other non-Federal entities. A steering committee, consisting of Messrs. McAleer, Douma, Tiffany, and Caldwell, was appointed by the Chief of Engineers to guide the effort. The steering committee determined that the study should include a methodology for comparison of alternative study methods for complete investigation of estuaries, including (1) hydraulic models, (2) computer models, and (3) more conventional methods of analysis. Rather than attempt a definitive comparison, the purpose of the study would be to establish useful guidelines for the Bureau of the Budget and others to evaluate future project submissions as to which alternative study methods would be most appropriate for a specific estuary, considering the relative importance of the various problems to be investigated. Subsequently, the steering committee requested that the Committee on Tidal Hydraulics submit a report giving its views on hydraulic models, computer models, and the more conventional methods of analysis to form a part of the response to item (a) of the Bureau of the Budget's request. The views of the Committee in these matters are contained in Committee Technical Bulletin 15, "Special Analytic Study of Methods for Estuarine Water Resources Planning," dated March 1969.

Loose-Leaf Publication on District Problems

The Committee in 1963, in coordination with a Corps-wide proposal of the Chief of Engineers, believed it desirable that it undertake a publication containing an assembly of available information on selected navigation projects in tidal waterways such as inlets, bays, tidal rivers, and canals. It was believed that the information thus presented would be of value in the planning, design, and maintenance of projects in waterways having similar characteristics. When similarity is established between the waterway and the channel involved in the project under consideration and one or more of the projects described in the publication, the experienced problems and the solutions for these projects may be of help in avoiding similar problems or in solving existing problems. Based on analysis of information provided by Corps field offices, the Committee issued such data on selected projects in Committee Technical Bulletin 17, "Estuarine Navigation Projects," dated January 1971.

Inventory and Central Storage of Estuarine Measurement Equipment

The Corps of Engineers has procured and used throughout the United States much equipment designed especially to measure estuarine physical properties, such as sediments, salinity, velocity, and tidal variations. This equipment is highly sophisticated and easily damaged. In 1962, the Committee initially conceived the idea of conducting an inventory of all such equipment in the hands of different offices of the Corps with the view to storing and servicing the equipment at the Waterways Experiment Station and making distribution from the Waterways Experiment Station to the different offices as needed. This idea was approved by the Chief of Engineers, subject to modification as recommended by the Director, Waterways Experiment Station, to retain all such equipment except the most specialized items in the district offices, with all interested offices notified of the nature and location of the equipment available. A listing of specific details regarding this equipment has been developed and is now being reviewed and updated by the field offices. It is possible that the updated listing will be published as a Committee Technical Bulletin in the near future.

Program Document

Beginning in 1964, the Committee developed for its internal use a Program Document designed to assist the Committee in fulfilling some of its responsibilities—annual review of existing and proposed programs of research, studies, and investigations for which the Committee has been assigned technical supervision, and the development of recommendations to the Chief of Engineers as to the type, scope, and funding of these studies and investigations. In doing so, the Program Document discusses in detail each of the areas of research and subjects outlined on pages 13 and 14 of this history and contains concise statements describing (a) problems and their significance, (b) information available and required, (c) means to satisfy deficiencies, (d) action under way and proposed, and (e) status of these endeavors. The Program Document is continually revised to reflect current research needs and thus serves as a living guide to Committee members and consultants.

APPENDIX G

EXPENDITURES BY CORPS OF ENGINEERS COMMITTEE ON TIDAL HYDRAULICS

Expenditures

Fiscal Year	ES 816 Meetings	ES 816 Reproduction and Distribution of Reports	ES 816 Consultants	ES 823 Effects of Adjacent Beaches on Tidal Inlets	ES 843 Salinity Intrusion and Related Phenomena
1949	$ 4,705				
1950	10,000				
1951	4,344	$ 200	$ 1,617		$ 13,000
1952	4,589	1,001	2,089		13,664
1953	6,973	515	3,109		25,585
1954[1]	7,000	5,000	5,000		26,000
1955	7,622	1,158	2,023	$ 5,096	19,761
1956	7,136	578	1,924	2,500	13,675
1957	8,420	2,285	3,401	7,500	12,548
1958	6,076	1,443	2,162	1,234	14,786
1959	8,196	3,515	2,575	4,983	12,684
1960	6,153	1,917	2,829	1,172	13,880
1961	11,766	2,263	3,932		2,391
1962	17,474	1,061	3,940	6,171	9,347
1963	11,832	1,945	7,551	3,316	6,485
1964	11,830	2,257	12,211	5,385	6,076
1965	10,665	18,472	12,934	8,042	6,155
1966	8,902	2,853	25,899	7,987	5,001
1967	8,343	11,450	21,523		20,548
1968	5,652	3,775	7,162		14,290
1969	9,110	5,921	12,239		20,242
1970	17,074	4,683	12,779		23,985
1971[1]	8,245	16,889	16,375		19,980
TOTALS	$202,107	$89,179	$163,274	$53,386	$300,083
Percent	14.2	6.3	11.5	3.8	21.1

[1] Approximate figures only.

Expenditures (continued)

ES 844 Existing Data-Tidal Entrances	ES 845 Tides and Currents in Tidal Waterways	ES 855 Mathematics of Flow in Tidal Entrances	ES 856 Shoaling Processes	ES 860 General Coastal Inlet Studies	Miscellaneous Studies[1]	Total Annual Expenditures
						$ 4,705
					$ 5,370	15,370
$ 516	$ 1,339	$1,940			1,148	24,104
	1,021				11,693	34,057
	6,828					43,010
	2,000					45,000
3,000	2,000					40,660
2,783	2,000					30,596
6,139	4,223					44,516
4,224	4,412		$ 2,000			36,337
2,102	3,592		4,866			42,513
688		943	3,596			31,178
72	2,150		1,529			24,103
			4,101			42,094
			13,418	$ 1,629		46,174
			9,919	23,371		71,049
			3,052	45,433		104,753
			540	35,000		86,182
			537	40,000		102,401
			6,331	60,000		97,210
			30,736	60,000		138,248
			10,924	65,000		134,445
			946	120,000		182,435
$19,524	$29,565	$2,883	$92,495	$450,433	$18,211	$1,421,140
1.4	2.1	0.2	6.5	31.6	1.3	100.0

[1] Includes work on Engineer Manual Chapter on Tidal Hydraulics, Current Observations, and Echo Sounding Equipment versus Lead-Line Soundings.

APPENDIX H
GROUP PHOTOGRAPHS OF COMMITTEE

Shown on the following pages are selected group photographs of the Committee on Tidal Hydraulics and its guests taken during the meetings listed below:

a. 4th Meeting, Philadelphia, Pennsylvania, 14-16 September 1949
b. 21st Meeting, Vicksburg, Mississippi, 25-27 January 1955
c. 37th Meeting, Portland, Oregon, 25-28 October 1960
d. 40th Meeting, Vicksburg, Mississippi, 28-30 November 1961
e. 43rd Meeting, Anchorage, Alaska, 4-8 June 1962
f. 71st Meeting, Washington, D. C., 9-11 March 1971

COMMITTEE ON TIDAL HYDRAULICS
Fourth Meeting
Philadelphia, Pennsylvania 14-16 September 1949

Left to right: Mr. Berkeley Blackman, South Atlantic Division; Mr. Martin A. Mason, Beach Erosion Board; Dr. Boris A. Bakhmeteff, Consultant; Mr. James R. Johnston, North Atlantic Division; Mr. Richard O. Eaton, South Pacific Division; Mr. Jacob H. Douma, Office, Chief of Engineers; Mr. Clarence F. Wicker, Philadelphia District, Chairman; Mr. Ralph F. Rhodes, Savannah District; Mr. Joseph B. Tiffany, Waterways Experiment Station, Recorder; Dr. Lorenz G. Straub, Consultant; Mr. Oscar Rosenzweig, Philadelphia District.

COMMITTEE ON TIDAL HYDRAULICS
21st Meeting
Vicksburg, Mississippi 25-27 January 1955

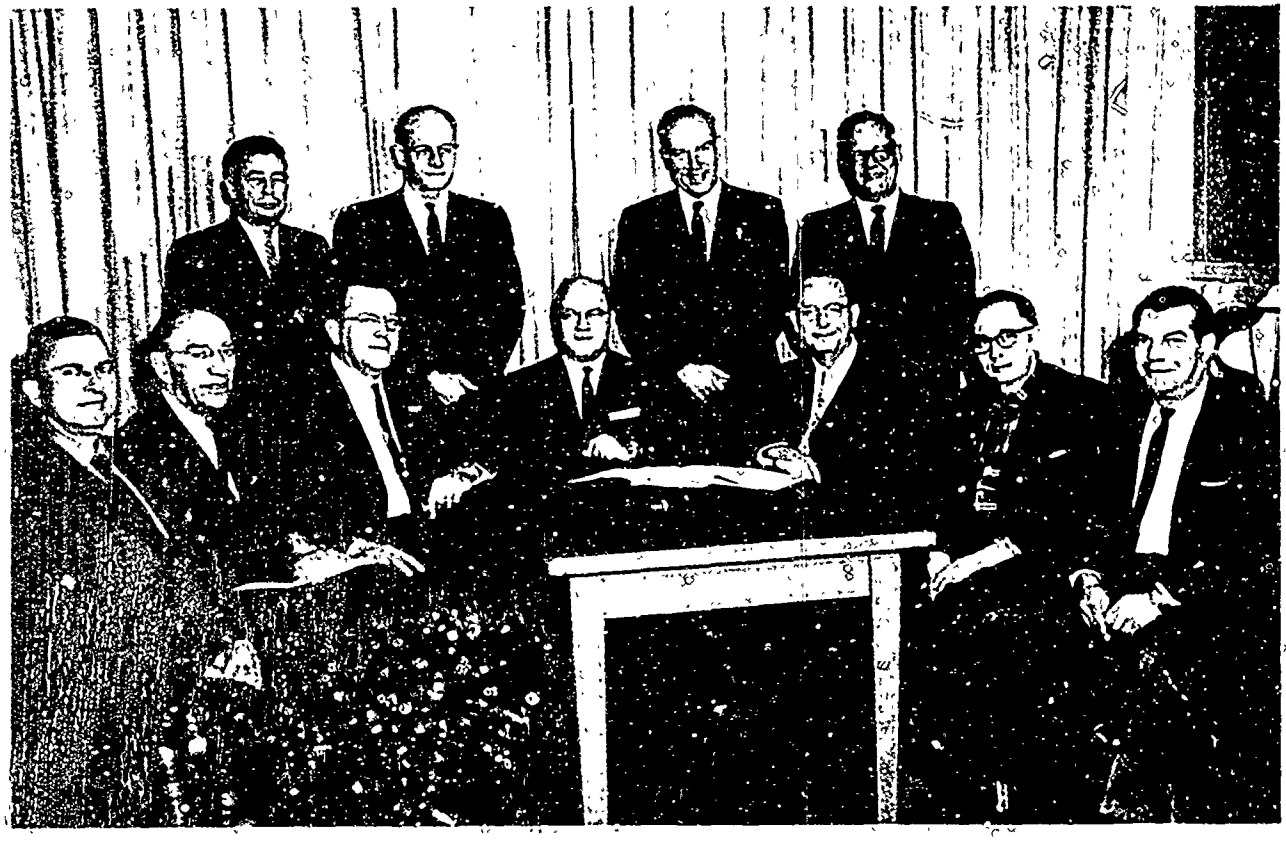
First Row, left to right: Mr. E. A. Schultz, Charleston District; Mr. H. W. Feldt, Southwestern Division; Mr. J. B. Tiffany, Waterways Experiment Station, Recorder; Mr. J. R. Johnston, North Atlantic Division; Mr. C. F. Wicker, Philadelphia District, Chairman; Mr. J. C. Marcroft, South Pacific Division; Mr. J. M. Caldwell, Beach Erosion Board; Mr. H. B. Simmons, Waterways Experiment Station. Second Row: Dr. A. T. Ippen, Massachusetts Institute of Technology; Dr. G. H. Keulegan, National Bureau of Standards; Dr. L. G. Straub, St. Anthony Falls Hydraulic Laboratory; Dr. M. A. Mason, George Washington University; Mr. L. P. Disney, U. S. Coast & Geodetic Survey; Mr. J. H. Douma, Office, Chief of Engineers. Back Row: Mr. E. P. Fortson, Sr., Waterways Experiment Station; Mr. P. A. Becnel, Jr., New Orleans District; Mr. G. B. Fenwick, Waterways Experiment Station; Mr. C. C. Bates, U. S. Navy Hydrographic Office; COL C. H. Dunn, Waterways Experiment Station; Mr. F. B. Toffaleti, Mississippi River Commission; CPT H. E. Finnegan, U. S. Coast and Geodetic Survey.

COMMITTEE ON TIDAL HYDRAULICS
37th Meeting
Portland, Oregon 25-28 October 1960

Left to right: Dr. L. G. Straub, University of Minnesota; Mr. J. B. Tiffany, Waterways Experiment Station; Dr. Donald Pritchard, Johns Hopkins University; Dr. Arthur T. Ippen, Massachusetts Institute of Technology; Mr. Joseph M. Caldwell, Beach Erosion Board; Mr. John Marcroft, South Pacific Division; Mr. James R. Johnston, North Atlantic Division; Mr. John B. Lockett, North Pacific Division; Mr. Richard O. Eaton, Beach Erosion Board; Mr. C. F. Wicker, Chairman, Philadelphia District; Mr. Henry B. Simmons, Recorder, Waterways Experiment Station; Mr. Robert Hickson, former member, formerly Portland District; Mr. J. H. Douma, Office, Chief of Engineers; Mr. Edward G. Schultz, San Francisco District.

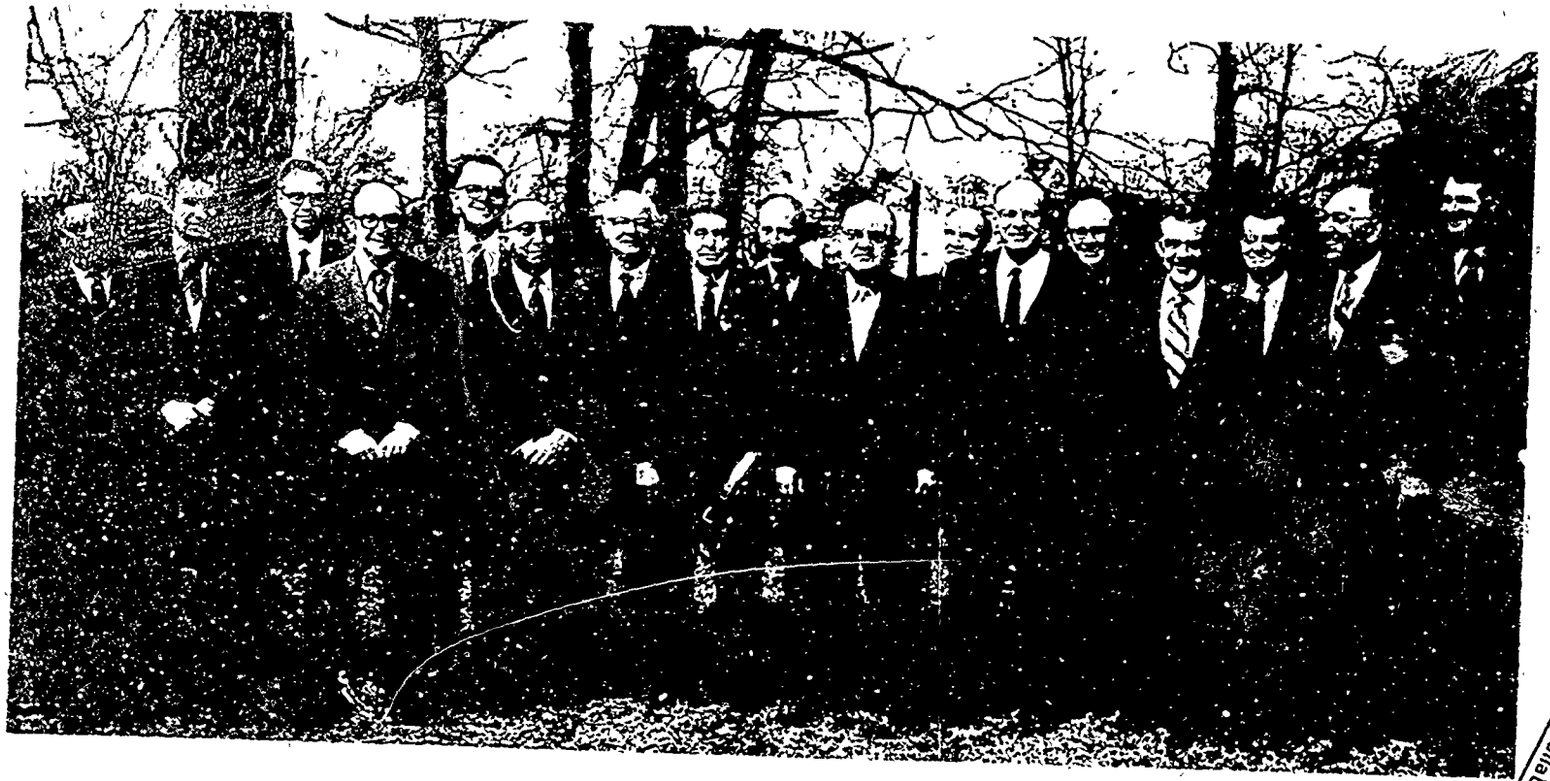
COMMITTEE ON TIDAL HYDRAULICS
40th Meeting
Vicksburg, Mississippi 28-30 November 1961

First Row, left to right: Mr. C. F. Wicker, Philadelphia District, Chairman; Mr. J. M. Caldwell, Beach Erosion Board; Mr. R. O. Eaton, Beach Erosion Board; Mr. J. R. Johnston, North Atlantic Division; Mr. E. A. Schultz, San Francisco District; Mr. J. B. Lockett, North Pacific Division; Mr. C. P. Lindner, South Atlantic Division; Mr. H. B. Simmons, Waterways Experiment Station, Recorder; Mr. J. B. Tiffany, Waterways Experiment Station. Second Row: Dr. D. W. Pritchard, Johns Hopkins University; Mr. J. H. Douma, Office, Chief of Engineers; Mr. L. Reid, New England Division; Mr. E. B. Madden, Southwestern Division; Mr. G. A. Makela, Southwestern Division; Mr. F. B. Toffaleti, Lower Mississippi Valley Division; Mr. G. A. Price, New Orleans District; Mr. T. H. Buhler, New Orleans District. Third Row: Mr. A. W. Carlson, Savannah District; Mr. E. G. Long, Wilmington District; Mr. E. A. Weiser, Galveston District; Mr. A. B. Davis, Galveston District; Mr. S. B. Powell, Portland District; Mr. I. H. Steinberg, San Francisco District; Mr. J. K. Searcy, Bureau of Public Roads. Back Row: Mr. W. E. Dvorachek, Office, Chief of Engineers; Mr. D. A. Burns, U. S. Navy Hydrographic Office.



COMMITTEE ON TIDAL HYDRAULICS
43rd Meeting
Anchorage, Alaska 4-8 June 1962

Left to Right: Mr. J. R. Johnston, North Atlantic Division; Mr. C. F. Wicker, Consulting Engineer, Philadelphia; Mr. E. B. Conner, Office, Chief of Engineers; Mr. H. B. Simmons, Waterways Experiment Station, Recorder; Mr. J. H. Douma, Office, Chief of Engineers; Mr. J. B. Tiffany, Waterways Experiment Station, Chairman; Mr. J. M. Caldwell, Beach Erosion Board; Mr. R. O. Eaton, Beach Erosion Board; Mr. J. C. Marcroft, South Pacific Division; Mr. C. P. Lindner, South Atlantic Division; Mr. E. A. Schultz, San Francisco District.



COMMITTEE ON TIDAL HYDRAULICS
71st Meeting
Washington, D. C. 9-11 March 1971

Left to Right: Mr. P. A. Becnel, New Orleans District; Mr. D. F. Hogan, Seattle District; Mr. T. Saville, Jr., Coastal Engineering Research Center; Mr. J. W. Harris, Savannah District; Mr. H. B. Simmons, Waterways Experiment Station; Mr. A. B. Davis, Galveston District; Dr. A. T. Ippen, Massachusetts Institute of Technology; Mr. E. B. Conner, Office, Chief of Engineers; Mr. J. B. McAleer, Office, Chief of Engineers; Mr. J. B. Tiffany, Chairman-Consultant; Mr. J. F. Phillips, Philadelphia District; Mr. J. H. Douma, Office, Chief of Engineers; Dr. D. W. Pritchard, Johns Hopkins University; Mr. J. B. Lockett, Recorder-Consultant; Mr. E. A. Schultz, San Francisco District; Mr. C. F. Wicker, Consulting Engineer, Philadelphia; Mr. F. A. Herrmann, Waterways Experiment Station.