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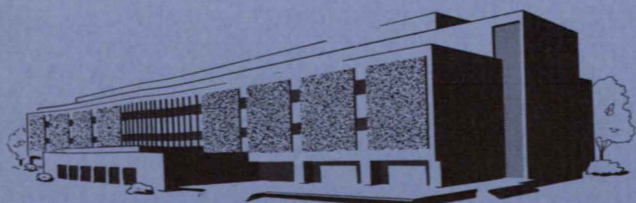
DELAWARE BAY REPORT SERIES

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Volume 1 **Series Summary** **Inventory and Evaluation of Information**



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DELAWARE BAY REPORT SERIES

Volume 1

SERIES SUMMARY

INVENTORY AND EVALUATION OF INFORMATION ON DELAWARE BAY

This series was prepared under a grant from the
National Geographic Society

Report Series Editor
Dennis F. Polis

Spring 1973

College of Marine Studies
University of Delaware
Newark, Delaware
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This volume also supported by Sea Grant No. 1-35377.

SERIES SUMMARY

The series consists of ten volumes which have as their overall purpose to report upon the present state of knowledge concerning the Delaware Bay system. The system is understood to include both natural and socio-economic elements; thus it covers topics from history and land use through physics, chemistry and biology of the bay.

Volume 1 Inventory and Evaluation of Information on Delaware Bay

The volume which the reader has in his hands is designed to provide a starting point for those wishing to become acquainted with the bay. It reviews briefly the present research on the bay, the general availability and quality of data (including maps and aerial photography); technical, research, and advisory groups dealing with the bay; and finally future plans and proposals for the bay region.

Volume 2 History, Land Ownership, and Laws

Volume 2 addresses itself to three areas of marine affairs vital for an understanding of the bay system. In the first part, the history of the region is discussed, with special emphasis on the role of waterborne transportation in the formation of land-use patterns. The second part delves into land ownership and use in the coastal margin around the bay. The third part reviews the state and federal laws available for the management of the bay.

Volume 3 Trace Metal Geochemistry of Estuarine Sediments

This volume consists of three sections. The first part of this volume relates to the general distribution and composition of fine-grained sediments in the bay. In the second section, the relationship between the character of the fine-grained sediments and trace metal levels is developed. The third attempts to evaluate domestic sewage discharge as a source of metals in the estuarine environment.

Volume 4 Physical Oceanography and Chemical Oceanography

The physical and chemical environment of the bay system is dealt with in this two-part report. Part one provides fundamental information on the morphology, tides, currents, salinity and temperature of Delaware Bay. The spatial and temporal variability of these factors are discussed and most of the available data is summarized. Part two treats the chemistry of the Delaware Estuary. Averaged over a two-year period, data on chloride, chromium, iron, chlorophyll, phenols, oxygen, phosphate, and nitrite are presented and discussed in terms of hydrographic conditions and biochemical reactions.

Volume 5 Guide to the Macroscopic Estuarine and Marine Invertebrates of the Delaware Bay Region

This volume represents the first major compilation of invertebrate species for the Delaware Bay region. Included in the volume are: a key to the major kinds of invertebrates in this region; taxonomic listings of over 300 species collected by the authors or referred to in other published papers; keys to these species;

lists of species which, because of their known geographic distribution, may be expected to occur in this region; and a comprehensive bibliography of papers dealing with the species listed.

Volume 6 The Biology of the Oyster Community and Its Associated Fauna in Delaware Bay

The purpose of this account is to describe the composition of the associated invertebrate fauna of Delaware Bay oyster beds, and to determine the effect of salinity, substrate, and season on this fauna. The dependence of the number of species in a bed community on maximum salinity is discussed, together with its temporal variability. The associated oyster fauna of Delaware Bay is very similar to estuaries throughout the world and thus this report may have more than local interest.

Volume 7 Pictorial Guide to Fish Larvae of Delaware Bay

This volume is divided into two parts:

The pictorial guide composing the first part includes two large charts which are, in effect, an illustrated table of contents, designed to permit quick identification of larval specimens. Following this, the larval stages of 56 species of marine fishes collected in the Delaware Bay are illustrated serially (from younger to older). The notes for each species discuss adult characteristics, egg and larval development, spawning, distribution and pertinent references.

The second part provides information on several aspects of the study of fish larvae, i.e., laboratory identification; preservation and sorting; laboratory rearing and field sampling methods. A

bibliography is included for each section, and there is also a bibliography of selected general references on fish eggs and larvae.

Volume 8 Economic and Social Aspects of Delaware's Coastal Zone

In this volume the economic and social aspects of Delaware's coastal zone are considered from several different viewpoints. The first section develops a management and regulatory perspective. This is followed by two sections which deal with historical and contemporary perspectives, placing emphasis upon general industrial and social development, and the evolution of transportation, recreation, and commercial fisheries. The closing section of the volume considers a planning perspective and looks briefly into development issues involved in the future economic and social development of the Coastal Zone.

Volume 9 Baseline Study Plans

The outline plan of a comprehensive and coordinated five-year study of the scientific and engineering aspects of Delaware Bay is presented in this volume. Specifications are provided for many subprojects, while others are simply outlined. The thrust of the study is the production of a crude overall predictive model for the physical and biological aspects of the bay system.

Volume 10 Comprehensive Bibliography on Delaware Bay

This series is completed by a comprehensive indexed bibliography on all aspects of the Delaware Estuarine system.

The Delaware Bay Report Series was supported by a grant from the National Geographic Society, and produced under the direction of Dr. Dennis F. Polis of the University of Delaware's College of Marine Studies. Members of the CMS staff who aided in the production of this series are: (production supervisor) Roslyn Foner; and (art and graphics) Frank Danberg assisted by Linda Patille.

PREFACE TO VOLUME 1

This volume is the result of a project undertaken in order to gain an overview of the present plans, projects and information base for Delaware Bay with a view to planning and possible future regulation by the Delaware River Basin Commission. The work reported here was carried out by the University of Delaware under contract to the Basin Commission with Sea Grant funding matched with a grant from the National Geographic Society. The project was directed by Dr. Dennis F. Polis.

Volume 1 consists of:

- I. A descriptive listing of major research projects underway or proposed for existing programs in the bay.
- II. An inventory and evaluation of the available scientific and engineering data on Delaware Bay.
- III. A list of the research, technical and advisory groups active in the bay area.
- IV. A descriptive listing of future plans and proposals.

Acknowledgement: We wish to thank all of those who have cooperated in the production or aided in the publication. Those who have contributed written material have been mentioned in the sections to which they contributed. Those who have cooperated by responding to letters of inquiry, telephone calls, and personal interviews are noted as contacts in the appropriate sections. Thanks are extended to members of the CMS staff for their assistance: (art work) Mr. Frank Danberg, assisted by Miss Linda Ewonishon; (typing) Miss Ellen Cooke, Mrs. Linda Hibberd, Mrs. Gloria Cresswell and Miss Brenda Schenck. Finally, appreciation is expressed to Mr. Joel Goodman for his support.

Dr. R. E. Fothergill has made a substantial contribution to the work by contacting numerous installations and agencies and working through their files and libraries in search of material for this report.

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I. RESEARCH PROJECTS UNDERWAY OR
PROPOSED FOR EXISTING PROGRAMS

A. MULTI-PROJECT PROGRAMS

Three large programs are currently underway, sub-projects of which deal with Delaware Bay. These are funded by 1) Sea Grant, 2) The Geography Programs of The Office of Naval Research (ONR) and 3) The National Science Foundation-Research Applied to National Needs (NSF/RANN).

1. SEA GRANT

Contact: J. Goodman

Sea Grant is a program administered by the National Oceanic and Atmospheric Administration of the Department of Commerce. Sea Grant emphasizes research that will aid regional concerns through the rational exploitation of marine resources. Every project must have an identifiable practical return on the research investment.

The University of Delaware has an on-going Sea Grant program and has submitted a proposal for its renewal. The following proposed projects will generate information on Delaware Bay and of the type being sought in this inventory:

R/B-1: NEW FOOD OR FORAGE RESOURCES OF DELAWARE BAY

Principal Investigator:
V. Lotrich, (CMS)

Objective:

To establish the availability, characteristics, and nutritional value of Fundulus heteroclitus (Killifish) as a potential source of food for commercially valuable species.

R/T-2: LOCAL THERMALLY CONVECTIVE FLOW IN THE OCEAN

Principal Investigator:
F. A. Costello (M&AE)

Objectives:

1) To develop a complete technique for predicting the dilution and trajectory for the jets (plumes) issuing from outfall lines and submerged heated objects.

2) To assess the importance of unequal diffusion rates on buoyant plumes.

3) To develop a method for predicting the flow, concentration and temperature near the impact point of the plume and the ocean surface.

4) To determine the effect of turbulence in the jet and in the ocean on the effects of diffusion near the impact point.

R/G-7: EVALUATION OF COLLIGATIVE PROPERTIES OF MARINE HUMUS

Principal Investigator:
F. M. Swain (Geology)

Objectives:

1) Determine the colligative properties of humic substances in Delaware Bay sediments.

2) Evaluate the potential application of the colligative properties to improve the engineering properties of muds and sands.

3) Recover valuable pharmaceuticals from marine humus.

R/N-5: EVALUATING TECHNIQUES FOR REDEVELOPMENT OF DEGRADED
SALT MARSHES

Principal Investigator:
J. E. Taylor (CMS)

Objectives:

1) Describe growth and production of naturally occurring stands of Phragmites as a potential replacement species and include plant components such as N, P, C, proteins, fats, carbohydrates.

2) Monitor production of Phragmites litter and its breakdown into detritus under controlled conditions as a way to partially assess its ecological role.

3) Associate vegetation development patterns on disturbed sites with soil chemistry, date of last disturbance, and tidal exposure.

4) In appropriate test sites, describe effects on vegetation succession of manipulated nitrogen levels and tidal exposure. The latter two objectives are seen as yielding guides for marsh management practices.

R/E-1: ASSESSING DELAWARE'S COASTAL ZONE ECONOMY:
ITS CHANGING STRUCTURE AND THE IMPACT OF
ALTERNATIVE ECONOMIC ACTIVITIES

Principal Investigator:
D. K. Smith (AG-ECON)

Objectives:

1) To compile basic planning and program data which measures the economic characteristics of Delaware's coastal zone economy and to delineate coastal zone planning and analysis regions.

2) To determine, through micro-regional analysis using inter-industry analysis techniques, the current economic structure of Delaware's "ocean shore area" and to measure the current and potential impact of recreational based activity on this area's economy.

3) To extend the application of the above micro-regional analysis to other selected areas in Delaware's coastal zone with analysis of the impact of alternative types of economic activity pertinent to these areas.

R/E-3: ANALYZING EVOLVING LAND USE PATTERNS IN THE
DELAWARE COASTAL ZONE USING AERIAL INFORMATION

Principal Investigator:
D. K. Smith (AG-ECON)

Objectives:

1) To develop and test techniques using aerial imagery for tracing past patterns and monitoring currently evolving land use patterns in a selected area of Delaware's coastal zone region.

2) To determine the relationships between evolving land use patterns in the selected area and the area's natural characteristics and economic and institutional forces, and the use of these

relationships to project alternative future changes in land use patterns.

3) To determine the feasibility of extending the above techniques and analysis to complete coverage of Delaware's coastal zone region.

R/B-3: RELATING EVOLVING LAND USE PATTERNS IN THE
DELAWARE COASTAL ZONE TO ECOLOGICAL IMPACT
ON MARINE FISHES IN THE WHITE CREEK ESTUARY

Principal Investigator:
K. S. Price (CMS)

Objectives:

1) To develop and test techniques using aerial imagery provided by R/E-3 for relating past and current land use patterns in a selected area of Delaware's Coastal Zone to the ecological impact on marine fishes utilizing an estuary in the region.

2) To determine the feasibility of extending the relationships developed to coastal zone land use planning.

R/M-6: COASTAL ZONE CO-EXISTENCE ALTERNATIVES

Principal Investigator:
J. M. Goodman (CMS)

Objectives:

The objective of this project will be to evaluate for initial techno-economic feasibility, ecological impact, and social impact, a set of development options which derive from the inter-sections of an activity - location matrix.

Typical of major classes to be considered are:

1. Offshore semi-detached and detached water-oriented recreational modules
2. Offshore, semi-detached and detached industrial modules
3. Land locked industrial site development based upon trans-state canal options w&w/o commuting systems for labor face mobility
4. Land-locked industrial site development based upon trans-state pipeline options.

A/I-1: MARINE ADVISORY SERVICES

Principal Investigator:
S. M. Gwinn (AG-EXT)

Objectives:

The objective of this project is to continue the development of informational and educational activity designed to meet the needs of all marine resource users--commercial fishermen, recreationists, transportation interests, industrial operations and coastal zone planning and development groups as well as provided for the edification of the general public, by establishing communication between this heterogeneous mass and the scientific community. Effective information transfer requires feedback from the public and the user. In this fashion university research and training should be initiated or redirected as a result of resource user need and interest.

2. OFFICE OF NAVAL RESEARCH

Contact: V. Klemas

The University of Delaware has a large research effort funded by the Geography Branch of the Office of Naval Research (ONR). The program, entitled "Research in the Coastal and Oceanic Environment, was begun at the University of Delaware at the beginning of September, 1969. The program has undergone a significant redirection as a result of the termination of the DOD Themis program and the transfer of support to the Geography Programs of the Office of Naval Research. With respect to program objectives, the research is designed to focus on specific and important coastal and estuarine problems. The program is moving toward closer coordination of work between investigators; and near-shore coastal processes are emerging as a unifying focal point.

The following subprojects will develop information of particular relevance to Delaware Bay.

COMPUTER MODELING OF SHORELINE EVOLUTION

Principal Investigators:

H. Wang

S. Liang

Summary

This is the second year of a two-year major effort to develop a computer program that performs time trend analysis of shoreline evaluation. It is anticipated that by the end of August, 1974, this research will lead to the completion of computer programming with test runs made and the computer model calibrated against a selected section of beach

along the Delaware Coast. It is hoped that the end product will be able to simulate and predict shoreline changes under assigned environmental conditions and thus facilitate decisions on beach protections and new coastal installations.

Research will continue on developing a dynamic shoreline evolution model for the following specific objectives:

- a) To establish time trend functions for shoreline evolution;
- b) To test the sensitivity of the time trend functions with respect to various governing processes;
- c) To examine the variation of time trend functions based on monthly and annual weather statistics;
- d) To examine the variation of time trend functions due to high intensity, short-term events such as storms, and artificial shoreline changes.

PHOTO-OPTICAL DETERMINATION OF DIRECTIONAL SHALLOW-WATER WAVE SPECTRA

Principal Investigators:
V. Klemas
A. Tayfun
H. Wang

Summary

Optical Fourier techniques will be employed to determine the changing directional spectrum of waves approaching a section of Delaware's Atlantic Coast. Data to be analyzed consist of a laser wave profile and a sequence of aerial photographs taken within a short time period from deepwater to the shoreline. Wave probes on near-shore

towers will provide ground truth. The area size of each photo-segment to be analyzed will be optimized to minimize errors due to statistical variability, resolution in wave number, and bias due to spatial inhomogeneity. The observed change in directional wave spectrum going from deepwater to near-shore conditions will be compared with spatial transformations used in a related subproject to forecast shallow water wave characteristics from the deepwater wave field.

DYNAMICS OF AQUATIC FRONTAL SYSTEMS IN DELAWARE BAY

Principal Investigators:

S. Kupferman

D. Polis

Summary

Aquatic fronts are similar to atmospheric fronts in that the denser fluid tends to underide the lighter fluid giving rise to an inclined interface. While fronts are often marked by differences in suspended sediment concentration, these differences do not strongly effect the density structure which determines the dynamics of the fronts. Many fronts have been observed across which there is no apparent difference in sediment concentration. These fronts are believed to have a strong influence on the transport and distribution of pollutants entering the bay.

The coming year's research will involve the use of combined ship aircraft operations to quantitatively describe the structure and dynamics of the fronts, thus providing the basis of an explanation of their origin and maintenance.

3. NATIONAL SCIENCE FOUNDATION - RESEARCH APPLICABLE TO NATIONAL NEEDS

Contacts:

See below

This is a joint program of the Academy of Natural Sciences, the University of Delaware and Rutgers University entitled, "The Delaware Estuary System: Environmental Impacts and Socio-Economic Effects". The program has a co-director from each institution. These are respectively: R. Patrick, W. S. Gaither, and W. Whipple, Jr. The program is currently in Phase I, during which an analysis will be made of the state-of-the-art in the several relevant fields and disciplines, and an approximate evaluation of the particular situations developing in the Delaware Basin. A number of interim reports will be prepared which should be of value to decision-makers. Also in Phase I, a detailed plan will be prepared for definitive research to be conducted as Phase II. Phase II will be coordinated closely with research efforts by others.

This proposal is devised to aid in the solution of seven national problems whose solution is pressing in the Delaware Basin. These are listed below:

1. Increased electric power generation.
2. General water transportation improvement.
3. East coast deep draft cargo transfer capability.
4. Increased home and industrial development.
5. Increased recreational demands.
6. Restoration of environmental quality.
7. Restoration of management of fisheries.

These problems are being attacked through the combined efforts of work groups in seven major areas. The work groups, their chairmen and the extent of participation by each of the institutions are shown on page 12:

<u>Work Group & Chairman</u>	<u>Academy</u>	<u>Delaware</u>	<u>Rutgers*</u>
1. Economic & social aspects (W. Whipple & M. Marcus)	-----	Lesser	Major effort
2. Water quality & transfer functions--upper estuary (W. Whipple)	-----	Lesser	Major effort
3. Marsh biology (R. Patrick & T. Bott)	Major effort	Lesser	-----
4. Biology & upper estuary (C. Hart & R. Patrick)	Major effort	-----	-----
5. Triple Bend Study (H. Wang)	-----	Major effort	-----
6. Lower estuary hydrodynamics & modeling (S. Kupferman)	Lesser	Major effort	Lesser**
7. Deepwater biology lower estuary (D. Maurer)	Lesser	Major effort	Lesser**

* Includes associated faculty at Princeton University and University of Pennsylvania

** Rutgers University has a major interest in these matters and anticipates taking a major role during Phase II.

While all of these work groups will develop information that will shed light on Delaware Bay problems, those which will have some particular concern with the region dealt with in this report are numbers 1, 3, 6, and 7. Among its other interests, Group I will

develop information on the economics of a deepwater port in the Bay and the economic value of fisheries. Among its other activities Group 3 is producing aerial photos of all Delaware's wetlands. Group 6 will devote its initial effort to the development of a two-dimensional model of the hydrodynamics of the lower Bay. Group 7 will make a general survey of the available data and results of prior and on-going research. The biologists will work closely with the physical and chemical oceanographers to develop a general model for predicting the impact of major projects proposed for the Bay region.

B. SMALLER PROJECTS

In addition to these three major programs a number of smaller projects are of interest:

1. BIOLOGICAL EFFECT OF OVERBOARD SPOIL DISPOSAL AT LEWES, DELAWARE, AND CAPE MAY, NEW JERSEY, FERRY TERMINALS--DELAWARE RIVER AND BAY AUTHORITY

Contacts:

D. Maurer
H. Haskin

Objectives:

The main objective of the investigations is to evaluate the gross biological effect of overboard spoil disposal on a macro-benthos in the Lewes, Delaware, and Cape May Ferry Terminal areas.

The short term depositional pattern of the spoil and its effect on the biology of the area are being determined, monitoring of spoil disposal to avoid ecological catastrophies will be evaluated. In addition, data on the present biological conditions in the area are being taken. D. Maurer of the College of Marine Studies is conducting the work on the Delaware side, while H. Haskin of Rutgers is working on the Cape May area.

2. SUPERTANKER ENVIRONMENTAL IMPACT STUDY--COUNCIL ON ENVIRONMENTAL QUALITY

Contact:
D. Maurer

Objectives:

To select a location for the accommodation of supertankers on the East and Gulf Coasts information is needed on the vulnerability of the environment at each of the proposed sites. Of the seven sites considered by a federal agency task force, preference is given to a location inside or outside the Delaware Bay. An assessment using available environmental investigation would be required. The College of Marine Studies of the University of Delaware is performing the local preliminary studies.

The guiding purpose of this study is to develop environmental, technological, and economic information and recommendations for consideration in formulating a national policy on the reception

of "supertankers" in U. S. ports, harbors, and coastal waterways.

Specifically, the study will determine and evaluate the environmental effects of various potential location/receiving facility alternatives for oil.

The end product will rank alternative location/receiving facilities by their relative environmental effects. Environmental effects are a function of several factors: probability of oil pollution, ecological vulnerability, impact of increased industrialization upon land use and shore based pollution. The study will also array projected dollar costs--environmental and other--for each alternative. The result should produce a matrix with which decisionmakers can identify advantages and disadvantages of the possible alternatives, and determine the desirability of supertanker location/receiving facilities.

3. EVALUATION OF ALTERNATIVE OIL TRANSPORT SYSTEMS TO DEFINE THE SAFEST WAY TO MOVE PETROLEUM UP THE DELAWARE BAY AND RIVER TO EXISTING REFINERIES -- DELAWARE BAY OIL TRANSPORT COMMITTEE

Contact:
W. S. Gaither

Objectives:

This study will cover items such as associated land use, effects on marine life, physical effects on the marine environment, accumulation of tars, and capacity for spill retention and removal. The study is being supervised by the Oil Transportation Committee of which W. S. Gaither is the chairman and J. Bivens the vice-chairman.

The study has been contracted to Bechtel, Inc. F. Watters of the Pipeline Division is in charge. The statement of work calls for the contractor to:

1) Define future tonnages of petroleum and petroleum products required by east coast to the year 2000 including a specific projection for the Delaware Valley.

2) Contact organizations with active plans for oil transfer facilities to handle east coast and Delaware Valley petroleum and petroleum products.

3) Examine existing operations and equipment (lightering, refinery docks and pipeline systems).

4) Review existing plans for east coast and Delaware facilities to handle Delaware Valley petroleum and petroleum products.

5) Investigate innovative transfer systems concepts now in use or planned for other parts of the world.

6) Develop criteria for the evaluation of alternative petroleum and petroleum product transport systems as they affect Delaware. This will include considerations as to operational requirements, environmental impacts, economic effects, legal implications, national defense requirements.

7) Identify new alternatives for the Delaware Bay crude transfer if appropriate.

8) Test alternative systems and identify optimum system(s).

9) Consider potential feasibility if multiple use is made of transport system (i.e., coal, steel, etc.).

10) Frame recommendations and write a report. The work is due to be completed in November of 1972.

4. EFFECTS OF THE IMPROVEMENTS ON THE CHESAPEAKE AND DELAWARE CANAL--U. S. ARMY CORPS OF ENGINEERS

Contact:
F. C. Daiber

Objectives:

The purpose of this program is to evaluate the biological effects of the recent widening and deepening of the Chesapeake and Delaware Canal. E. Cronin of the University of Maryland's Chesapeake Bay Laboratory is the prime contractor and is dealing specifically with the biology of the Maryland side. F. C. Daiber and V. Lotrich of CMS are dealing with the biological problems of the Delaware side. D. Prichard of the Johns Hopkins University's Chesapeake Bay Institute is treating the physical oceanographic aspect of the problem. The funding is coming through the Baltimore office of the Corps. This problem is physically outside of this study's area, but is included because of its strong impact on the Bay system which will be discussed in Part II.

5. AN ECOLOGICAL STUDY OF THE DELAWARE RIVER IN THE VICINITY OF ARTIFICIAL ISLAND--PUBLIC SERVICE ELECTRIC & GAS OF NEW JERSEY

Contact:
V. Schuler

Objectives:

This 10 year study is being conducted by the Ichthyological Associates in connection with the Salem Nuclear Generating Station presently under construction. It began in June 1968. It also is above this study's area of concern, but is important in that the biota do not respect legal boundaries. The study is described at greater length in the biological section of Part II in this report. V. Schuler is in charge of the project and may be contacted at Smyrna, Delaware.

6. DELAWARE BAY SHELLFISH RESEARCH--NATIONAL MARINE FISHERIES SERVICE AND STATE OF DELAWARE

Contact:
D. Maurer

Objectives:

The National Marine Fisheries Service and the State of Delaware are jointly sponsoring this project on four of the commercially valuable shellfish species of the bay. The species being studied are the oyster, hard clam, blue crab and lobster.

7. HYDROGRAPHY OF THE DELAWARE BAY ESTUARY

Contact:
A. M. Hirsh

Objective:

This work, which is being conducted by the Marine Sciences Center at Rutgers, has as its object to assemble and organize in convenient form previously obtained physical data.

8. CIRCULATION OF THE SOUTHEASTERN SECTION, DELAWARE BAY

Contact:
H. H. Haskin

Objective:

The Marine Sciences Center of Rutgers is undertaking the monitoring of currents by fluorescent injections of dye in order to resolve certain pollution problems which have become important.

9. EFFECTS OF SALINITY AND OTHER WATER QUALITY PARAMETERS ON NEW JERSEY OYSTER BEDS---OFFICE OF WATER RESOURCES

Contact:
H. H. Haskin

Objective:

This work on New Jersey's Delaware Bay oyster beds is being funded by the Office of Water Resources through the Water Resources Institute at Rutgers.

10. BATHYMETRIC SURVEY OF DELAWARE BAY--NATIONAL OCEAN SURVEY

Contact:
G. Lill, Deputy Director

This project is discussed in Part II-A-4.

11. CENTRAL ATLANTIC REGIONAL TEST SITE--NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND DEPARTMENT OF THE INTERIOR

Contact:
R. Alexander, Test Site Coordinator

Objectives:

The Central Atlantic Regional Test Site (CARETS), which has been established by the Department of the Interior and the National Aeronautics and Space Administration includes the Delaware Estuary and adjacent areas. The purpose is to test and demonstrate the use of high-flying aircraft, spacecraft and satellites to monitor precisely what is happening on earth, by means of remote sensing of electromagnetic radiation, ultraviolet, infrared, and visible light and reflected microwave emissions. It is understood that in order to process the resulting data, and to evaluate the system, it will be necessary to obtain inventories of vegetation, soil type, water quality, and possibly other ecological features.

12. WETLANDS MAPPING--NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF MARINE LANDS MANAGEMENT

Contact:

H. Barker, Chief

Objective:

The Bureau is now involved in an extensive mapping program. Mapping activities are completed at two test site areas at Marrington Meadows and a Marsh near Tuckerton. Mapping procedures are being carried out northward from Tuckerton toward Mercer County. When these areas have been surveyed, mapping activities will proceed southward from Tuckerton addressing counties in the following order: Atlantic, Cape May, Cumberland, Salem, Gloucester, Camden, and Burlington.

13. DEEPWATER PORT STUDIES-- U. S. MARITIME ADMINISTRATION

Contact:

R. Blackwell, Assistant Secretary for
Maritime Affairs

Objective:

The Administration is conducting a study of Delaware Bay as input to an evaluation of perspective supertanker terminal facilities. The project has been contracted to Soros Associates of New York City.

14. WETLANDS ECOLOGY STUDY--NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION, SECTION OF WETLANDS ECOLOGY

Contact:

F. Ferrigro, Head

Objectives:

The Section commenced a study of wetlands ecology on July 1. A description of the study is available as of that date. The study includes the following applied research projects, long-term studies of the department, some of which continue:

1) A study of marsh destruction to determine the forces at work, the extent of damages and recommendations to prevent future losses.

2) A study of waterfowl harvest, to include an assessment of hunting uses and management techniques.

3) An aerial survey of coastal waterfowl.

4) A study of wildlife indexes and the interrelationship

of the food chain.

5) A cooperative mosquito management study with the Cumberland County Mosquito Control Commission to evaluate open marsh management in Fortesque Township.

6) A study of the ecology and management of upland marshes.

7) Studies on the clapper rail, the wood cock, beavers, otters and muskrats.

8) An aerial survey of marshlands using infrared photographs to provide an accurate accounting of various cover types.

9) An evaluation of the techniques and effects of restoring closed marshes to tidal inundation. This study will focus on three different types of impoundments.

a. Mosquito impoundments in Cape May County.

b. Agricultural impoundments in Salem and Upper Cumberland Counties.

c. Agricultural impoundments in Upper Cumberland County.

10) A review of the effects of all riparian grants and permits.

15. OYSTER SETTING AND SPAT SURVIVAL AT CRITICAL SALINITY LEVELS
ON THE NEW JERSEY NATURAL SEED OYSTER BEDS OF DELAWARE BAY--
RUTGERS

Contact:
H. Haskin

16. ECOLOGICAL EFFECTS OF POWER PLANTS IN THE LOWER DELAWARE ESTUARY--NSF & PSEF

Contact:
R. Patrick

Objective:

This project is being carried out by the Academy of Natural Sciences as a member of the Institute for the Development of Riverine and Estuarine Systems (IDRES).

17. APPLICATION OF GEOLOGICAL, ECOLOGICAL AND OCEANOGRAPHIC ERTS-A IMAGERY TO DELAWARE'S COASTAL RESOURCES PLANNING--NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contact:
V. Klemas

This program is just beginning at the University of Delaware.

18. SPECIAL PROJECT--COASTAL ZONE PLANNING IN DELAWARE--DELAWARE STATE PLANNING OFFICE

Contact:
D. R. Keifer, director

This project is funded by the Department of Housing and Urban Development. The work elements are as follows:

1) Collection, organization and evaluation of information on the natural and cultural (man-made) resources of the Coastal Zone to provide a factual basis for a comprehensive management plan for the coastal zone and for administrative decisions under the Coastal Zone Act.

2) Identification or devising of criteria and standards

by which to judge the impact of industrial development on the natural environment and aesthetic values of the coastal zone.

3) Refinement of the definition of "heavy industry" in order to identify only those, but all those, types of industry likely to be detrimental to the coastal zone environment and to optimum utilization of the coastal zone in terms of public benefits vs. costs.

4) Drafting of material for Coastal Zone Act administration including:

- a. Permit and appeals application procedures, forms, fee requirements, and project plan and document requirements.
- b. Public hearing procedures including advertising hearing notices.
- c. Checklists for administrative use to insure that permit and appeals applications meet all procedural and documents requirements of the Coastal Zone Act.
- d. Guidelines in pamphlet form to provide permit applicants with clear, concise instructions as to procedural and other requirements of the coastal zone law and regulations.

5) Preparation of a coastal zone comprehensive management plan coordinated with the revised State Comprehensive Development Plan to provide policy guidelines for industrial, port, recreational,

and other development decisions.

19. THE NECESSITY FOR AND FEASIBILITY OF DEEPWATER OFF-SHORE
TERMINALS--U. S. ARMY CORPS OF ENGINEERS

Contact:

P. Cheney, Nathan Associates

Objective:

This project is being undertaken by Nathan Associates and deals with Delaware Bay as one among a number of possible locations for a deep draft port.

II. AVAILABLE SCIENTIFIC AND ENGINEERING DATA

Data on the natural environment of Delaware Bay are needed to provide a means of evaluating on-going and proposed projects such as: The Tocks Island Reservoir; the enlargement of the Chesapeake and Delaware Canals; the installation of waste treatment plants at Philadelphia and in Kent and lower Sussex counties in Delaware; the Salem Nuclear Generating Station in New Jersey; and deep-draft port development in the lower Bay area. In addition, oceanographic information is required for such purposes as hurricane protection, flushing pattern prediction, the prevention of salt water intrusion, identification of source of material for beach nourishment and to provide a context for the ecological understanding of the bay system.

The information presented here represents the results of extensive reviews of the literature and raw data on the Bay. Obviously, there has not been time to correlate data or to evaluate it in any detail. The project sought rather to identify major sources of published and unpublished data, make a rough estimate of its reliability and suggest what work might be done based on it and where it is insufficient for anticipated needs.

In addition to the data reviewed in the report, there is a very small amount of chemical data available on the Bay. It was intended to devote a section of the report to this data; however, this has not been possible, and the reader is referred to Volume 4 of this report series for a discussion of the Bay's chemistry.*

* Dr. Adel Kamel assisted in the preparation of this section.

A. EVALUATION OF AVAILABLE HYDROGRAPHIC DATA

For the purposes of this report "hydrographic data" covers the following items: Bathymetry, tides, currents, sea conditions (waves and storm surges), meteorological data (wind speed and direction, air temperature, pressure, precipitation, evaporation, dew point and sky cover), sedimentation, salinity and water temperature.

1. TIDES

Tide predictions for the Delaware Bay system are made by the National Ocean Survey (NOS-formerly the Coast and Geodetic Survey) and published in the annual tide tables (44). In addition, tides are being, or have been, observed at several stations located on both sides of the Bay and estuary (Figure 1). The available information is summarized in Table 1. Harmonic constants for the prediction of the height of tide are available from NOS for Cape May, Breakwater Harbor, Reedy Point and Philadelphia. The actual tides may vary from those predicted from the harmonic constants. This is primarily due to meteorological conditions. Figure 2 shows the discrepancy between observed and predicted tides at Philadelphia in an extreme case. Prediction of meteorological effects on the height of tide is possible. The required analysis correlates the difference between predicted and actual tides with meteorological phenomena. This type of analysis yields only a first approximation of the meteorological effects since the interaction between wind and tide is nonlinear--particularly for storm surges. The method would be most accurate for mild winds since the nonlinearity would be less pronounced. In order to accomplish such an analysis a length of tidal record would be selected for a time when the wind field was variable, but other parameters that might cause a change in water level (such as river flow) were essentially constant. A similar analysis could be used to separate water level variations due to river flow from observed tides.

TABLE I

SUMMARY OF TIDAL OBSERVATIONS

NO.	NAME OF STATION	LAT. N° '	LONG. W° '	KNOWN PERIOD OF RECORD	AGENCY	NOTES
1.	Ship John Lt.	39 18	75 23	Jan. 1931 - Dec. 1939	Corps of Eng.	
2.	Miah Maull Lt.	39 08	75 13	28 Aug. 1931 - Feb. 1934	Corps of Eng.	
3.	Brandywine Lt.	38 59	75 07	28 April 1932 - 31 Mar. 1939	Corps of Eng.	
4.	Breakwater Harbor	38 47	75 06	58 days in 1883 7 Jan. 1919 - 11 Jan. 1920 1 Jan. 1922 - 5 Jan. 1923 30 Mar. 1932 - 31 Mar. 1939 Scattered to 1957	U S C & G S	A
5.	Lewes	38 47	75 08	28 July 1931 - 1 Nov. 1932 May 1936 - Dec. 1939	U S C & G S	B
6.	Reedy Island	39 31	75 34	Oct. 1921 - Oct. 1930	U S C & G S	
7.	Reedy Point	39 33.74	75 33.74	June 1928 - Dec. 1939 Aug. 1956 - Dec. 1966	U S C & G S	B A
8.	Cape May	38 58.1	74 57.6	1 Jan. 1966 - 1968, 1970	U S C & G S	B
9.	Delaware Bay Entrance	38 48	74 01.4	17 Apr. 1940 - 21 Apr. 1940	U S C & G S	A
10.	Delaware City	39 35	75 35	25 Aug. 1923 - 29 Aug. 1924	U S C & G S	B
11.	Cape May Point	38 56	74 58			
12.	Bay Shore Channel	38 58	74 58			
13.	Miami Beach	39 02	74 56			C
14.	Dennis Creek entrance	39 10	74 54			
15.	East Point, Maurice River Cove	39 12	75 02			C
16.	Maurice River, Port Norris	39 14	75 02			
17.	Maurice River, Mauricetown	39 17	75 00			
18.	Maurice River, Millville	39 24	75 02			C
19.	Egg Island Point	39 11	75 08			
20.	Fortescue	39 14	75 10			C

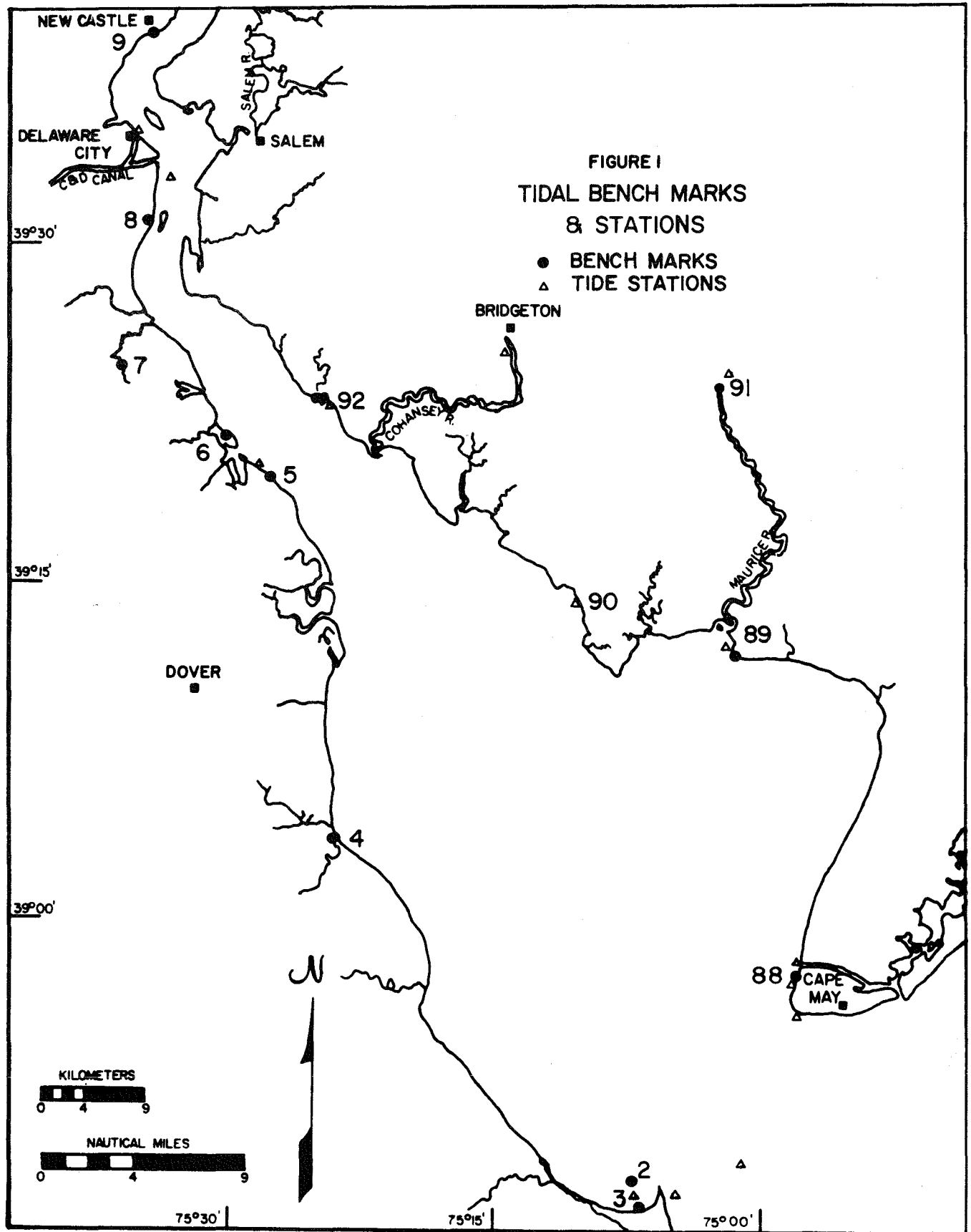
TABLE I
SUMMARY OF TIDAL OBSERVATIONS

NO.	NAME OF STATION	LAT. N ^O '	LONG. W ^O '	KNOWN PERIOD OF RECORD	AGENCY	NOTES
21.	Ben Davis Point	39 17	75 17			
22.	Cohansey River Entrance	39 21	75 22			
23.	Cohansey River, Laning Wharf	39 23	75 20			
24.	Cohansey River, Fairton	39 23	75 14			
25.	Cohansey River, Bridgeton	39 25	75 14			C
26.	Bay Side	39 23	75 24			C
27.	Fourteen Foot Bank Light	39 03	75 11			
28.	Elbow of Cross Ledge Light	39 11	75 16			
29.	Cape Henlopen	38 48	75 05			
30.	Roosevelt Inlet	38 49	75 12			
31.	Mispillion River entrance	38 57	75 19			
32.	Murderkill River entrance	39 04	75 24			
33.	St. Jones River entrance	39 04	75 24			
34.	Mahon River entrance	39 11	75 24			
35.	Leipsic River entrance	39 15	75 24			
36.	Leipsic, Leipsic River	39 15	75 31			
37.	Woodland Beach	39 20	75 28			C
38.	Liston Point	39 25	75 32			

Notes:

- A- National Ocean Survey has harmonic constants for prediction.
- B- NOS has harmonic constants - Not used for prediction.
- C- Sufficient data for harmonic analysis is available in the Judgement of Mr. D.C. Simpson,
Acting Chief, Predictions Branch, Oceanographic Division, NOS.

Sufficient observations of the tides at various locations in the bay have been made to allow the type of analysis discussed to be effected. The presently available river flow data is certainly adequate to a first order analysis of its effect on water level in the bay. The availability of meteorological data (discussed in II-A-3) appears to be the limiting factor. It is anticipated that the analysis for gross meteorological effects will be performed by CMS-possibly under funding from NSF/RANN.



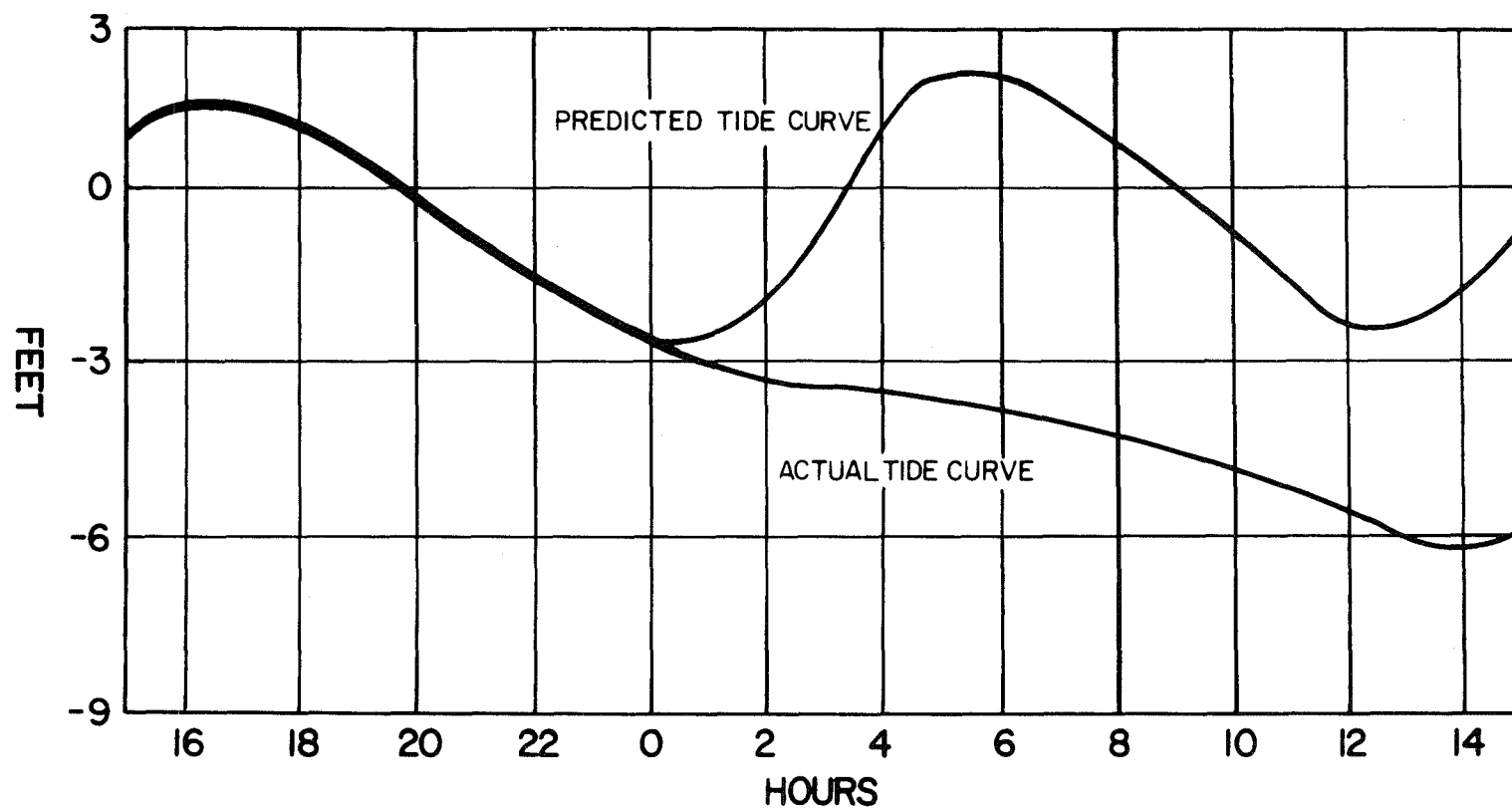


FIGURE 2

PREDICTED AND OBSERVED TIDE CURVES, PHILADELPHIA

MARCH 1-2, 1914

after ZESKIND AND LeLACHEUR

1926

2. CURRENTS

Under normal weather and river flow conditions, tidal currents would be the primary currents in the bay. Tidal current information available consist of:

- a. Current observations at various locations in the bay by the Coast and Geodetic Survey. The original data is still on file in the NOS offices in Rockville, Maryland.
- b. Drogue studies performed on the New Jersey side of the bay by Rutgers University. (The College of Marine Studies has not been able to inspect these data.)
- c. Current measurements made by the University of Delaware at the mouth of the bay and at other select locations (17) during 1968-70.
- d. Prototype and model measurements of the upper bay made by the Corps of Engineers (30) in connection with the River Model Study.
- e. Measurements of surface currents made by drift bottles conducted by Woods Hole Oceanographic Institution (16) off the mouth of Delaware Bay.
- f. Dye dumps made by NREC in cooperation with CMS in connection with the study of the effects of spoil disposal at the Lewes Ferry Terminal.
- g. Tidal current predictions made by NOS (43) at the entrance of Delaware Bay. The Tidal Current Tables give the time and velocity of maximum current and slack water time. Current predictions are made

using the current harmonic constants calculated from long term data observed off the mouth of the bay.

h. Tidal current pattern in Delaware Bay and estuary during different times of the tidal cycle as published in the Tidal Current Atlas (45) prepared by NOS.

Figures 3a and 3b show the location of current observations while Tables II and IIa provide detail on the observations.

Wind and river flow cause the observed currents to differ from current predictions made using the harmonic constants. A procedure similar to that suggested for tides to predict the effect of wind and river flow by separating the current predicted by the harmonic constants from observed currents would be less reliable here than for the tides. In addition, current observations available (with the exception of station 1, Figure 3a) are less adequate for this purpose than observations available for tides.

The direct effect of river discharge total flow is quite small in the lower bay; however, the bay is observed to change its estuarine circulation type when the river flow changes the bay's salinity structure. In general, the dependence of currents in the bay on river discharge will be that as the discharge increases there will develop a stronger two-layered "estuarine" circulation. The circulation will be generally inland at the north and bottom, and seaward on the south and top. In order to understand the extent of estuarine circulation present at any time, it is necessary to examine the temperature and (especially) the salinity distributions in the water column. For al-

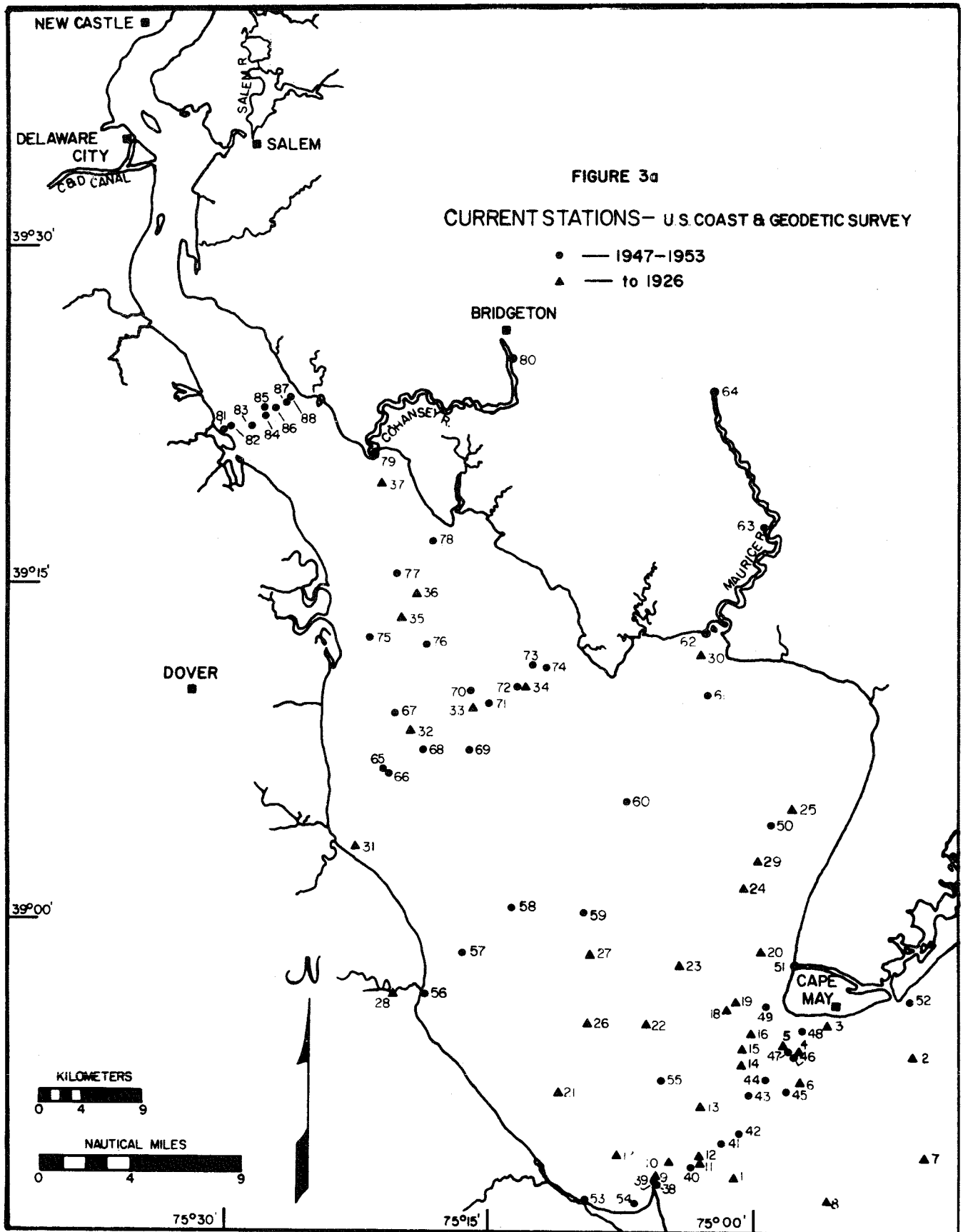


FIGURE 3b

CURRENT STATIONS FROM MISCELLANEOUS SOURCES

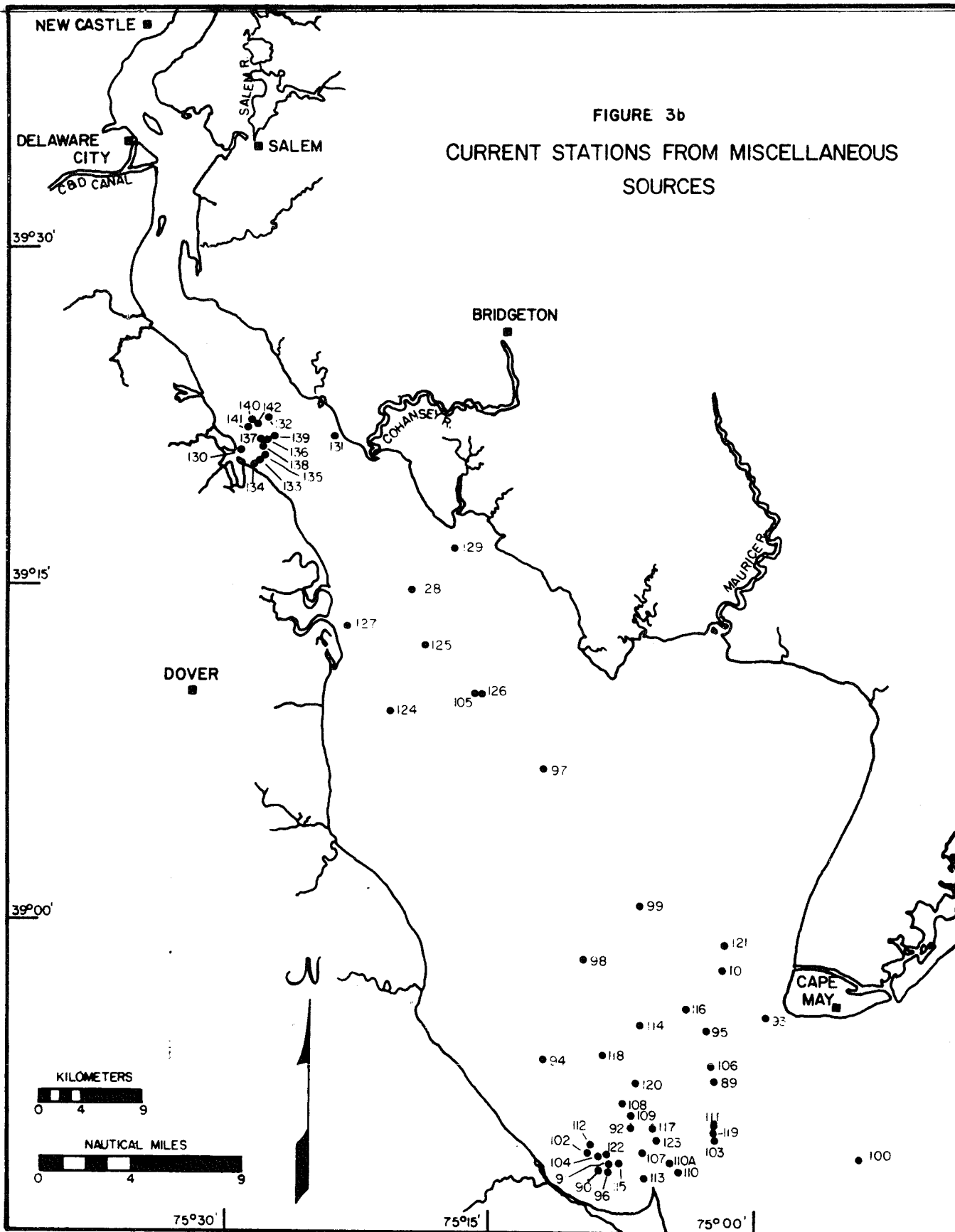


TABLE II
CURRENT DATA SUMMARY

#	Ref.#	N. Lat	W. Long	Date	Period Days	Method	Depth (ft)
		° ' "	° ' "				
1	7a	38 48.9	75 01	Aug 18-22, 1925 1912-13, 1918-21 1925, 1940-41 See Table IIa	4 1552	PM P	7, 15, 35, 55 7
2	9a	38 54.2	74 51.2	Sept 15-16, 1847	$\frac{1}{2}$	P	7
3	10a	38 55.5	74 56.0	Aug 26, 1847	$\frac{1}{2}$	P	7
4	11a	38 54.5	74 57.5	Sept 6-7, 1847	$\frac{1}{2}$	P	7
5	12a	38 58.2	74 54.6	Aug 27, 1847	$\frac{1}{2}$	P	7
6	13a	38 53	74 57.5	Sept 8-9, 1847	$\frac{1}{2}$	P	7
7	14a	38 49.8	74 50.5	Sept 16-17, 1847	$\frac{1}{2}$	P	7
8	15a	38 47.8	74 56	Sept 18, 1847	$\frac{1}{2}$	P	7
9	1a	38 48.2	75 05.5	Aug 21-22, 1924	1	P, PM	7, 15, 38, 60
10	2a	38 49.5	75 04.9	Aug 20-21, 1924	1	P, PM	7, 14, 35, 56
11	3a	38 49.6	75 03.2	Sept, 1847	$\frac{1}{2}$	P	7
12	4a	38 49.7	75 03.3	Aug, 1886	$2\frac{1}{2}$	P	7

TABLE II
CURRENT DATA SUMMARY

#	Ref.#	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		°	'	°	'				
13	5a	38	51.9	75	03.0	Aug 21-23, 1924	1½	P	7,8,20,32
14	6a	38	53.8	75	00.7	Sept, 1847	½	P	7
15	7a	38	54.5	75	00.7	Aug 22-23, 1924	1	P, PM	7,5,14,22
16	8a	38	55.2	75	00.1	Aug, 1947	½	P	7
17	9a	38	49.8	75	07.5	Aug, 1847	½	P	7
18	10a	38	56.2	75	01.5	Aug, 1847	½	P	7
19	11a	38	56.5	75	01.0	Aug, 1847	½	P	7
20	12a	38	59.9	74	58.8	Aug, 1847	½	P	7
21	13a	38	52.4	75	11.0	Aug 26-27, 1924	½	P, PM	7,6,15,24
22	14a	38	55.5	75	06.0	Aug, 1874	½	P	7
23	15a	38	58.0	75	04.0	Aug, 1874	½	P	7
24	16a	39	01.5	75	00.5	Aug 28-29, 1924	½	P, PM	7,5,12,20
25	17a	39	05.0	74	58.0	Sept, 1885	½	P	7

TABLE II
CURRENT DATA SUMMARY

#	Ref. #	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		o	'	o	'				
26	18a	38	55.5	75	09.4	Aug, 1847	$\frac{1}{2}$	P	7
27	19a	38	58.6	75	07.4	Aug, 1847	$\frac{1}{2}$	P	7
28	20a	38	56.4	75	20.0	Aug 25, 1924	$\frac{1}{2}$	P, PM	7,3
29	21a	39	02.8	74	59.8	Aug 27-28, 1924	$\frac{1}{2}$	P	7,8,19,30
30	22a	39	11.8	75	03.0	Aug 27-28, 1924	1	P	7,3,5,12
31	23a	39	03.4	75	22.5	Aug 30-31, 1924	1	P	7,3,6
32	24a	39	08.6	75	19.2	Sept 2-3, 1924	1	P	7,T,M,B
33	25a	39	09.5	75	16.0	Sept 3-5, 1924	3	P	7,9,22,35
34	26	39	10.5	75	12.9	Sept 5-6, 1924	1	P	7,4,11,18
35	27a	39	13.6	75	20.0	Aug 20, 1924	$\frac{1}{2}$	P	7,5,11,18
36	28a	39	14.6	75	19.2	Aug 20, 1924	$\frac{1}{2}$	P	7,8,15,24
37	29a	39	19.4	75	21	Sept 8, 1924	$\frac{1}{2}$	P	7,6,15,24
38	1b	38	48.2	75	05.4	May 18-22, 1953	4	RCM	7,34,62

TABLE II
CURRENT DATA SUMMARY

#	Ref.#	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		o	'	o	'				
39	2b	38	48.3	75	05.3	June 25-28, 1947	3	P, PM	7,13,34,54
40	3b	38	49.2	75	03.4	May 22-24, 1953	1½	RCM	7,48,89
41	4b	38	50.2	75	01.9	May 13-16, 1953 May 18-22, 1953	7	RCM	7,17,26
42	5b	38	50.8	75	00.7	May 9-13, 1953	4	RCM	8,23,36
43	6b	38	52.4	75	00.2	May 9-13, 1953	4	RCM	6,12,17
44	7b	38	53.1	74	59.2	May 12-18, 1953	6	RCM	7,14,23
45	8b	38	52.6	74	58.2	June 18-21, 1947	3	P, PM	7,6,15,24
46	9b	38	54.2	74	57.9	June 17-20, 1947	3	P, PM	7,5,13,21
47	10b	38	54.3	74	58.1	May 5-9, 1953	4	RCM	7,14,23
48	11b	38	55.4	74	57.5	May 5-9, 1953	3	RCM	6,12,17
49	12b	38	56.3	74	59.1	June 20-23, 1947	3	P, PM	7,7,16,26
50	13b	39	04.4	74	59.0	July 10-13, 1947	3	P, PM	6,10
51	14b	38	58.0	74	57.7	Oct 31-Nov 2,	2	P, PM	3,4

TABLE II
CURRENT DATA SUMMARY

#	Ref. #	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		°	'	°	'	1947			
52	15b	38	56.6	74	52.2	Oct 29-31, 1947	2	P	7,5,12,20
53	16b	38	47.5	75	09.5	Nov 5-7, 1947	2	P, PM	4,5
54	17b	38	47.6	75	06.5	Oct 28-31, 1947	3	P, PM	4,5
55	18b	38	53.0	75	05.3	July 28-31, 1947	3	P, PM	7,15,36,60
56	19b	38	56.8	75	18.9	Nov 7-9, 1947	2	P, PM	4,5
57	20b	38	58.7	75	16.6	June 26-29, 1947	3	P, PM	5,8
58	21b	39	00.5	75	13.9	June 23-26, 1947	3	P, PM	7,14,35,56
59	22b	39	03.3	75	09.5	June 28 - July 1 1947	3	P, PM	7,8,20,33
60	23b	39	06.4	75	07.1	July 10-13, 1947	3	P, PM	7,8
61	24b	39	10.1	75	02.5	July 13-16, 1947	3	P, PM	3,5
62	25b	39	13.0	75	02.7	Oct 23-26, 1947	3	P, PM	7,10
63	26b	39	17.2	74	59.6	Oct 20-22, 1947	2	P, PM	3,10

TABLE II
CURRENT DATA SUMMARY

#	Ref.#	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
64	27b	39	23.7	75	02.4	Oct 12-20, 1947	1	P, PM	4,6
65	28b	39	06.9	75	20.9	May 29-30, 1953 June 3-7, 1953	4	CM	7
66	29b	39	06.6	75	20.8	June 3-7, 1953	4	RCM	7
67	30b	39	09.2	75	20.4	Aug 4-7, 1947	3	P, PM	4,6
68	31b	39	07.7	75	18.7	May 29 - June 3 1953	5	RCM	7
69	32b	39	07.6	75	16.2	May 24-29, 1953	4	RCM	7,14,21
70	33b	39	10.2	75	16.2	Aug 8-11, 1947	3	P, PM	7,6,16,26
71	34b	39	09.7	75	15.0	April 22-26, 1953	4	RCM	7,18,31
72	35b	39	10.4	75	13.4	April 22-26, 1953	4	RCM	6,12,17
73	36b	39	11.4	75	12.5	July 13-16, 1947	3	P, PM	7,10
74	37b	39	11.4	75	11.7	April 22-26, 1953	3	RCM	6,12
75	38b	39	12.8	75	21.7	Aug 5-8, 1947	3	P, PM	4,6

TABLE II
CURRENT DATA SUMMARY

#	Ref. #	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		°	'	°	'				
76	39b	39	12.4	75	18.6	Aug 8-11, 1947	3	P, PM	4,9
77	40b	39	15.4	75	20.3	Aug 16-19, 1947	3	P, PM	7,6,15,29
78	41b	39	16.9	75	18.2	Aug 13-16, 1947	3	P, PM	4,8
79	42b	39	20.9	75	21.6	Oct 24-27, 1947	3	P, PM	8,10
80	43b	39	25.6	75	14.2	Oct 17-18, 1947	1	P, PM	4,8
81	44b	39	21.8	75	29.0	Sept 6-9, 1947	3	P, PM	3,6
82	45b	39	21.8	75	28.7	June 9-13, 1953	4	RCM	7
83	46b	39	22.0	75	28.4	June 9-11, 1953 June 13-18, 1953	6	RCM	7,12,18
84	47b	39	22.4	75	27.7	June 10-14, 1953	4	RCM	7,16,25
85	48b	39	22.6	75	27.8	Aug 24-27, 1947	3	P, PM	7,16,16,26
86	49b	39	22.8	75	26.9	June 9-14, 1953	5	RCM	7,14
87	50b	39	23.0	75	26.5	Aug 21-24, 1947	3	P, PM	4,8
88	51b	39	23.1	75	26.2	June 14-18, 1953	4	RCM	7,15

TABLE II
CURRENT DATA SUMMARY

#	Ref. #	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		°	'	°	'				
89	301c	38	53.0	75	02.0	Spring (1969?)	2?		7,15
90	33c	38	49.0	75	08.6	Spring (1969?)	?		
91	55c	38	49.4	75	08.0	April 6, 1969	$\frac{1}{2}$		5,11,16,20,24
92	58c	38	51.0	75	06.8	Spring (1969?)	?		
93	80c	38	55.9	74	59.1	May 2, 1970	$\frac{1}{4}$		
94	31c	38	53.9	75	11.9	Spring (1969?)	?		
95	84c	38	55.2	75	02.5	May 2, 1970	$\frac{1}{4}$		
96	86c	38	49.0	75	08.0	May 2, 1970	?		
97	88c	39	06.9	75	12.0	May 2, 1970	?		
98	21c	38	58.3	75	09.6	Summer (1969?)	?		
99	24c	39	00.9	75	06.3	Summer (1969?)	?		
100	25c	38	49.8	74	54.0	Summer (1969?)	?		
101	40c	38	57.9	75	01.6	July 18, 1968	2/3		5,10,20,30

TABLE II
CURRENT DATA SUMMARY

#	Ref. #	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		°	'	°	'				
102	41c	38	49.9	75	09.2	July 31, 1968	2/3		1,5,10,15,20
103	94c	38	50.5	75	02.0	Summer (1969?)	?		
104	96c	38	49.8	75	08.5	Summer (1969?)	?		
105	308c	39	10.1	75	15.9	Summer (1969?)	?		
106	309c	38	53.8	75	02.1	Aug 6-7, 1969	2		2,10,25,35
107	402	38	49.9	75	06.2	July 9, 1969	1/2		5,10,25,35,40
108	405c	38	52.0	75	07.2	July 30, 1969	1/4		
109	406c	38	51.4	75	06.8	Summer (1969?)	?		
110	43c	38	49.0	75	04.0	Fall (1968?)	?		
110a	404c	38	49.3	75	04.6	Fall (1968?)	?		
111	44c	38	51.0	75	02.0	Oct 12, 1968	1/2+		4,10,15,19,24,27
112	57c	38	50.1	75	09.0	Fall (1968?)	?		
113	100c	38	48.7	75	06.0	Fall (1968?)	?		

TABLE II
CURRENT DATA SUMMARY

#	Ref.#	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		°	'	°	'				
114	102c	38	55.4	75	06.3	Fall (1968?)	?		
115	505c	38	49.3	75	07.4	Oct 11-12, 1969	1.2		1,5,10,15,20
116	508c	38	56.2	75	03.7	Fall (1969?)	?		
117	509c	38	50.9	75	05.5	Dec 6-7, 1969	1		10,13,23,30,45 60,70,80,85,89
118	30c	38	54.1	75	08.2	Winter (1969?)	?		
119	47c	38	50.1	75	02.0	March 16, 1969	$\frac{1}{2}$		1,6,11,20,25,30,34
120	82c	38	52.9	75	06.5	May 2, 1970	$\frac{1}{2}$		
121	702c	38	59.0	75	01.5	Feb 7-8, 1970	$\frac{1}{2}+$		Several
122	703c	38	94.7	75	08.1	Winter (1969?)	?		
123	704c	38	50.4	75	05.2	Winter (1969?)	?		
124	20d	39	09.5	75	20.5	?	$\frac{1}{2}?$		M
125	21d	39	12.3	75	18.5	?	$\frac{1}{2}?$		M
126	22d	39	10.1	75	15.4	?	$\frac{1}{2}?$		M

TABLE II
CURRENT DATA SUMMARY

#	Ref. #	N. Lat	W. Long	Date	Period Days	Method	Depth (ft)
127	24d	39 13.1	75 22.9	?	$\frac{1}{2}$?		M
128	25d	39 14.7	75 19.4	?	$\frac{1}{2}$?		M
129	26d	39 16.7	75 17.0	?	$\frac{1}{2}$?		M
130	28d	39 20.8	75 29.0	?	$\frac{1}{2}$		M
131	29d	39 21.7	75 23	?	$\frac{1}{2}$		M
132	30d	39 22.3	75 27.5	?	$\frac{1}{2}$		M
133	9A	39 20.5	75 27.0	July 8-18, 1952	$\frac{1}{2}$		T,M,B
134	9B	39 20.4	75 27.2	July 8-18, 1952	$\frac{1}{2}$		T,M,B
135	9F	39 20.6	75 26.8	July 8-18, 1952	$\frac{1}{2}$		T,M,B
136	8A	39 21.4	75 27.5	July 8-18, 1952	$\frac{1}{2}$		T,M,B
137	8B	39 21.35	75 27.7	July 8-18, 1952	$\frac{1}{2}$		T,M,B
138	8C	39 21.3	75 27.7	July 8-18, 1952	$\frac{1}{2}$		T,M,B
139	8F	39 21.5	75 27.1	July 8-18, 1952	$\frac{1}{2}$		T,M,B

TABLE II
CURRENT DATA SUMMARY

#	Ref. #	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
140	7A	39	22.1	75	82.5	July 8-18, 1952	1		T,M,B
141	7B	39	22.0	75	28.6	July 8-18, 1952	1		T,M,B
142	7F	39	22.1	75	28.4	July 8-18, 1952	1		T,M,B

The Ref. # indicates the number of the station in the document where it was found, while the letter indicates the source. Thus:

- a. Zeskind & LeLacheur (69)
- b. National Ocean Survey Unpublished (70)
- c. Oostdam (17)
- d. U.S. Army Corps of Engineers (30)

The locations were generally scaled off of charts and figures and their accuracy should be interpreted accordingly. The period is generally to the nearest tidal cycle of 12.42 hours ($\approx 1/2$ day.) A question mark after a period indicates that the period of observation is at least that given. In the method column "P" indicates pole and log line, "PM" is Price current meter with telephone attachment, "RCM" is recording current meter. The depths are those given in the sources, except in series (c) where representative values were scaled from graphs. "T" indicates top, "M" mid-depth and "B" bottom.

TABLE IIa

CURRENT DATA SERIES AT OVERFALLS LIGHT VESSEL* (STATION 1, fig. 3a)

Nov. 7, 1912 - Feb. 6, 1913	92	days
Sept. 13 - Dec. 18, 1918	98	"
Feb. 22 - May 2, 1919	70	"
July 1, 1919 - Jan. 17, 1920	201	"
Mar. 21, 1920 - Jan. 20, 1921	316	"
Mar. 13 - July 31, 1921	141	"
Aug. 18, 1924 - May 14, 1925	270	"
Apr. 17, 1940 - Apr. 21, 1941	369	"

* Compiled from Zeskind and LeLacheur (1926) and unpublished sources

most all of the observations of currents in the bay, there are no concurrent temperature and salinity data. Thus, at the present time, (1972), it is impossible to say how representative the net current observed at any station is. It is the net current which is responsible for the transport of substances through the bay.

The NOS observations noted above under item (a) comprise the bulk of the data. They have concurrent observations of wind speed and direction, but as each station was occupied only once for 3-4 days and the stations were occupied successively rather than simultaneously, they do not provide sufficient data for deducing the response of the current system to meteorological factors.

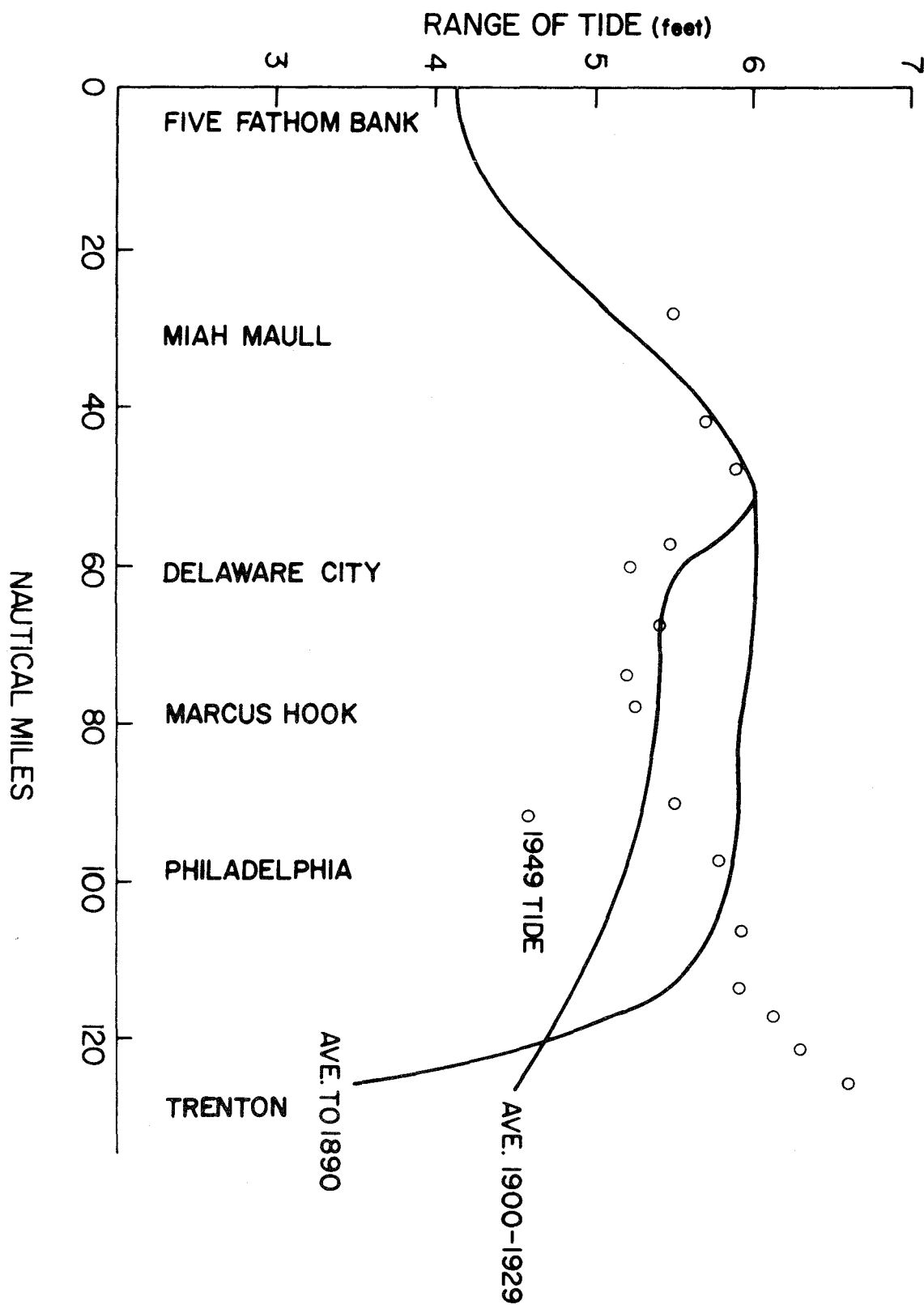
In addition to these difficulties, there is considerable doubt as to the usefulness of historical current data in describing the circulation of a rapidly changing area such as Delaware Bay. To be more specific it is known that:

a. The tidal boundary condition at Trenton has changed considerably with time (Figure 4). So that whereas it was formerly an energy absorbing boundary, it is now a reflecting boundary. This is doubtless a result of dredging.

b. Cape Henlopen is advancing into the bay at an annual average rate of about 80 feet per year (14). This is accompanied by filling of the entrance channel and affects the tidal boundary conditions at the mouth of the bay.

c. The bathymetry of the bay is changing fairly rapidly due to natural causes as well as engineering modifications (such as channel

Figure 4
Historical Variation of Tidal Range



dredging and the installation of protective works, e.g., the turning vanes in the vicinity of the Chesapeake and Delaware Canal). This has an effect on the salinity distribution and currents--especially in the upper bay.

d. Perhaps most important is the recent widening and deepening of the C&D Canal. This has led to net flows through the canal of the order of the average discharge at Trenton (Prichard, private communication). These net flows can be in either direction and may typically last 3-4 days in each direction. It is possible that they may be due to meteorological variations in tidal height, but whatever their cause they make earlier data on currents of doubtful value in the absence of more recent verification.

3. METEOROLOGY

Sources of information available on meteorological conditions for the Bay are:

a. J-D and Winterim cruises in the bay covering the period 1954-1972 provide information on wind direction, sea, weather and cloud and air temperature (61). The cruises were conducted by the University of Delaware and Rutgers University.

b. Data on precipitation and runoff in the Delaware River Basin for 1964-1965 is available in the U.S. Weather Bureau Hydrologic Atlas (59). Further data of this kind is available from the Environmental Data Service and the U.S. Geological Survey.

c. Climatological data collected at lighthouses and lightships. The College of Marine Studies has only recently been able to obtain samples of these lighthouse data and therefore has not been able to evaluate them. A private communication from Dr. John Mather of the geography department at the University of Delaware indicates that they are very probably of low quality. Other sources of information are (15, 25, 41, 58, 59 and 60).

Most of these sources of information are of limited value since they do not provide a continuous record of meteorological conditions over a long enough time to permit meaningful analyses. The meteorological data available for different inland stations--particularly Dover AFB--would be of some limited use for correlating with those hydrographic parameters affected by local meteorological conditions.

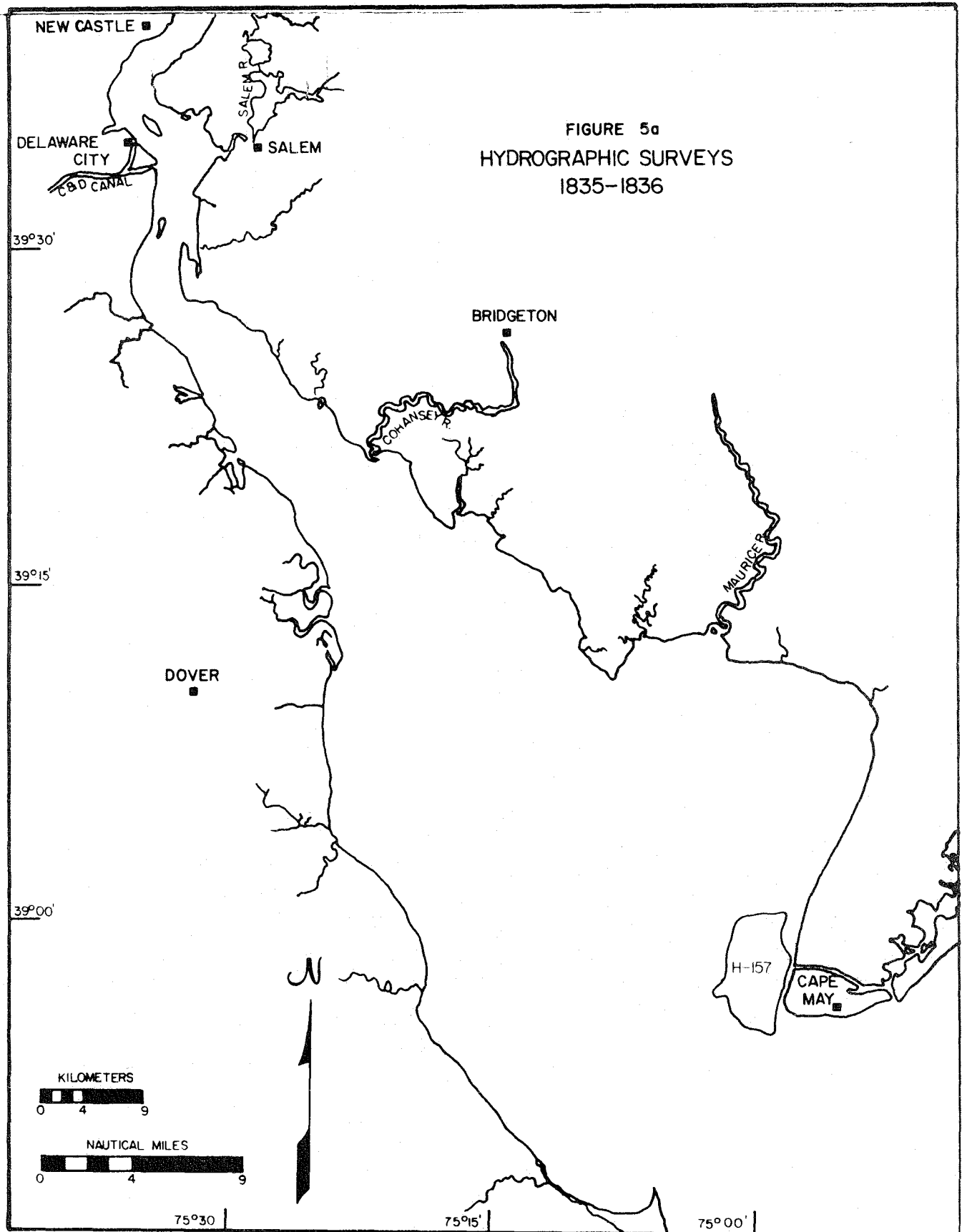
Indeed some work of this type has been undertaken by Oostdam (17). Information on precipitation, air temperature, evaporation and sky cover would be needed for the prediction of salinity and especially temperature patterns in the bay.

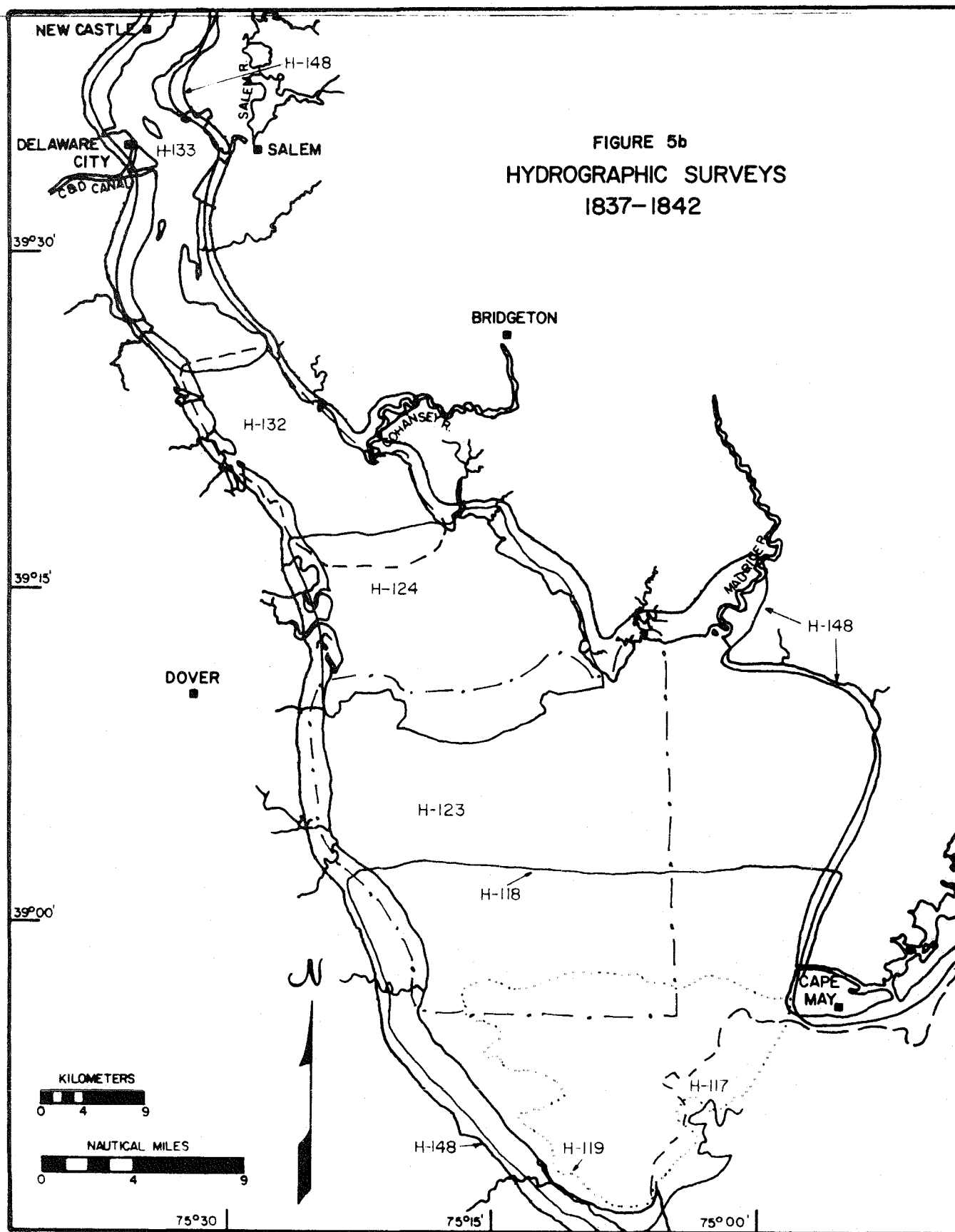
4. SEDIMENTATION, SHORE PROCESSES AND BATHYMETRY

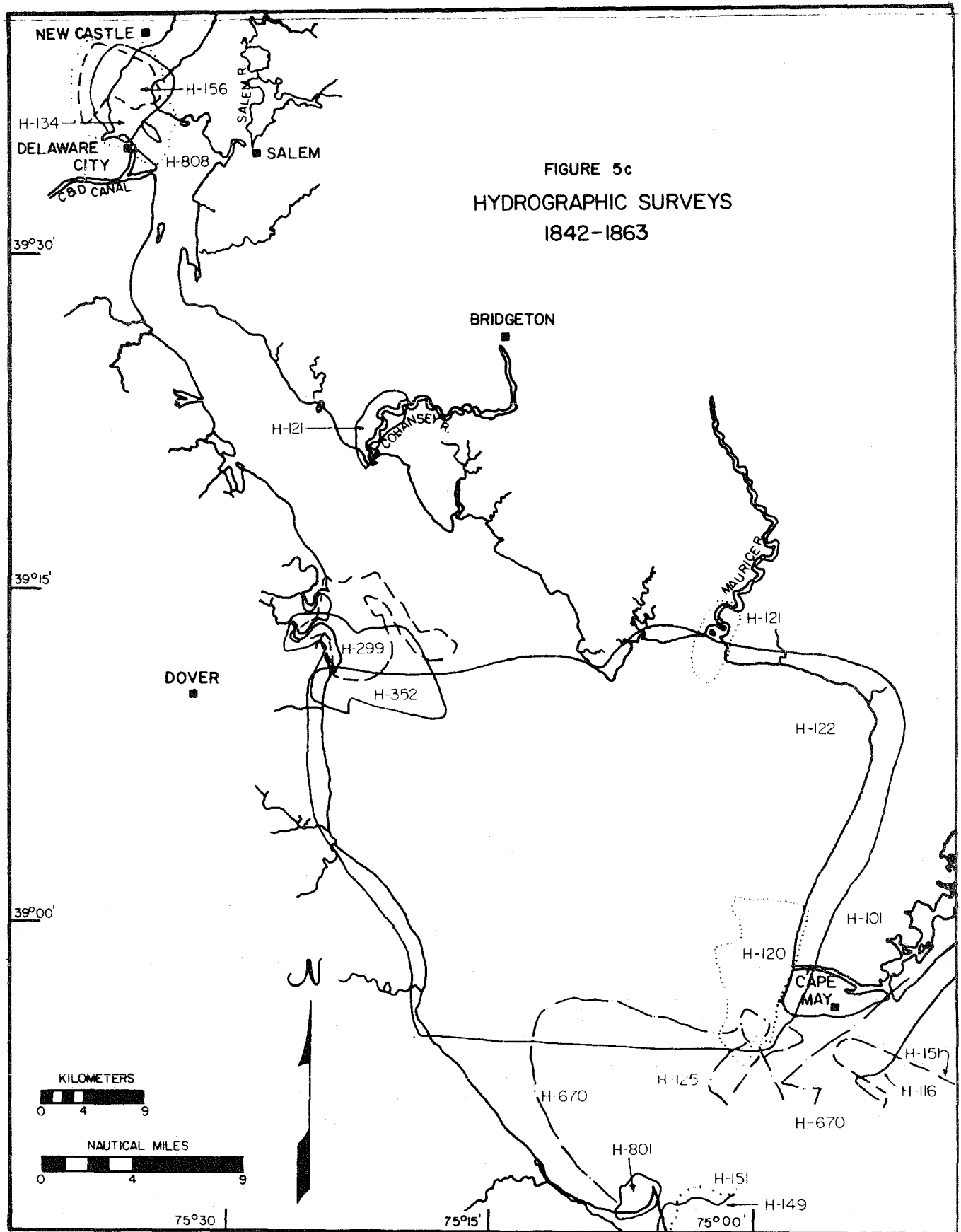
A sizable number of observations have been made on sedimentation and shore processes in Delaware Bay (2, 14, 26, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 63 and 66). A detailed appraisal of the character and source of shoal material to the Delaware River estuary is given by (39). The best documented study on shore processes in the primary coastal zone of the States of Delaware and New Jersey in the vicinity of the bay mouth is that conducted by the U.S. Army Corps of Engineers and published in their latest report "Beach Erosion Control and Hurricane Protection Along the Delaware Bay, Philadelphia District, 1967." The study was made in cooperation with the State of Delaware to formulate a comprehensive plan for restoration of adequate protective and recreational beaches. The study covered the Delaware Bay shore from Kitts Hummock to Cape Henlopen to the state line at Fenwick Island. The following items were studied: the sources and movement of beach material; the changes in the shoreline and the offshore bottom; the effects of waves, storm and of existing structures. The studies providing information on shoreline changes and beach profiles are those by the U.S. Army Corps of Engineers, Philadelphia District, "Beach Erosion Control Report on Cooperative Study of Delaware Coast: Kitts Hummock to Fenwick Island, 1956," and earlier surveys made by the Corps of Engineers 1902-1903 and 1914, and by the U.S. Coast and Geodetic Survey, 1843, 1884, 1910 and 1929. Information available on shore processes for the bay appear to be adequate and need to be

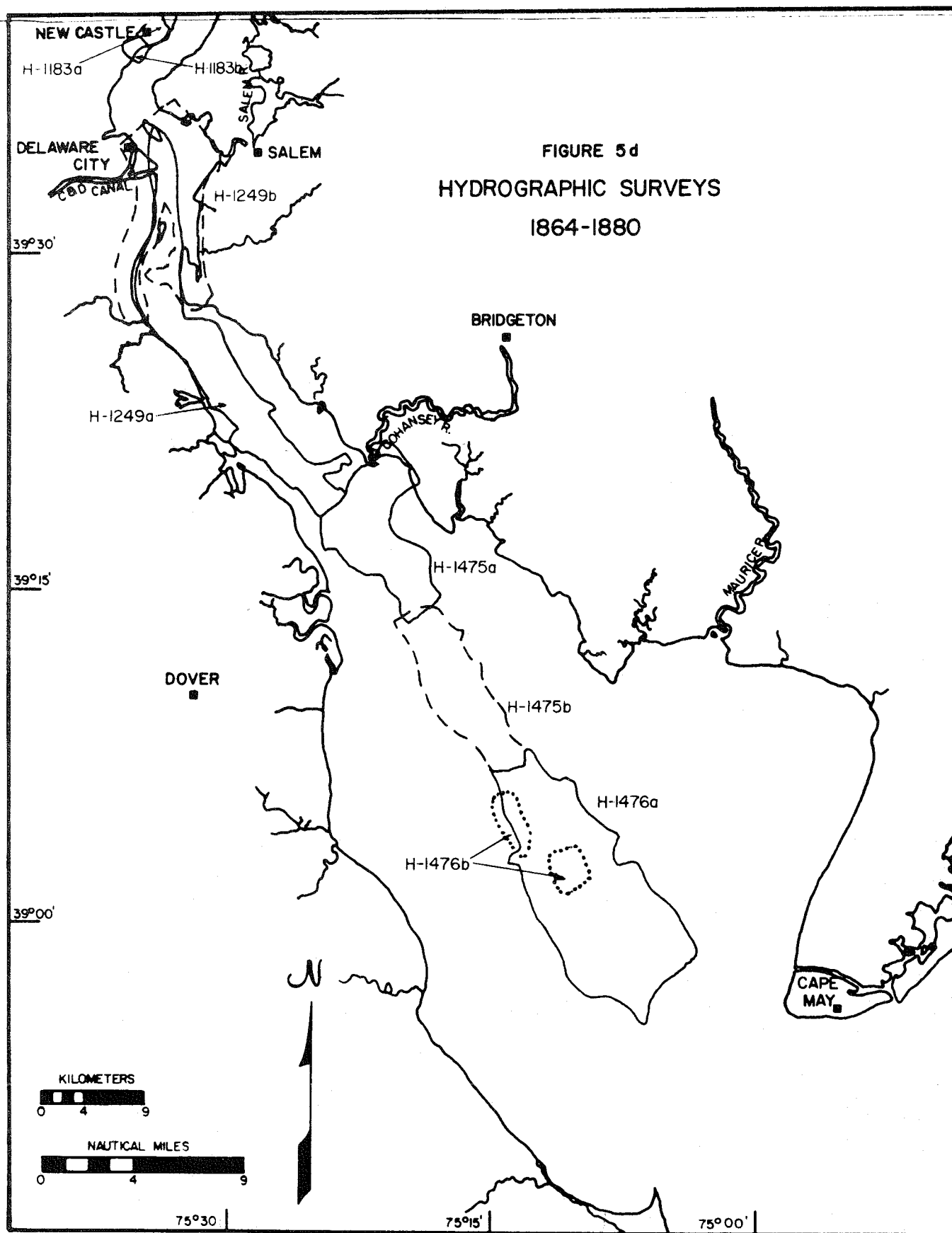
correlated with sea level changes, storm surges, waves, wind, tides, river flow and the supply and loss of beach material. A rigorous analysis cannot be made because of the lack of a comprehensive data collection program where all parameters of interest are monitored to enable their correlation with each other. The analysis of the planned and proposed projects for the Delaware Bay - especially the deep-draft terminal facilities - would require knowledge of the detailed pattern of sedimentation process rather than the general pattern that could be obtained from analyses of existing data such as given in (39). A more detailed examination of the sedimentation pattern is given by Oostdam (17)--showing time series of sediment suspension and turbidity at selected locations in the Bay.

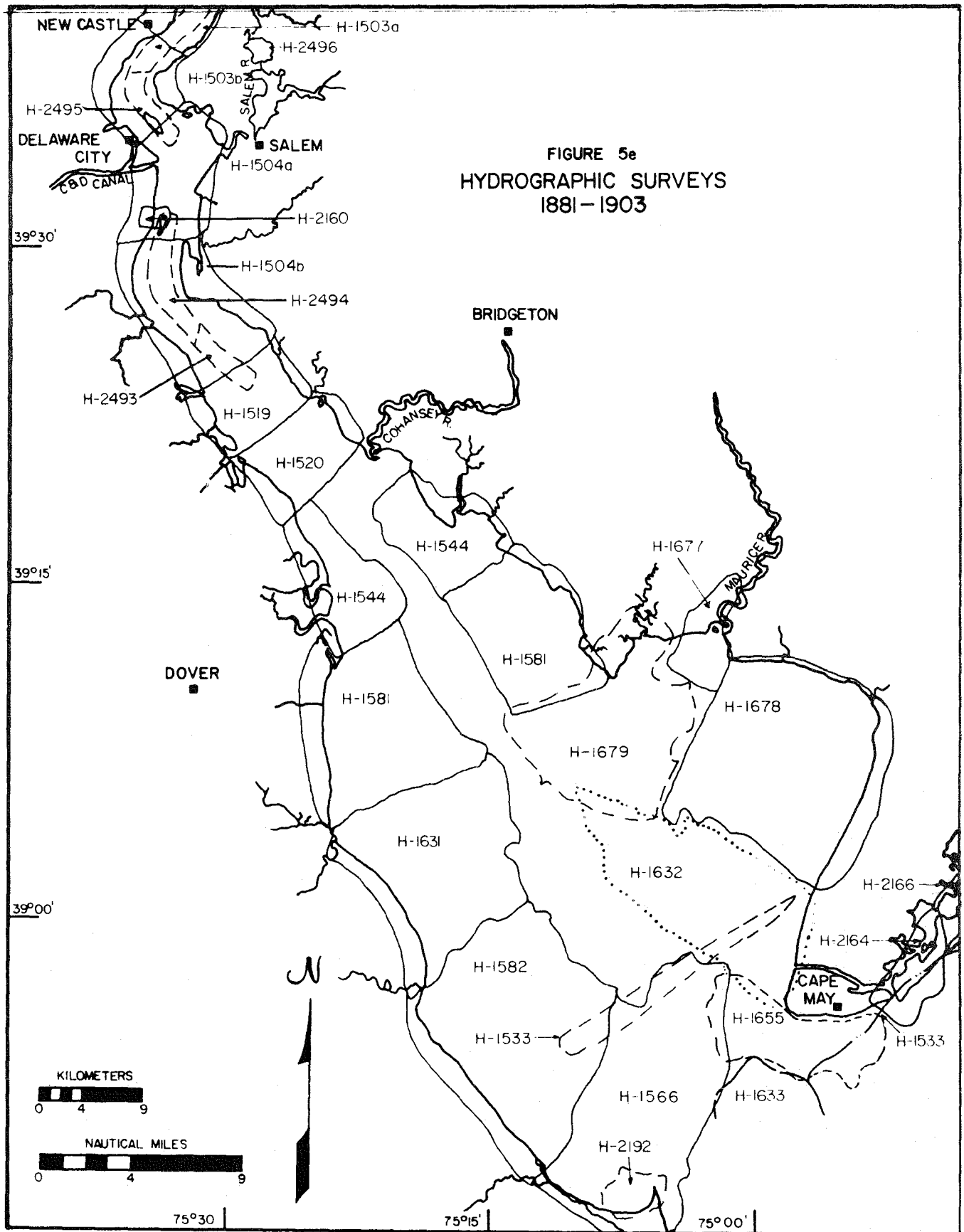
The situation as regards detailed bathymetry is quite unsatisfactory, but is being corrected. Figures 5a-5h show the location and extent of historical surveys of the Bay's bathymetry, while Table III provides the survey dates. A study of these will indicate that there are areas of the Bay (e.g., Joe Flogger Shoal) which have not been systematically surveyed since 1880. Thus, the presently used navigation chart (#1218) has areas in which the depths are off by a factor of 2 (R. Sheridan, private communication). This presents considerable difficulty to anyone attempting to model the hydrodynamics of the lower Bay, as accurate depth information is essential to all state-of-the-art computer and physical models. This situation is being remedied by NOS, which is presently engaged in a five-year project to resurvey the bay. At present only the area around the entrance of the bay has been resurveyed (see figure 5h).

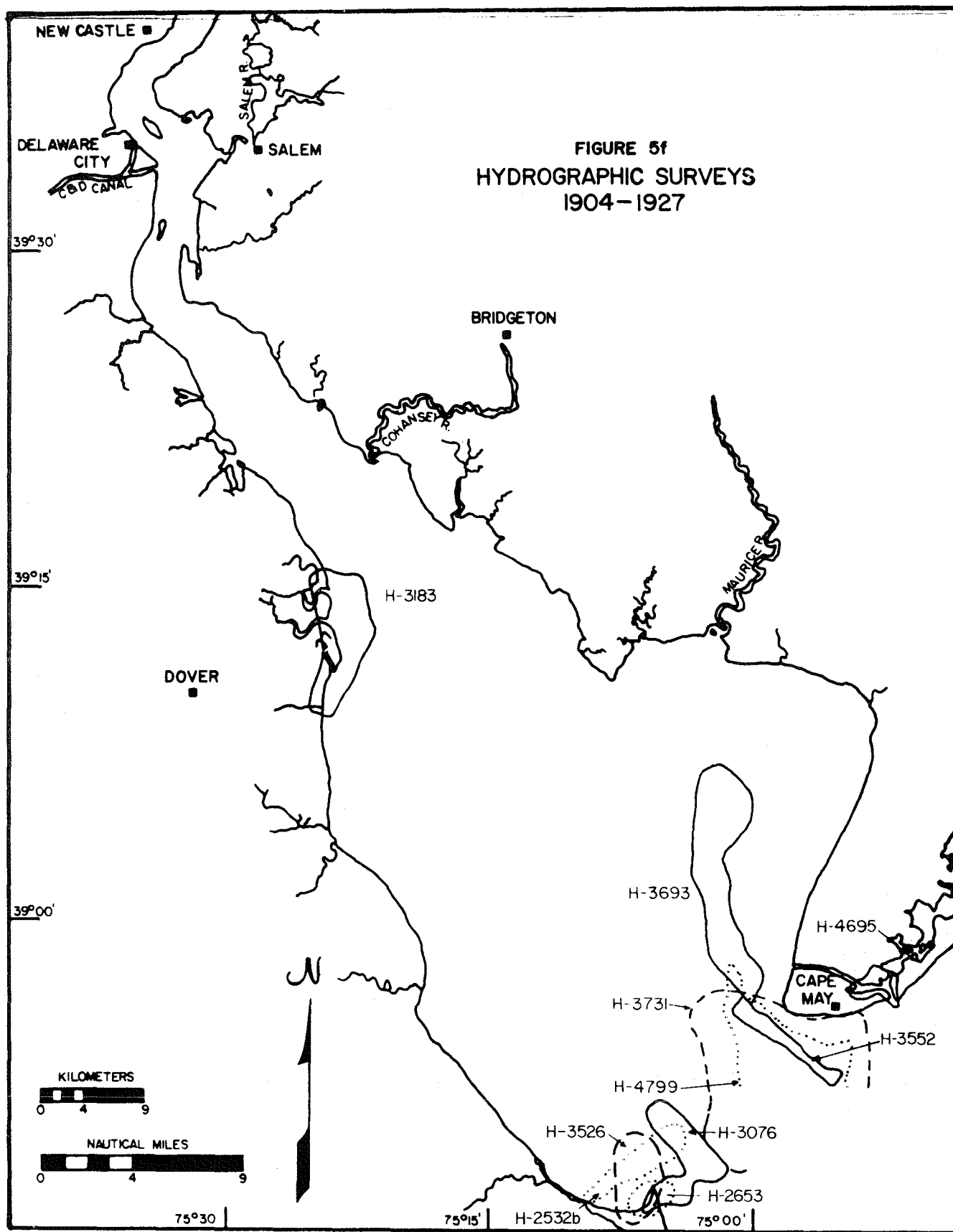


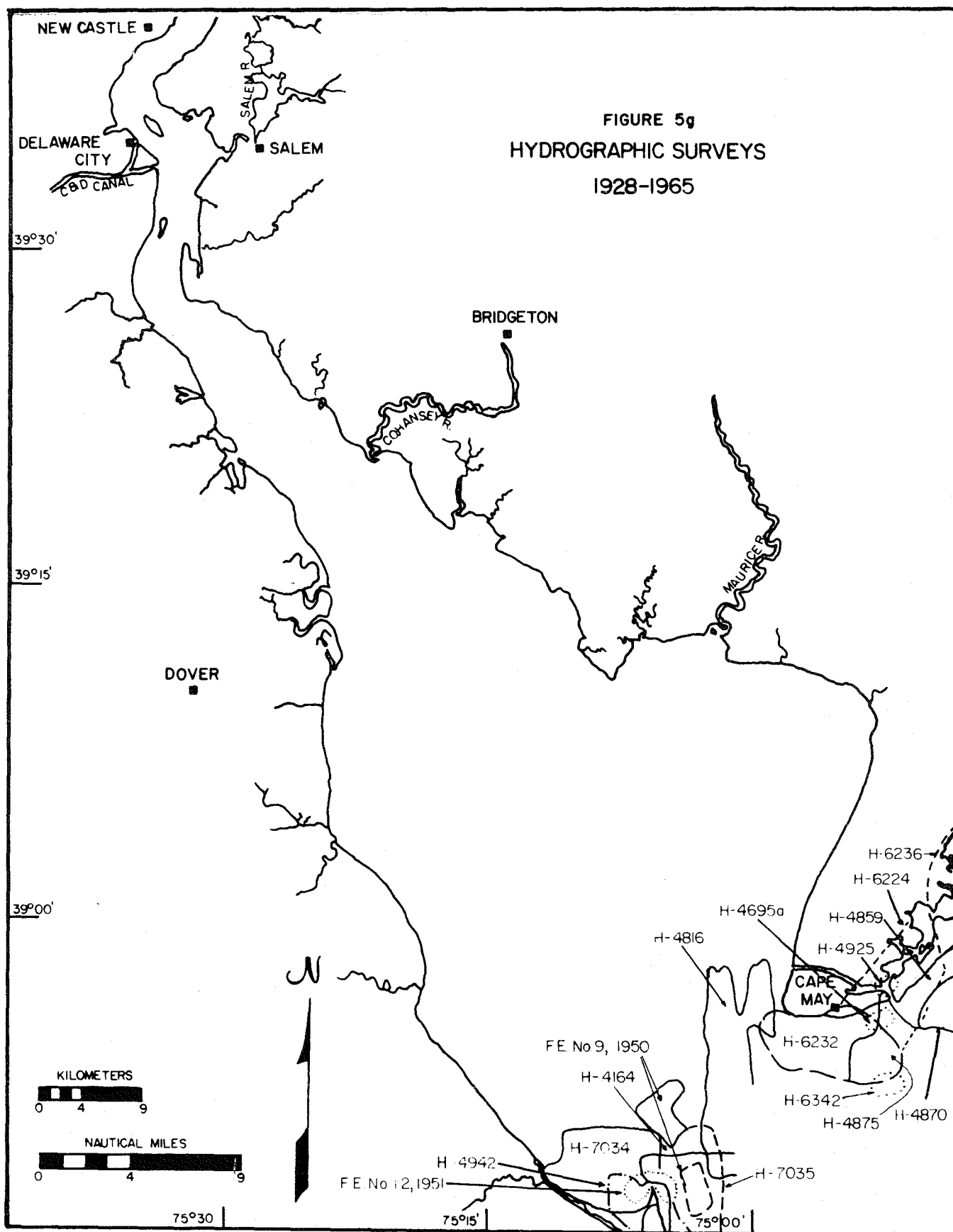












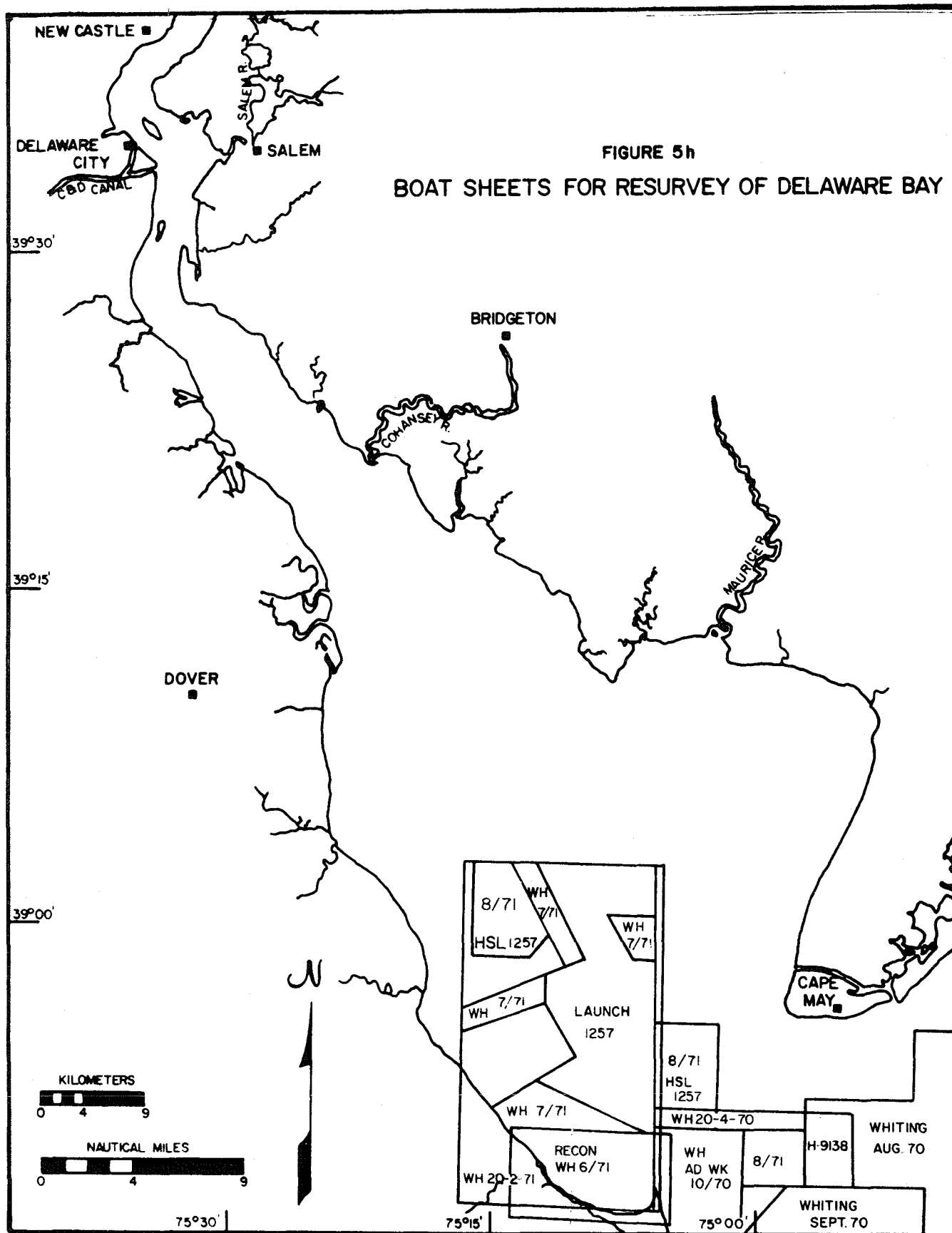


TABLE III*
BATHYMETRIC SURVEYS

<u>Survey No.</u>	<u>Year</u>	<u>Scale</u>	<u>Hydrographic Index Sheet Nos.</u>
H-101	1844	400,000	66C
H-116	1843	40,000	66C
H-117	1841	40,000	66B, 67A
H-118	1842-43	20,000	66C, 67A
H-119	1842	20,000	66C, 67A
H-120	1842	20,000	67A, 66C
H-121	1843	20,000	67B
H-122	1842	20,000	66C, 67A
H-123	1842	20,000	66C, 67A
H-124	1841	20,000	66B, 67A
H-125	1847	20,000	66C, 67B
H-132	1841	20,000	67A
H-133	1840-41	10,000	67A
H-134	1848	20,000	67B
H-148	1841-43	80,000	66B, 67A
H-149	1844	20,000	67B
H-151	1844	40,000	66C, 67B
H-156	1846-47	10,000	67B
H-157	1836-47	10,000	66A
H-299	1852	20,000	67B
H-352	1852	10,000	67B
H-670	1859	400,000	67B, 66C
H-801	1863	3,600	67B
H-808	1861	10,000	67B
H-11832	1873	1,250	67C
H-1183b	1873	1,250	67C
H-1249a	1875	20,000	67C
H-1249b	1875	20,000	67C
H-1475a	1880	20,000	67C
H-1475b	1880	20,000	67C
H-1476a	1880	20,000	67C, 66E
H-1476b	1880	10,000	67C, 66E
H-1503a	1881	5,000	67D
H-1503b	1881	10,000	67D
H-1504a	1881	10,000	67D
H-1504b	1881	10,000	67D
H-1519	1882	10,000	67D
H-1520	1882	10,000	67D
H-1533	1882-1900	40,000	66F, 67D
H-1544	1882	20,000	67D
H-1566	1883	20,000	66F, 67D

TABLE III*
BATHYMETRIC SURVEYS

<u>Survey No.</u>	<u>Year</u>	<u>Scale</u>	<u>Hydrographic Index Sheet Nos.</u>
H-1581	1882-85	20,000	66F, 67D
H-1582	1883	20,000	66F, 67D
H-1631	1884	20,000	67D, 66F
H-1632	1884	20,000	66F, 67D
H-1633	1884	40,000	66F
H-1655	1885	10,000	66G, 67D
H-1677	1885	10,000	66G, 67D
H-1678	1885	20,000	67D, 66G
H-1679	1885	20,000	66G, 67D
H-2164	1891	10,000	66G
H-2166	1891	10,000	66G
H-2192	1894	10,000	67D
H-2493	1900	9,600	67D
H-2494	1900	9,600	67D
H-2495	1900	9,600	67D
H-2496	1900	9,600	67D
H-2532b	1910	20,000	67E
H-2653	1903	10,000	67E
		10,000	
H-3076	1910	20,000	67E
H-3183	1910	20,000	67E
H-3552	1913	25,000	66H, 67E
H-3693	1914	30,000	66H, 67E
H-3731	1914	20,000	66H, 67E
H-4164	1920	40,000	67F
H-4695	1927	5,000	66H
H-4695a	1928	5,000	66I
H-4799	1927	20,000	66H
H-4816	1928	20,000	66I, 67F
H-4859	1928	10,000	66I
H-4870	1928	20,000	66I
H-4875	1928	20,000	66I
H-4925	1929	5,000	66I
H-4942	1929	20,000	67F
H-6224	1937	10,000	66J
H-6232	1937	10,000	66J
H-6236	1937	10,000	66J
H-6342	1938	40,000	66J
H-7034	1945	10,000	67F
H-7035	1945	10,000	67F

TABLE III*
BATHYMETRIC SURVEYS

<u>Survey No.</u>	<u>Year</u>	<u>Scale</u>	<u>Hydrographic Index Sheet Nos.</u>
F. E. No. 9, 1950	1950	40,000	67F
F. E. No. 12, 1951	1951	10,000	67F

*Prepared from National Ocean Survey Hydrographic Index Sheets.

5. FRESH WATER INFLOW

River flow affects tidal heights, current, salinity and sedimentation patterns. River flow data is well documented in (6, 7, 19, 42, and 52). Daily discharge at Trenton data is available for the period 1914-present. The reports of the Delaware River Master (19) provide daily discharge at Trenton since 1954. River discharge data is available in (42) since 1931. Reference (68) provides flow data for tributaries discharging into the Delaware downstream of Trenton. The effect of river flow on estuarine circulation has been discussed in the section on currents.

6. SALINITY

A large amount of salinity data is available for the bay and consist of:

i. Data obtained during the DELZOOOP, J-D, and Winterim cruises covering the period 1951-1959 and January, 1972. The general location of the J-D and Winterim stations are shown in figure 6. The dates of these cruises are shown in Table IV.

ii. Extensive salinity recordings made by the Corps of Engineers in connection with the Delaware River Estuary model study (3). The recordings (24) covered the period 1930-1939 and were made by the Philadelphia District.

iii. An hourly time series of salinity measurements made by the Corps of Engineers for the period 25 January to 8 February 1932 for the following locations: Ship John, abreast Ben Davis Gas Buoy, abreast Elbow of Cross Ledge Light House, abreast Miah Maull and abreast Brandywine Shoal.

iv. Daily recordings made by the Delaware River Master (19) since 1954 at Reedy Island, Delaware Memorial Bridge and Chester.

v. Hourly salinity recordings at Ship John for the period 1969-present from the U.S. Geological Survey.

vi. The National Ocean Survey has data on temperature and salinity at Cape May and Break Water Harbor summarized in (48). The Cape May data covers the period November 1965 - the present with the exception of April - October 1967. Data for Break Water Harbor is

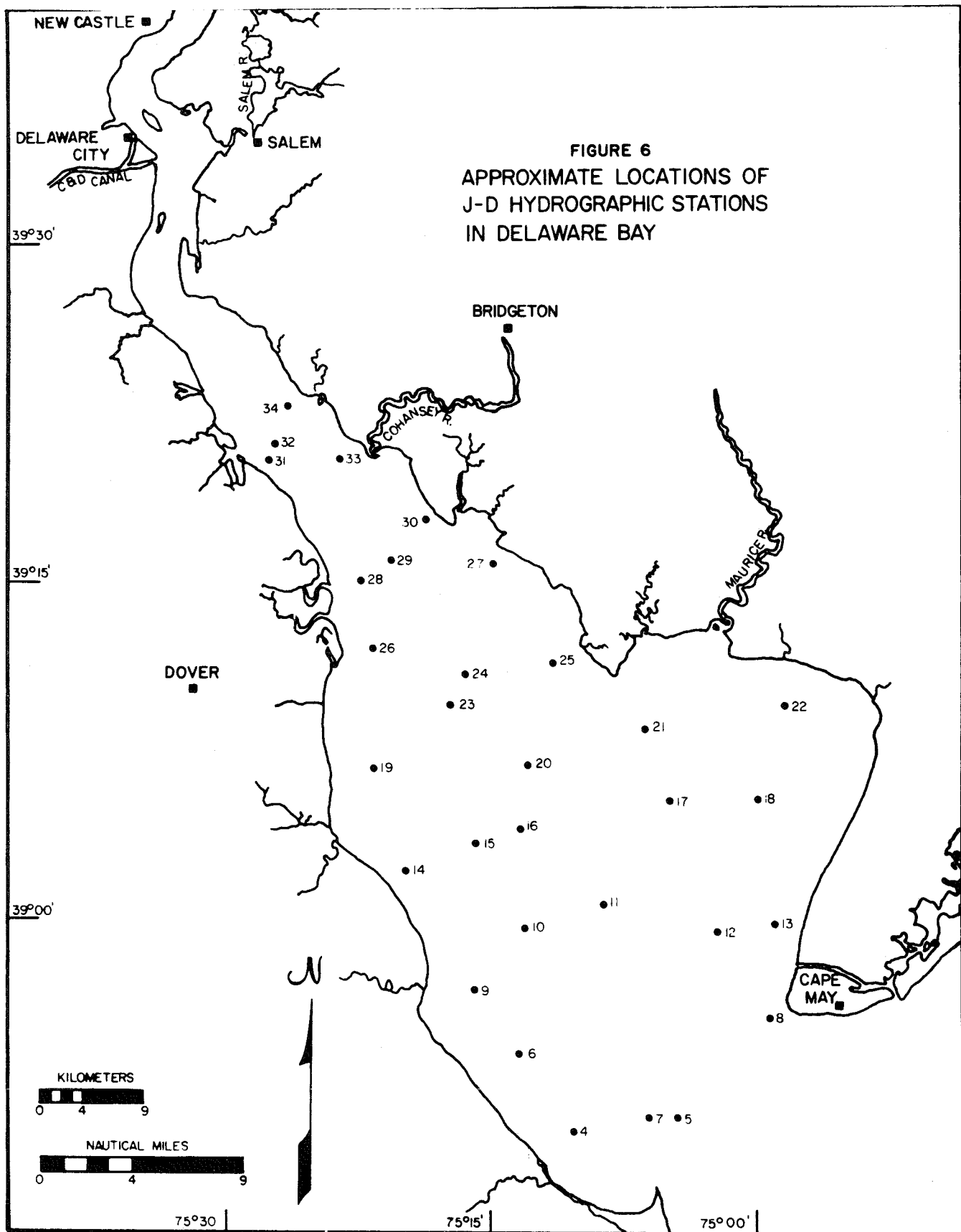


TABLE IV
HYDROGRAPHIC CRUISES IN DELAWARE BAY

<u>Cruise</u>	<u>Date</u>
DELZOOP I	10 Oct. - 10 Nov. 1951
DELZOOP II	30 Nov. - 3 Dec. 1951
DELZOOP III	1-6 Feb. 1952
DELZOOP IV	22-29 May 1952
DELZOOP V	18-22 Aug. 1952
DELZOOP VI	10-17 Nov. 1952
DELZOOP VII	5-12 Feb. 1953
DELZOOP VIII	30 May - 6 June 1953
DELZOOP IX	20-25 Aug. 1953
J-D I	9-13 Aug. 1954
J-D II	18-20 Oct. 1954
J-D III	7-14 March 1955
J-D IV	1-3 Aug. 1955
J-D IV A	22 Aug. 1955
J-D IV B	29 Aug. 1955
J-D V	24-29 Sept. 1955
J-D VI	6, 8, 9 Feb. and 3 March 1956
J-D VII	27 July - 2 Aug. 1956
J-D VIII	10-13 Oct. 1956
J-D IX	? Winter 1957
J-D X	?? 10-25 July 1958 (Spring 1957?)
J-D XI	?
J-D XI A	21-29 Aug. 1957
J-D XII	30-31 Oct. and 7 Nov. 1957
J-D XIII	5, 6, 10 March 1958
J-D XIV	30 April 1958 and 1, 7, 12, 26 May 1958
J-D XV	Sept. 1958
J-D XVI	4, 5, 12 Nov. 1958
J-D XVII	25-27 Feb. 1959 and 3-5 March 1959
Winterim	10-12, 19 Jan. 1972

considerably more extensive running in broken series from 1919 to the present.

vii. Observations on salinity variation with depth (17, 61, and 67).

Salinity pattern in the upper reach of the Delaware estuary would be affected primarily by fresh water inflow and to a lesser extent by tidal height and mean sea level. In the Bay, the variations in the salinity of coastal water moving down the New Jersey coast must also be considered.

Dr. Harold Haskin (71) has made some very rough analyses of the correlation of river flow with salinity. These analyses are rough in that no attempt was made to analyze for the effects of tidal flow on salinity or even to take into account the fact that the salinity at any point in time depends on past rather than present river flow. One would expect on theoretical grounds that the salinity at a given station at a given tidal stage would be a functional of past river flow--e.g., a weighted sum. Ketchum (12) has shown that a characteristic time for this phenomenon--the flushing time--varies from 60-120 days depending on river flow. It is thus not casually significant that salinity in the Bay is correlated with the river flow at Trenton on the day of observation. A more sophisticated analysis was carried out by the Corps for the upper part of the Bay system (31).

Daily salinity recordings at Reedy Island and daily discharge recordings at Trenton (19) for 1967-1970 were prepared for correlation analysis. It is perhaps surprising that for an advanced upstream

location such as Reedy Island no correlation appears to exist between discharge and salinity contrary to the expectation that salinity would decrease for an increase in river flow--tidal activity and mean sea level being constant--but tends to reinforce the criticism of Haskin's work. The river discharge at Reedy Island was not considered in the data since the contribution from the tributaries of Schuylkill, Christina and Salem, as well as the C & D Canal, were not available at the time of the analysis. The combined discharge from these tributaries is about half the discharge at Trenton. Because of the lack of correlation between salinity and river discharge at Reedy Island, salinity was not correlated with river discharge at Ship John which is further downstream than at Reedy Island.

The effect of river flow in changing the estuarine circulation has been discussed above, but the concomitant effect on the salinity structure was not brought out. The effect of increase flow is to increase the stratification of the water column. This means that while the surface salinity will decrease with increased river flow the bottom salinity will not decrease as rapidly, and under some circumstances may actually increase. The data indicates that the Bay actually changes estuarine type with variations in discharge, going from a vertical homogeneous to a partially mixed configuration.

One point that has not been discussed is the presence of salinity frontal systems in the Bay (Szekiela, Klemas, Kupferman and Polis, 1972). These systems are discontinuous breaks in the horizontal

salinity pattern observed in the Bay. (An example may be seen as an irregular white line in Plate 1). They are currently being studied by the referenced authors under funding from the Geography Branch of the Office of Naval Research. During the Winterim Cruise variations up to 4 parts per thousand in one meter horizontally were observed. On one occasion such a front moved through a station being occupied. Had the station been taken 15 minutes earlier or later the front would not have been observed. The existence of such anomalies means that it is important to be extremely careful in interpolating point salinity measurements either in space or in time. The biological effects of these sudden changes on benthic populations can only be guessed at present.

The presently available data are probably adequate to provide a historical baseline on the salinity distributions in Delaware Bay prior to the widening of the C & D Canal. Since that time there has been only one systematic hydrographic cruise--the Winterim Cruise of 1972. However, there has been data taken at the fixed continuous stations listed under items (iv) and (v) above. It is recommended that these data be analyzed to find the effects of the navigation improvements on the canal.

7. TEMPERATURE

Temperature data available is slightly less extensive than that for salinity and consists of:

- i.* Observations made during DELZOO, J-D, and Winterim cruises.
- ii.* Temperature recordings in the Bay (17) and in the vicinity of breakwater (67).
- iii.* Mean monthly temperature for Delaware estuary collected by the U.S. Coast and Geodetic Survey (now NOS) in references (47 and 48). See item *vi* in the last section.

These data reveal that the temperature generally increases with depth in the winter and decreases with depth in the summer. Slight lateral variations also occur. Temperature has some slight effect on the density of the water and so upon the circulation pattern of the Bay; however, this effect is generally negligible in comparison with that of salinity. More important is the effect of temperature on the biota where it is often a controlling fact.

The data on temperature are believed adequate to the foreseeable short term needs. They should be particularly useful for power plant siting studies. The possibility and effects--both physical and biological--of changes in the temperature regime should be the object of special attention in such studies. Massive amounts of hot water effluents could have the effect of further stabilizing the water column against turbulent mixing. The effect of this would be to increase

stratification and alter the circulation pattern and salinity balance of the Bay. A biological consequence might be the further invasion of oyster drills than might otherwise be the case.

8. CONCLUSIONS ON HYDROGRAPHIC DATA

There is a large amount of data available for the Bay. The lack of a planned data gathering program when the data was collected limits its value. The data available was collected to meet the needs of particular studies and not for use in future studies of the Bay. Thus all pertinent parameters were not recorded. The large amount of data available mitigates to a certain extent the lack of a planned data collection program in that accidental coincidences in time are occasionally found.

The hydrographic data needed are:

i. Tides:

The tidal data is generally adequate for the purpose of tidal prediction. It would, however, be useful to augment the existing stations with a number of additional stations both in and around the Bay for a short time--say one or two years--in order that detailed tidal information can be correlated with current, salinity, river discharge, wind and barometric pressure observations.

ii. Currents:

Detailed information on spatial and temporal variations of currents in Delaware Bay would be needed for studies of flushing pattern, mixing, sedimentation, salinity and water quality. There is a need for a two-year program of continuous monitoring of the spatial variation (also with depth) of currents

in the Bay and coastal zone and correlation of currents measured with the parameters enumerated above. This could be achieved by emplacing multisensor arrays in the Bay. Current data would serve as input to planned mathematical and physical models for the Bay which in turn would predict the detailed current pattern in the Bay needed for ecological, engineering and management studies.

iii. Meteorological and Climatological Data:

A two-year time series of wind speed and direction, air temperature, pressure, precipitation (water equivalent), precipitation (ice), evaporation, dew point, and cloud cover for Delaware Bay would prove extremely useful and could be conveniently obtained from the multi-sensor system suggested.

iv. Sedimentation:

Information on the fine details of the sedimentation process in the Bay is needed for the analyses of proposed navigation projects. This is a difficult task and would require the continuous monitoring (for a period of about 2 years) of the suspended and bed load material and its correlation with pertinent parameters such as currents, salinity and river discharge. The collection of data on suspended sediments could also be achieved from a multi-sensor system. Sedimentation data collected could be correlated with the gross sediments balance for the Bay obtained from periodic surveys. Knowledge of the

fine details of sedimentation (a nonstationary stochastic process) in the Bay might require the stochastic modeling of the process. This would be a timely undertaking. The planned mathematical model, the proposed rotating physical model and a stochastic sedimentation model would be complementary to each other.

v. Fresh Water Inflow:

Continuation of daily discharge data currently being taken together with monitoring of flows through the C & D Canal.

vi. Salinity

Salinity data needed consist of a continuous monitoring or frequent periodic sampling for a period of two years of salinity variation with depth at a few selected locations. The latter alternative should be supplemented with full tidal cycle observations at each station for a number of representative salinity distributions. The former alternative can be conveniently implemented from the multi-sensor system. Periodic sampling of salinities at a larger number of stations in a manner similar to that employed in J-D Cruises to complement the salinity information obtained in the above, is also necessary.

vii. Temperature

A program similar to that for salinity above is needed.

The available data could be analyzed to give useful information on the Bay. This would require additional data gathering to fill the gaps that are present—particularly in wave and meteorological record-

ings. A proposed method of analysis would be to develop a functional representation for each of the parameters of interest such as height of tide, current speed, wave height, salinity, temperature and sedimentation patterns, for instance, the height of tide at the location as predicted from tidal harmonic constants, wind speed and river flow. In this case the functional relationship would be developed for selected locations in the Bay and estuary and would utilize available data and perhaps some additional data to be gathered when found necessary. Such a scheme of data analysis might give insight into the physical processes in the Bay but would not serve as a predictor of conditions in the Bay resulting from modifications of existing conditions. The scheme would not give a detailed representation of the physical processes in the Bay. Both these shortcomings could be overcome by a simulation model for the Bay as planned by CMS under the NSF/RANN program.

9. SUMMARY ON HYDROGRAPHIC DATA

i. Adequate observations on tidal heights are available for locations on both sides of the Delaware Bay for navigational purposes. Additional data would be needed at locations in the Bay for more sophisticated modeling work.

ii. Current observations available are inadequate to establish the fine structure of the current pattern in the Bay, and to predict the effects of wind and river flow on the currents, as well as the effects of recent engineering changes.

iii. Only sparse meteorological data (wind speed and direction, air temperature, pressure, precipitation, evaporation, dew point and sky cover) could be obtained for Delaware Bay. Extensive information is available from ESSA for inland stations only.

iv. A sizeable amount of sedimentation data is available for the Bay. The lack of a comprehensive data acquisition program for the Bay during the time when sedimentation observations were made limits the value of the data.

v. The current bathymetric data for the Bay is the result of surveys dating back to 1880. The badly needed resurvey is currently being undertaken by NOS.

vi. Data on fresh water inflow provided in the form of daily discharges is adequate for foreseeable needs in the bay.

vii. A large amount of salinity data is available. Additional

measurements are needed to determine the temporal variation of salinity with depth at representative locations in the Bay. Periodic sampling in a manner similar to that followed in J-D Cruises would be needed to complement the time series salinity data.

viii. Temperature data available is adequate for short-term planning needs; however, this type of data should be routinely acquired with salinity data in order to calculate the density of the water.

ix. Future data gathering to fill in present gaps could be conveniently made from multi-sensor arrays at selected locations in the Bay and the coastal zones of Delaware and New Jersey. The sensors should provide a continuous record (for a period of about two years) of height of tides, currents, salinity, temperature, sedimentation, waves, and meteorological and climatological conditions. The data gathered could be used in the development of functional representations and the simulation model outlined in Section 8-*vii* above.

x. Use of remote sensing to study sedimentation and temperature pattern for the Bay and the coastal zone could be effective and should be further investigated.

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B. EVALUATION OF AVAILABLE BIOLOGICAL DATA

We have far more biological knowledge about Delaware Bay than physical knowledge, but in view of the greater complexity of the biological aspects of the Bay ecosystem, still more knowledge in this area is necessary in order to develop an integrated view of the system. At the same time, the scientific and technical community is more familiar with the sources and types of biological data available than with those of physical knowledge. This inventory highlights the biological data for the Bay, rather than treating it in exhaustive detail. A more comprehensive treatment is available in a report to the Council on Environmental Quality prepared by D. Maurer, in connection with a preliminary study of the ecological impact of a deep-draft terminal in Delaware Bay. In addition the reader is referred to volumes 5, 6, and 7 of this series where several of the more important biological areas are dealt with in detail.*

* See the Series Summary in this volume, beginning on page xiv.

1. GENERAL DESCRIPTION OF THE BAY ECOSYSTEM

The organisms of the estuarine system may be divided into various communities or local associations: the tidal marsh community, the benthic (or bottom) community, and the pelagic (or water-borne) community. Each of these plays a vital role in the total economy of the Bay. The marshes and tidal creeks are the nurseries for many important species, and are also vital as a source of nutrients. The benthic community includes such shell fisheries as blue crab, oysters, and clams. It is also of importance as an indicator of pollution, as many of its organisms are immobile. The pelagic community encompasses the major fin fisheries and the various species of plankton that form the foundation of the Bay's food webs.

The biota of the Bay can also be described by their functional character in the food chain. This allows us to follow the biological energy flow in a scheme that begins with the photosynthesizing plants as primary producers, runs through the primary consumers, on up to the top carnivores, and finally back down through the decomposing organisms that recycle the nutrients.

These two ways of describing the biology of the ecosystem may be displayed against one another in a matrix:

Functional Communal	Primary Producers	Primary Consumers	Intermediate Consumers	Top Carnivores	Decomposers
Pelagic	Phyto-plankton	Zooplankton and Nektonic Organisms	Nektonic Organisms (Vertebrates & Invertebrates)		Bacteria & Fungi
Benthic	Benthic Algae	Benthic Invertebrates Fish Fish			
Marsh, Tidal Creek & Shore Zone	Algae & Higher Plants	Insects, Protozoa, Etc.	Fish & Invertebrates	Birds & Fish	

Here we have displayed the various trophic levels in the horizontal direction, while arranging the communities vertically. In each square is the name of the group or groups of organisms functioning on a given trophic level in the appropriate community.

This review has evaluated the available information against this theoretical description and has revealed that only a small portion of this system has been investigated. In particular, the only boxes that have been well studied are the fin-fish and some benthic invertebrates, although there has been some work on the zooplankton (Cronin, Daiber, and Hulbert, 1962).

2. GENERAL SOURCES AND SUMMARIES OF BIOLOGICAL INFORMATION

The principal sources of biological information for Delaware Bay are the marine biologists at Rutgers University and the University of Delaware. Rutgers University has been active since before the turn of the century, while the University of Delaware began its research in this area with the founding of a marine field station in 1951. More recently (1970) the University of Delaware founded a College of Marine Studies which absorbed the marine biology group and supplemented it with workers in other areas of marine research. At Rutgers, H. Haskins, who has long been noted for his careful work on the biological problems of the New Jersey side, is the person to contact. At Delaware, F. Daiber is the most experienced biologist and is most familiar with the biology of the marshes and ichthyology of the Bay; D. Maurer has worked extensively on the benthic populations and interdisciplinary problems involving environmental impacts. Other members of the faculty have their individual areas of expertise and rather than list them all the enquirer is advised to contact K. Price, assistant dean and head of the field station at Lewes, Delaware.

Other sources of biological information are: the Ichthyological Associates, who have been studying the estuary in the vicinity of Artificial Island in connection with the Salem Nuclear Generating Station (Schuler, 1971); R. Patrick's group at the Philadelphia Academy of Science, which has carried out some marsh work along the

estuary; and W. Amos at St. Andrew's School in Middletown, Delaware, who is in possession of a great deal of unpublished historical data.

The last comprehensive summary of the Bay's biology is that of Shuster (1959). Newer summaries on special aspects of the Bay's biology are to be found in other volumes of this series as was noted above. Entrance to the literature may be gained through the comprehensive bibliography in Volume 10 of this series as well as the supplementary bibliography at the end of this section.

3. BENTHIC INVERTEBRATES*

The literature on marine invertebrates is huge and even the subcategory of bottom dwelling marine invertebrate communities is extremely large. A few of the major reviews on benthic communities include Thorson (1957), Ramont (1963), Carriker (1967), Muus (1961), Pearce (1967), Lie (1968), and Jones (1969). These publications together with the extensive surveys off southern California, the biotic census of the Cape Cod area by the Systematics Ecology Program, Woods Hole, Massachusetts, and the near shore and oceanic benthic investigations by the Duke Marine Laboratory, Beaufort, North Carolina, represent the majority of work done in this field in the United States.

In terms of publications on benthic communities in Delaware Bay, the situation is considerably different. To date, the only work has been concerned with a single species, a specific taxonomic group or a special problem (Stauber 1950, Bousfield 1969, Watling and Maurer 1972 a, b). Although there is no published information on benthic communities in the Bay area, this does not mean there has been no activity. The Rutgers University Oyster Laboratory has been collecting data on associated oyster fauna for many years. In the early fifties, W. Amos, resident biologist, University of Delaware Marine Laboratories, conducted benthic research from the mouth of

*Prepared by D. Maurer

the bay almost to Trenton. At present a private research group, Ichthyological Associates, is conducting an extensive survey in the area of Artificial Island. Research on benthic communities in Rehoboth and Indian River Bays was recently completed by the CMS laboratories. This research has resulted in a manuscript on "Shallow Water Amphipods of Delaware Bay", which has been accepted for publication.

Most of the local benthic research conducted in the past had a variety of limitations. In some cases the work was seasonal with greater emphasis on summer collections. In other cases, surveys were restricted by geographic boundaries, hydrographic conditions, and ecologic units. Still others did not involve systematic quantitative collecting methods. Finally, these studies were not integrated with simultaneous studies of other aspects of the ecosystem to provide a comprehensive integrated knowledge of ecological interactions.

4. FINFISH*

June and Reintjes (1957) describe the Delaware Bay area as one of the most productive coastal regions in North America. As far as fish are concerned, this area is an important spawning and nursery ground for many species. Also the fish fauna (see Table V) present is distinct from adjacent estuarine systems in that it is a geographical overlap area for boreal and subtropical species. Since the demand for fish and sport fishing is constantly increasing, and since approximately 70% of marine fish depend directly on the estuary in some way, it is imperative that we understand how fish utilize this area. Without adequate knowledge of these natural demands the Commission cannot properly dictate the guidelines man must follow in developing and utilizing the Delaware estuarine area.

According to Stevenson (1952), the University of Delaware began an inventory of the marine natural resources of the State in January 1952. Before this time, he states, the only consistent records kept were annual estimates compiled by the Fish and Wildlife Service. Stevenson gives data on types of commercial fishing gear operating from Delaware ports in 1952, and also data on the marine sport fishery for the State south of Slaughter Beach in 1952. Daiber (1954a) lists catch statistics for commercial fishing in Delaware in 1952, pounds of fish landed by species for boats out

* Prepared by K. Price and R. Smith

of Lewes from 1947-1954, and data on the marine sports fishery in Delaware for 1953. Data on the relative abundance of fish as sampled in the commercial catch from 1951-54, and by a research vessel 1953-54 are given by Daiber (1954b). He also gives a brief description of a beach zone investigation for fish. Fish were collected with a 25-foot hand seine at five locations: Lewes Beach, Slaughter Beach, Kitts Hummock, Woodland Beach, and Augustine Beach. These stations were all sampled on the same day at biweekly intervals from September 1952-October 1953. Data from this shore zone fish survey is given in Shuster (1959). Shuster (1959) also has a figure showing the commercial fishing areas in Delaware Bay, and from this we can relate the commercial catch to these areas of the Bay.

June and Reintjes (1957) surveyed the fisheries in the coastal area between Barnegat Lightship and Winter Quarter Lightship seaward to the 100-fathom contour line. Reintjes and Roithmays (1960) did a supplemental survey in the above area. Another study on changes of fish populations in the middle Atlantic area was done by Perlmutter (1959).

A fish survey program was organized and started for the Delaware River estuary and coastal area in 1958 by de Sylva (1959). The survey included 24 trawl stations and 20 shore seine stations; and four trolling cruises were made in the ocean off Rehoboth. The locations of these stations are given in Figure 7. Trawl sampling was done with a 30-foot otter trawl being towed 30 minutes at each station. Lengths, scales, and stomachs were taken from some fish

caught. Other samples or observations taken at the trawl stations included a half-hour tow with a Clarke-Bumpus sampler or a 1-meter plankton net at the surface; 1-liter water samples at the surface, mid-depth, and bottom along with temperatures at these depths; secchi disk reading; and meteorological conditions, air temperature, and relative humidity. Water samples were analyzed for salinity, dissolved oxygen and oxygen saturation, and inorganic phosphate. The 24 stations were only sampled twice, once in September and once in October-November, because of lack of funds. The shore zone stations were sampled with a 50-foot 1/2 inch stretch mesh seine. Other data taken and observations made included air and water temperature; water samples; bottom type; and meteorological and general ecological conditions. Fifteen of these stations were sampled approximately every two months, while others were sampled more frequently. A total of 74 collections was made.

This shore zone survey was continued until February, 1960, with sampling of 16 of the 20 original stations being done approximately every two months (de Sylva, Kalber, and Shuster, 1962). Sampling under this program was done using a 60 x 4-foot seine with 1/2 inch stretch mesh and a 6-foot bag of 1/4 inch stretch mesh sewn in the middle. Normally, three hauls of about 50 yards in length were made at each station; the hauls being made with the tide whenever possible. Stomachs of fish were usually examined whenever sufficient fish were available. A description of the sampling stations is given in the report along with data collected. An excellent bibliography con-

TABLE V

FISH OBSERVED IN THE DELAWARE BAY AREA*

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
SAND TIGERS	ODONTOSPIDIDAE	
Sand Tiger	<u>Odontaspis taurus</u> Rafinesque	dS, K, & S. Given as: sand shark: Carcharius Taurus
REQUIEM SHARKS	CARCHARHINIDAE	
Smooth dogfish	<u>Mustelus canis</u> Mitchill	dS, K & S
Sandbar Shark	<u>Carcharhinus</u> <u>milberti</u> Valenciennes	dS, K & S
Blue Shark	<u>Prionace glauca</u> Linnaeus	dS, K & S
Atlantic sharpnose shark	<u>Rhizoprionodon</u> <u>terraenovae</u> Richardson	dS, K & S; given as Scoliodon terraenovae
CAT SHARKS	SCYLORHINIDAE	
Chain dogfish	<u>Scyliorhinus</u> <u>retifer</u> Garman	FCD

*Prepared by J. Gordon

References noted are as follows: USFS = United States Fisheries Statistics; IA = Schuler, V. J. (1971); dS = de Sylva, Kalber and Shuster (1962); FCD = supplemental information from course on ichthyology given by F. C. Daiber.

TABLE V

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
DOGFISH SHARKS	SQUALIDAE	
Spiny dogfish	<u>Squalus acanthius</u> Linnaeus	dS, K & S
ANGEL SHARKS	SQUATINIDAE	
Atlantic angel shark	<u>Squatina dumerili</u> Lesueur	dS, K & S
HAMMERHEAD SHARKS	SPHYRNIDAE	
Bonnethead	<u>Sphyrna tiburo</u> Linnaeus	dS, K & S
ELECTRIC RAYS	TORPEDINIDAE	
Atlantic torpedo	<u>Torpedo nobiliana</u> Bonaparte	FCD
SKATES	RAJIDAE	
Clearence skate	<u>Raja eglanteria</u> Bosc	dS, K & S
Little skate	<u>Raja erinacea</u> Mitchill	dS, K & S
Barndoor skate	<u>Raja laevis</u> Mitchill	dS, K & S
Rosette skate	<u>Raja garmani</u> Whitley	FCD
Winter skate	<u>Raja ocellata</u> Mitchill	FCD
STINGRAYS	DASYATIDAE	
Roughtail stingray	<u>Dasyatis centroura</u> Mitchill	dS, K & S

TABLE V

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
Bluntnose stingray	<u>Dasyatis sayi</u> Lesueur	dS, K & S
Spiny butterfly ray	<u>Gymnura altavela</u> Linnaeus	FCD
Smooth butterfly ray	<u>Gymnura micrura</u> Block & Schneider	FCD
Yellow stingray	<u>Urolophus</u> <u>jamaicensis</u> Cuvier	FCD
EAGLE RAYS	MYLIOBATIDAE	
Bullnose ray	<u>Myliobatis</u> <u>freminvillei</u> Lesueur	dS, K & S
Cownose ray	<u>Rhinoptera</u> <u>bonasus</u> Mitchill	FCD
CHIMAERA	CHIMAERIDAE	
Ratfish	<u>Hydrolagus colliei</u> Lay & Bennett	FCD
STURGEONS	ACIPENSERIDAE	
Atlantic sturgeon	<u>Acipenser</u> <u>oxyrhynchus</u> Mitchill	FCD, dS, K & S
FRESHWATER EELS	ANGUILLIDAE	
American eel	<u>Anguilla rostrata</u>	IA, dS, K & S
HERRINGS	CLUPEIDAE	
Blueback herring	<u>Alosa aestivalis</u>	IA, dS, K & S
Hickory shad	<u>Alosa mediocris</u>	IA, FCD

TABLE V

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
Alewife	<u>Alosa pseudoharengus</u>	IA, dS, K & S
American shad	<u>Alosa sapidissima</u>	IA, dS, K & S
Atlantic menhaden	<u>Brevoortia tyrannus</u>	IA, dS, K & S
Atlantic herring	<u>Clupea harengus</u> <u>harengus</u>	dS, K & S
Round herring	<u>Etrumeus teres</u>	dS, K & S; given as, Etrumeus sadina
Gizzard shad	<u>Dorosoma cepedianum</u>	IA
Atlantic thread herring	<u>Opisthonema oglinum</u>	
ANCHOVIES	ENGRAULIDAE	
Striped anchovy	<u>Anchoa hepsetus</u>	dS, K & S, IA
Bay anchovy	<u>Anchoa mitchilli</u>	dS, K & S
LIZARDFISHES	SYNODONTIDAE	
Inshore lizardfish	<u>Synodus foetens</u>	dS, K, & S
MINNOWS AND CARPS	CYPRINIDAE	
Goldfish	<u>Carassius auratus</u>	dS, K & S
Carp	<u>Cyprinus carpio</u>	dS, IA
Cutlips minnow	<u>Exoglossum</u> <u>maxilllingua</u>	FCD
Silvery minnow	<u>Hybognathus nuchalis</u>	dS, K & S, IA
Golden shiner	<u>Notemigonus</u> <u>crysoleucas</u>	dS, IA
Bridle shiner	<u>Notropis bifrenatus</u>	dS, K & S

TABLE V

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
Spottail shiner	<u>Notropis hudsonius</u>	dS, IA
Satinfin shiner	<u>Notropis analostanus</u>	IA
FRESHWATER CATFISHES	ICTALURIDAE	
White catfish	<u>Ictalurus catus</u>	dS, K & S, IA
Brown bullhead	<u>Ictalurus nebulosus</u>	dS, IA
Channel catfish	<u>Ictalurus punctatus</u>	IA
RIGHTEYE FLOUNDERS	PLEURONECTIDAE	
Winter flounder	<u>Pseudopleuronectes americanus</u>	dS
SOLES	SOLEIDAE	
Hogchoker	<u>Trinectes maculatus</u>	dS, IA
TRIGGERFISHES AND FILEFISHES	BALISTIDAE	
Orange filefish	<u>Aluterus schoepfi</u>	dS (as: Alutera)
PUFFERS	TETRAODONTIDAE	
Smooth puffer	<u>Lagocephalus laevigatus</u>	dS
Northern puffer	<u>Sphaeroides maculatus</u>	dS
PORCUPINEFISHES	DIDONTIDAE	
Striped burrfish	<u>Chilomycterus schoepfi</u>	dS

TABLE V

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
MOLAS	MOLIDAE	
Ocean sunfish	<u>Mola mola</u>	dS
BLUEFISHES	POMATOMIDAE	
Bluefish	<u>Pomatomus saltatrix</u>	dS
REMORAS	ECHENEIDAE	
Remora	<u>Remora remora</u>	FCD
WOLFFISHES	ANARHICHADIDAE	
Atlantic wolffish	<u>Anarhichus lupus</u>	FCD
SAND LANCES	AMMODYTIDAE	
American sand lance	<u>Ammodytes americanus</u>	FCD
GOBIES	GOBIIDAE	
Naked goby	<u>Gobiosoma boscii</u>	dS, IA
Seaboard goby	<u>Gobiosoma ginsburgi</u>	dS
MACKERELS & TUNAS	SCOMBRIDAE	
Atlantic mackerel	<u>Scomber scombrus</u>	dS, USFS
Atlantic bonito	<u>Sarda sarda</u>	dS
BILLFISHES	ISTIOPHORIDAE	
White marlin	<u>Tetrapturus albidus</u>	dS (as: Makaira albaida)
Blue marlin	<u>Makaira nigricans</u>	dS
Pinfish	<u>Lagodon rhomboides</u>	dS

TABLE V

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
DRUMS	SCIAENIDAE	
Silver perch	<u>Bairdiella chrysura</u>	dS, IA
Weakfish	<u>Cynoscion regalis</u>	dS, IA
Spot	<u>Leiostomus xanthurus</u>	dS
Northern kingfish	<u>Menticirrhus saxatilis</u>	dS
Atlantic croaker	<u>Micropogon undulatus</u>	dS
Black drum	<u>Pogonias cromis</u>	dS
BUTTERFLYFISHES	CHAETODONTIDAE	
Blue angelfish	<u>Holacanthus bernudensis</u>	FCD
Queen angelfish	<u>Holacanthus ciliaris</u>	FCD
WRASSES	LABRIDAE	
Tautog	<u>Tautoga onitis</u>	USFS, dS
Cunner	<u>Tautogolabrus adspersus</u>	FCD, dS
PARROTFISHES	SCARIDAE	
Rainbow parrotfish	<u>Scarus guacamaia</u>	FCD
MULLET	MUGILIDAE	
Striped Mullet	<u>Mugil cephalus</u>	dS
STARGAZERS	URANOSCOPIDAE	
Northern stargazer	<u>Astroscopus guttatus</u>	dS

TABLE V

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
TOADFISHES	BATRACHOIDIDAE	
Oyster toadfish	<u>Opsanus tau</u>	dS
GOSEFISHES	LOPHIIDAE	
Goosefish	<u>Lophius americanus</u>	dS
CODFISHES	GADIDAE	
Fourbeard rockling	<u>Enchelyopus cimbrius</u>	dS
Atlantic cod	<u>Gadus morhua</u>	dS
Haddock	<u>Melanogrammus aeglefinus</u>	FCD
Silver hake	<u>Merluccius bilinearis</u>	dS
Pollock	<u>Pollachius virens</u>	dS
Red hake	<u>Urophycis chuss</u>	dS (as: squirrel), USFS
Spotted hake	<u>Urophycis regius</u>	dS
CUSK-EELS & BROTLAS	OPHIDIIDAE	
Striped cusk-eel	<u>Rissola marginata</u>	FCD
FLYINGFISHES AND HALFBEAKS	EXOCEETIDAE	
Atlantic flyingfish	<u>Cypselurus heterurus</u>	FCD
Halfbeak	<u>Hyporhamphus unifasciatus</u>	dS

TABLE V

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
NEEDLEFISHES	BELONIDAE	
Flat needlefish	<u>Ablennes hians</u>	dS
Atlantic needlefish	<u>Strongylura marina</u>	dS
Houndfish	<u>Tylosurus crocodilus</u>	dS (as: <u>Strongylura raphidoma</u>)
KILLIFISHES	CYPRINIDONTIDAE	
Sheepshead minnow	<u>Cyprinodon variegatus</u>	dS
Banded killifish	<u>Fundulus diaphanus</u>	dS, IA
Mummichog	<u>Fundulus heteroclitus</u>	dS, IA
Striped killifish	<u>Fundulus majalis</u>	dS
Spotfin killifish	<u>Fundulus luciae</u>	dS
Rainwater killifish	<u>Lucania parva</u>	dS
LIVEBEARERS	POECILIIDAE	
Mosquitofish	<u>Gambusia affinis</u>	dS
SILVERSIDES	ATHERINIDAE	
Rough silverside	<u>Membras martinica</u>	dS, IA
Tidewater silverside	<u>Menidia beryllina</u>	dS, IA
Atlantic silverside	<u>Menidia menidia</u>	dS, IA
BEARDFISHES	POLYMIXIIDAE	
Beardfish	<u>Polymixia lowei</u>	FCD

TABLE V

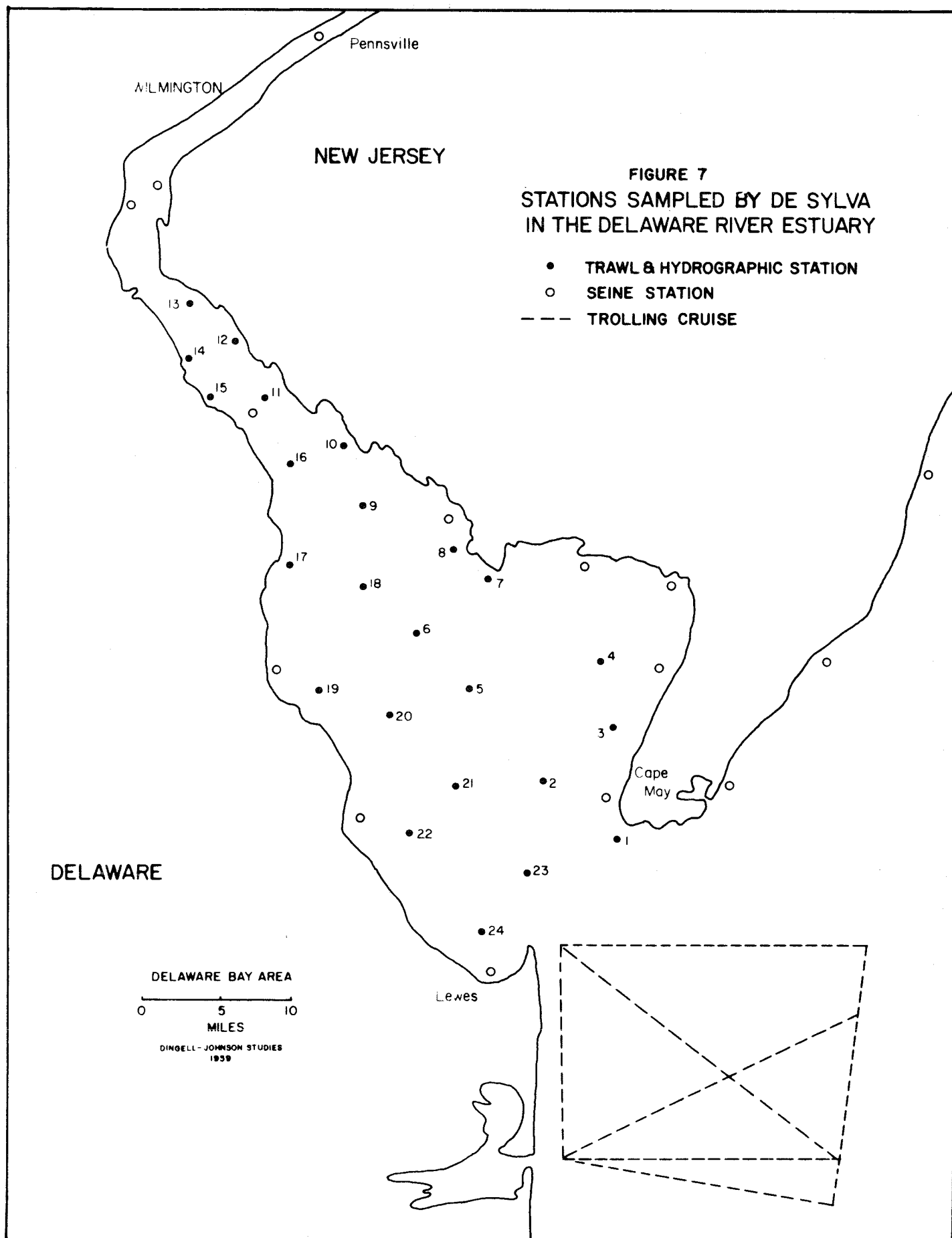
<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>REFERENCES & NOTES</u>
STICKLEBACKS	GASTEROSTEIDAE	
Fourspine stickleback	<u>Apeltes quadracus</u>	dS
Threespine stickleback	<u>Gasterosteus aculeatus</u>	dS
CORNETFISHES	FISTULARIIDAE	
Bluespotted cornetfish	<u>Fistularia tabacaris</u>	dS (as: Cornetfish)
SEAROBINS	TRIGLIDAE	
Armored searobin	<u>Peristedion miniatum</u>	FCD
Northern searobin	<u>Prionotus carolinus</u>	dS
Striped searobin	<u>Prionotus evolans</u>	dS
SCULPINS	COTTIDAE	
Longhorn sculpin	<u>Myoxocephalus octodecemspinosus</u>	FCD
LUMPFISHES AND SNAILFISHES	CYCLOPTERIDAE	
Striped seasnail	<u>Liparis liparis</u>	FCD
FLYING GURNARDS	DACTYLOPTERIDAE	
Flying gurnard	<u>Dactylopterus volitans</u>	dS (in gut of white marlin)

TABLE V

<u>COMMON NAMES</u>	<u>SCIENTIFIC NAMES</u>	<u>REFERENCES & NOTES</u>
LEFT EYE FLOUNDERS	BOTHIDAE	
Smallmouth flounder	<u>Etropus microstomus</u>	dS
Summer flounder	<u>Paralichthys dentatus</u>	dS
Fourspot flounder	<u>Paralichthys oblongus</u>	dS
Windowpane	<u>Scophthalmus aquosus</u>	dS
SNAPPERS	LUTJANIDAE	
Vermilion snapper	<u>Rhomboplites aurorubens</u>	dS
GRUNTS	POMADASYIDAE	
Pigfish	<u>Orthopristis chrysoptera</u>	dS (as: O. chrysopterus)
PORGIES	SPARIDAE	
Scup	<u>Stenotomus chrysops</u>	dS
PIPEFISHES AND SEAHORSES	SYNGNATHIDAE	
Northern pipefish	<u>Syngnathus fuscus</u>	dS
Lined seahorse	<u>Hippocampus erectus</u>	dS (as: Spotted SH)
SEA BASSES	SERRANIDAE	
Black sea bass	<u>Centropristis striata</u>	dS (other spelling)
Snowy grouper	<u>Epinephelus niveatus</u>	dS

TABLE V

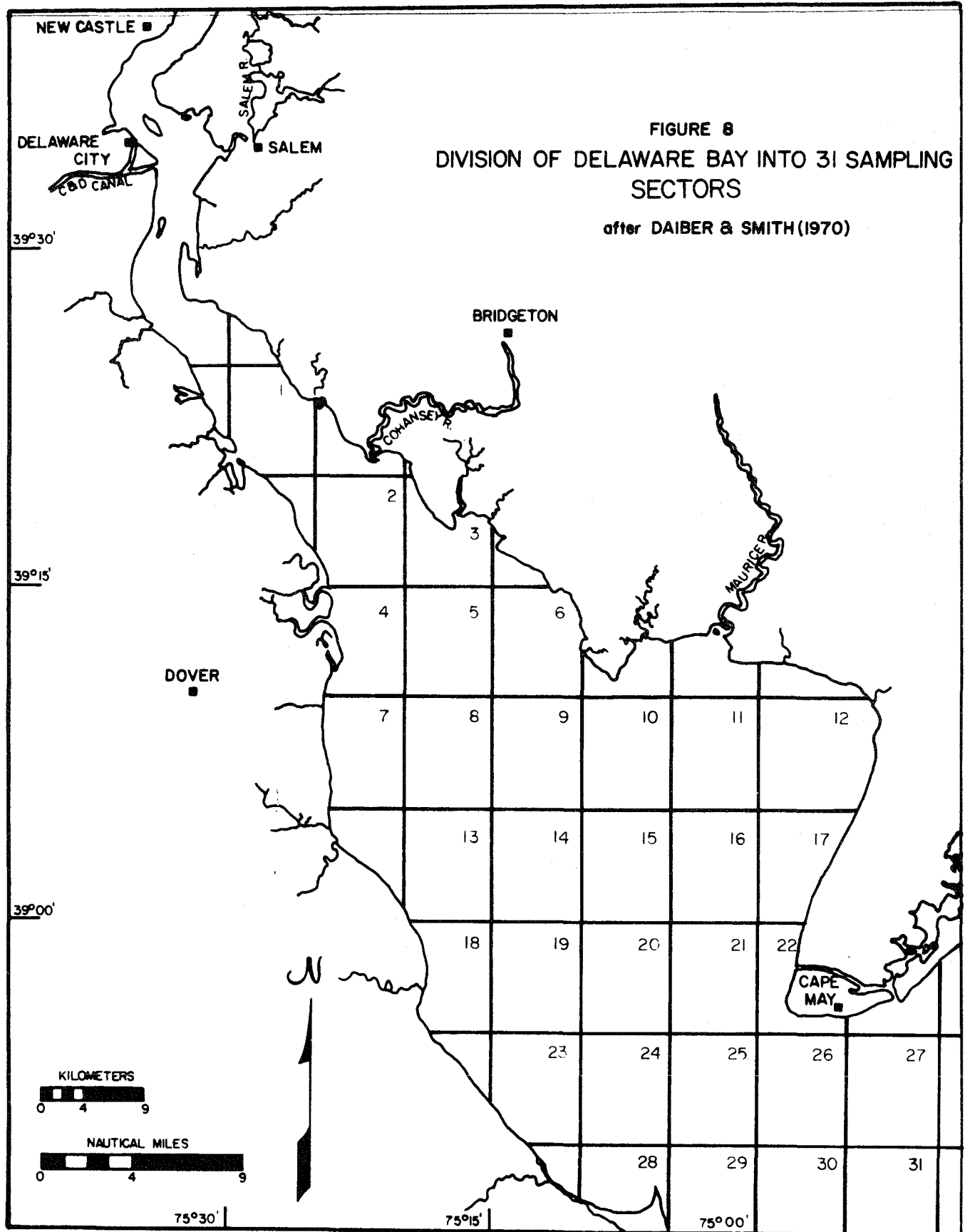
<u>COMMON NAMES</u>	<u>SCIENTIFIC NAMES</u>	<u>REFERENCES & NOTES</u>
TEMPERATE BASSES	PERCICHT HYIDAE	
White perch	<u>Morone americana</u>	dS (as: Roccus)
Striped bass	<u>Morone saxatilis</u>	dS, IA
JACKS & POMPANOS	CARANGIDAE	
Blue runner	<u>Caranx crysos</u>	dS
Crevalle jack	<u>Caranx hippos</u>	dS, IA
Round scad	<u>Decapterus punctatus</u>	dS
Lookdown	<u>Selene vomer</u>	dS
Banded rudderfish	<u>Seriola zonata</u>	dS
Florida pompano	<u>Trachinotus carolinus</u>	dS (as: Pompano)
Permit	<u>Trachinotus falcatus</u>	dS



cerning fish found in Delaware waters and on fish populations in general is also given in this report. A limited Delaware shore zone survey was conducted in July and August 1966 (Smith, personal communication). Sampling stations were located at Lewes, Primehook, Bennetts Pier, and Woodland Beach. Sampling consisted of making several hauls with a 48-foot 1/2 inch stretch mesh seine. Various physical parameters were noted at the time of collections. Derickson (1970) and Scotton (1970) have done a shoreline fish survey and larval fish survey in Indian River and Rehoboth Bays, and this information will be very useful for comparison with that collected in this study.

F. C. Daiber has done extensive survey work on fish populations of the Delaware River estuary. This work is reported in Annual Dingell-Johnson Reports to the Delaware Board of Game and Fish Commissioners from 1955 onward. De Sylva and Kalber (1960) also have a report on fishes captured by trawl in the Delaware Bay area. In August, 1966, a survey of fish populations in Delaware Bay was started and is continuing at present: Daiber and Abbe, (1967), Daiber and Wockley (1968), and Daiber and Smith (1969 and 1970).

For this survey Delaware Bay was divided into 31 sectors, each sector being five nautical miles long by about four nautical miles wide (Figure 8). Sectors sampled so far include 2, 5, 8, 13, 14, 16, 19, 20, 21, 24, 25, 23, and 28. At least three of these sectors were sampled monthly, weather permitting. A total of 280 samples were taken through January 1971. Sampling each sector consisted of getting a bottom water sample for salinity (later in the study for



dissolved oxygen also) and a water temperature, and then the trawl with 3-inch stretch mesh in wings and body, and a 2-inch stretch mesh in the cod-end. Starting and ending positions were determined and tow length noted. A recording fathometer plotted water depth during the tow. Other information recorded was date and time, weather, tide stage and boat direction, and engine speed. Fish caught were identified and measured and/or counted. Stomachs of some fish caught have been examined.

An ecological study of the Delaware River around Artificial Island, New Jersey, was started in June, 1968, by Ichthyological Associates and is continuing at present (Raney, Schuler, and Denoncourt, 1969; Schuler, 1971). The study area includes the river ten miles above and below Artificial Island and the eastern end of the Chesapeake and Delaware Canal, as well as adjacent marshes and tidal creeks. This area is located just above where the river becomes the Bay, and Figure 9 shows the area along with seining sites for 1968. Daily, seasonal, and yearly variations in numbers and distributions of organisms are being studied. Intensive sampling of fish populations is being done by trawl with 1 1/2 inch stretch mesh in cod-end, and an innerliner of 1/2 inch stretch mesh in the cod-end. The trawl was towed for 10 minutes. For seining, 25 and 75-foot bagseines with 1/2 inch stretch mesh webbing, 5 feet deep, were used. From one to four hauls were made at each station, depending on the size of the seine so that approximately 100 yards was covered. Detailed studies are being made in the life histories of important fish.

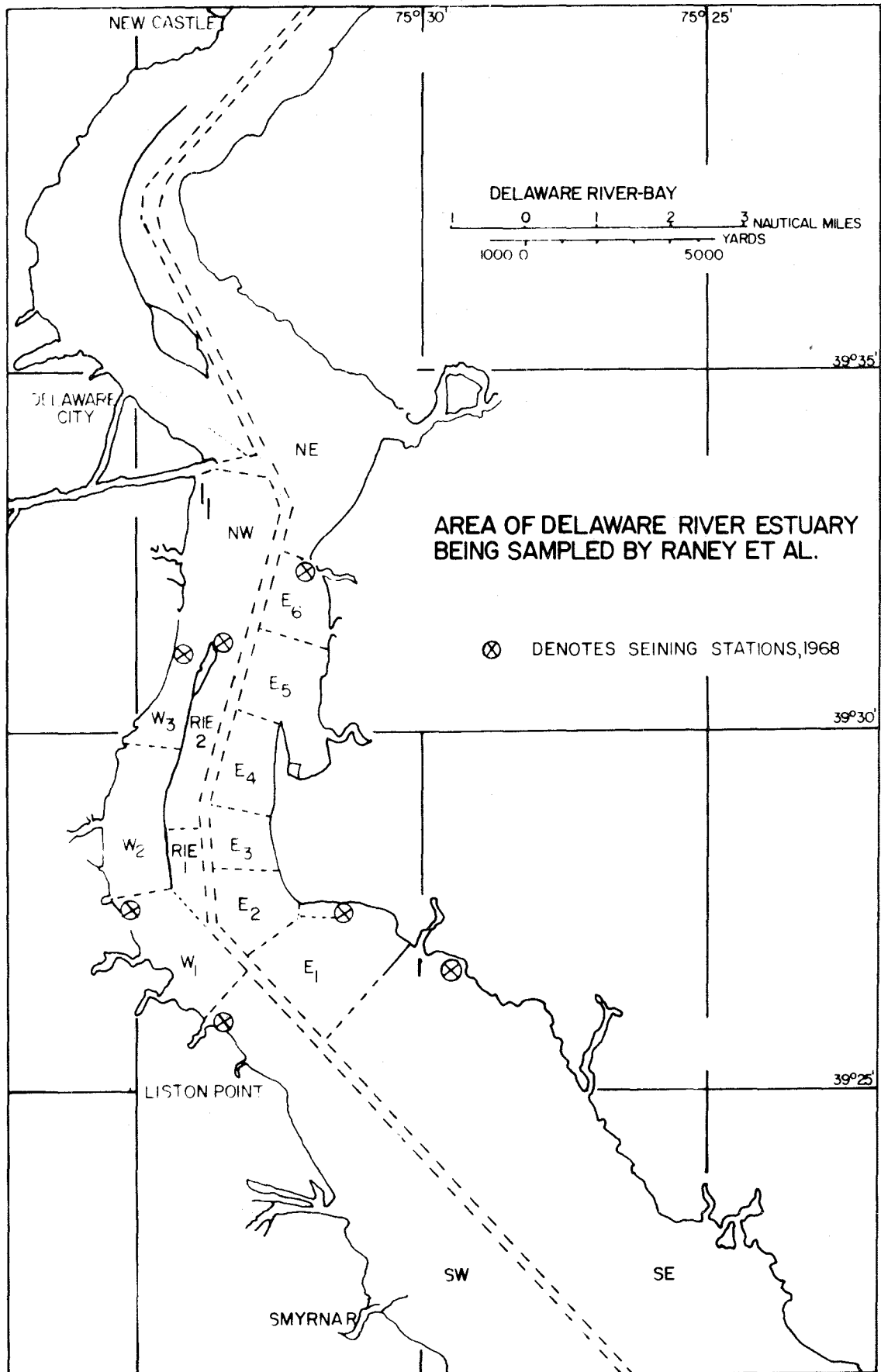


FIGURE 9

An ecological survey including fish populations has been under way in the Chesapeake and Delaware Canal since early 1971, with stations also located around the mouth at either end (Daiber, personal communication). This study will include trawl samples and possibly seine samples, and will run until September, 1973. The methods used will be similar to those given by Daiber and Smith (1970).

Murawski (1968) has studied various aspects of fish abundance and distribution in the New Jersey area over the past five years or so. The reference noted is just one example of his research efforts, which should be very helpful in understanding data collected in the future.

All of the aforementioned work in the Delaware Bay area is valid research, with the primary limitations being the restricted area covered and/or the short sampling time.

5. CONCLUSIONS ON BIOLOGICAL DATA

As with the hydrological data, the biological data suffers from the fact that it was not gathered as part of a coordinated program to provide an integrated understanding of the bay ecosystem. Such a program would be one that gave simultaneously at least gross data on each of the boxes discussed in Section B-1. A data base sufficient to develop a predictive model would deal with the populations of the major species by year class, provide estimates of primary productivity and the trophic transfer between functional groups, and correlations between these biological data and the concomitant physical and chemical conditions.

The model to take advantage of these data does not yet exist--largely because of the lack of a sufficient data base, but also because an interdisciplinary team with sufficient competence, interest, and funding has not been available. The current RANN project provides a significant opportunity for the development of such a model.

The Baseline Study planned and proposed by the University of Delaware and incorporated in the NOAA environmental quality plan for Delaware Bay (see Part I) is specifically designed to provide a predictive model for the total Bay system.

In the absence of a major data collection and modeling effort, knowledgeable management of the Bay will have to depend on expert opinion--which is notorious for its divergence on ecological matters.

6. BIOLOGICAL BIBLIOGRAPHY*

During the course of writing a report on the probable effects of deep water port facilities in Delaware Bay it became necessary to compile a list of literature on the biology of the area. Although this search is still in progress a preliminary bibliography has been developed. Several areas of research are extremely well covered while others have yet to be started. For example, the area of finfish research and marsh chemistry has been the subject of many theses supervised by F. Daiber. In addition, considerable research has been performed on finfish in the upper Bay by Ichthyological Associates. Rutgers University has amassed a great deal of information on the oyster. On the other hand, zooplankton, phytoplankton, and invertebrate surveys have received very little attention. Some of this research has been performed, but the data are in general unavailable for use.

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C. CATALOGUE OF MAPS AND PHOTOS*

This catalogue represents an attempt to summarize existing photographic and cartographic data on the coast and wetlands of Delaware Bay and the Atlantic Coast of Delaware. It is by no means intended to be complete in its initial form as limits on time and resources prevented a truly rigorous survey of existing sources. It is hoped that users of this catalogue will contribute additional information to it as the opportunity arises.

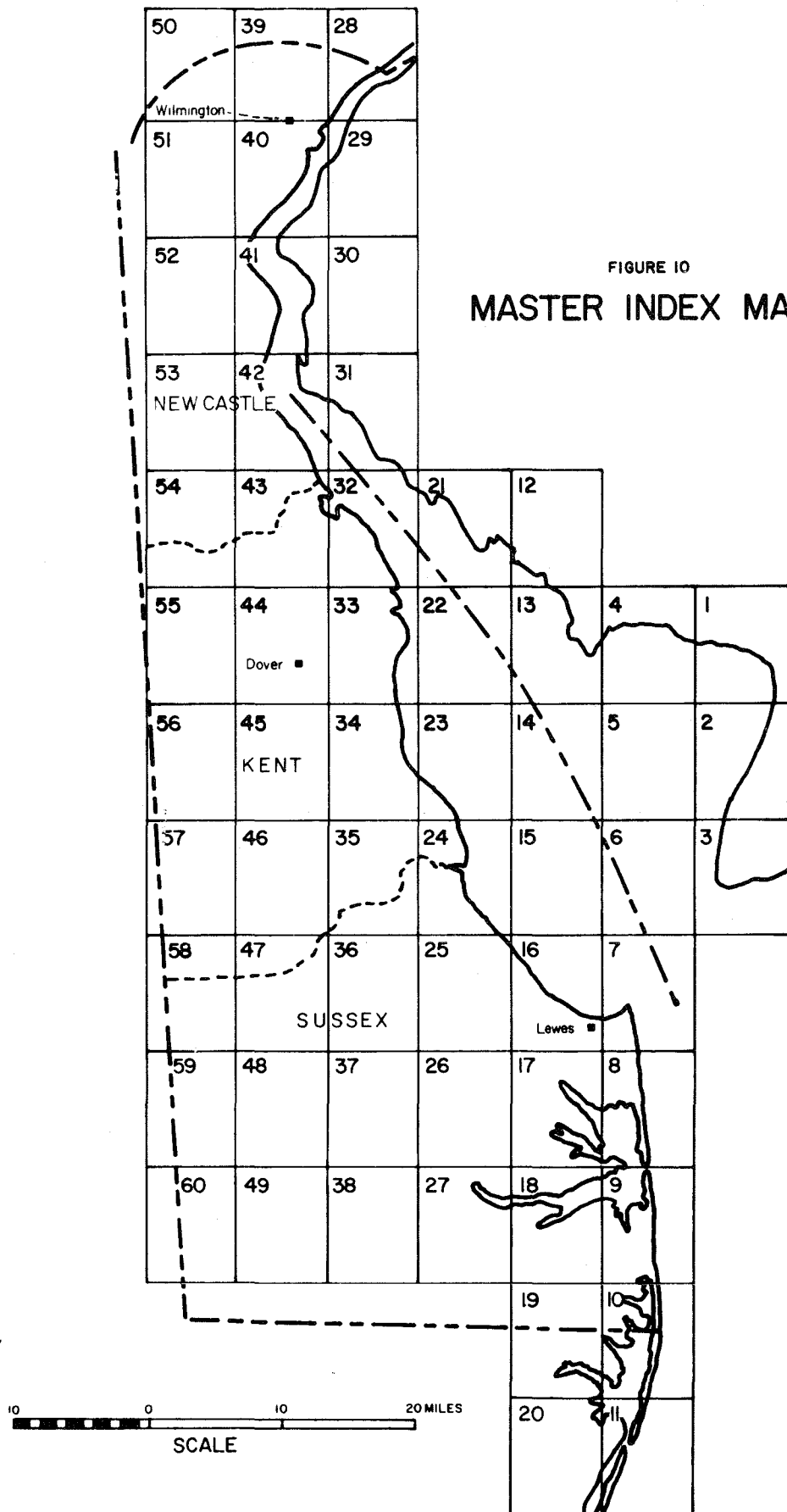
*Prepared under the direction of V. Klemas,
assisted by D. Bartlett and R. Artusy.

1. USE OF THE CATALOGUE

A catalogue system is included to help the user find the information that he seeks. The user should begin with the Master Index Map (Figure 10) and identify the area(s) in which he is interested by number. The catalogue is divided into two sections - Maps and Photos-and depending on which type of data he wants, the user should turn to the "Agency - Photo (or Map) Type Index" page which identifies both agencies or groups which produce the data and the type of data produced by each agency. These indexes are found at the beginning of the Photo and Map sections. Depending on what type(s) of data he wants, the user can now select the agency or agencies which produce that type and turn to the catalogue pages under that agency. These pages are self-explanatory but some conventions are used which may not be clear from the headings over each column. In the Photo Section, the column headed "Area" indicates that portion of Delaware's Bay and Atlantic Coast for which the agency produces the particular type of photo listed. Under "Key Contact", the agency from which data can be ordered is listed first. If part or all of this data is available at the University of Delaware, the University contact is listed after the agency under "Key Contact". The areas (identified by number as on the Master Index Map) for which each University contact (if any) has data are listed under "Additional Information".

The same procedure is followed in listing map data.

Index sheets referred to are available on file at the University contacts - most are on file at the College of Marine Studies even if the data itself is not available through the University.



2. APPLICATION OF PHOTOGRAPHIC TECHNIQUES

Several photographic techniques were used by the agencies listed in this catalogue. Each displays specific reflectance characteristics of the area photographed, with the result that each has its own specific applications in soil, vegetation, drainage and land use mapping. In addition, factors such as cost and availability combine to make each technique useful in particular studies. A brief summary of the characteristics of each photographic technique follows to aid the user of this catalogue in choosing those photographs which can be most effectively applied to his particular study.

a. Panchromatic (Black and White) Photography

Panchromatic film has by far the broadest appeal in aerial photography, primarily because it is the least expensive film to process making coverage of extensive areas possible. Most panchromatic photo series are taken with sufficient overlap of adjacent photos to allow stereoscopic viewing of the scene. For many years panchromatic photography was the only technique used. If aerial coverage over time and/or space showing topographic relief, small trees and shrubs, buildings etc. is desired, panchromatic photography will probably prove most useful. (See Plate 1)

b. Black & White Infrared Photography

Different reflectance characteristics of vegetation in the infrared band make this an excellent technique for distinguishing

Plate 1

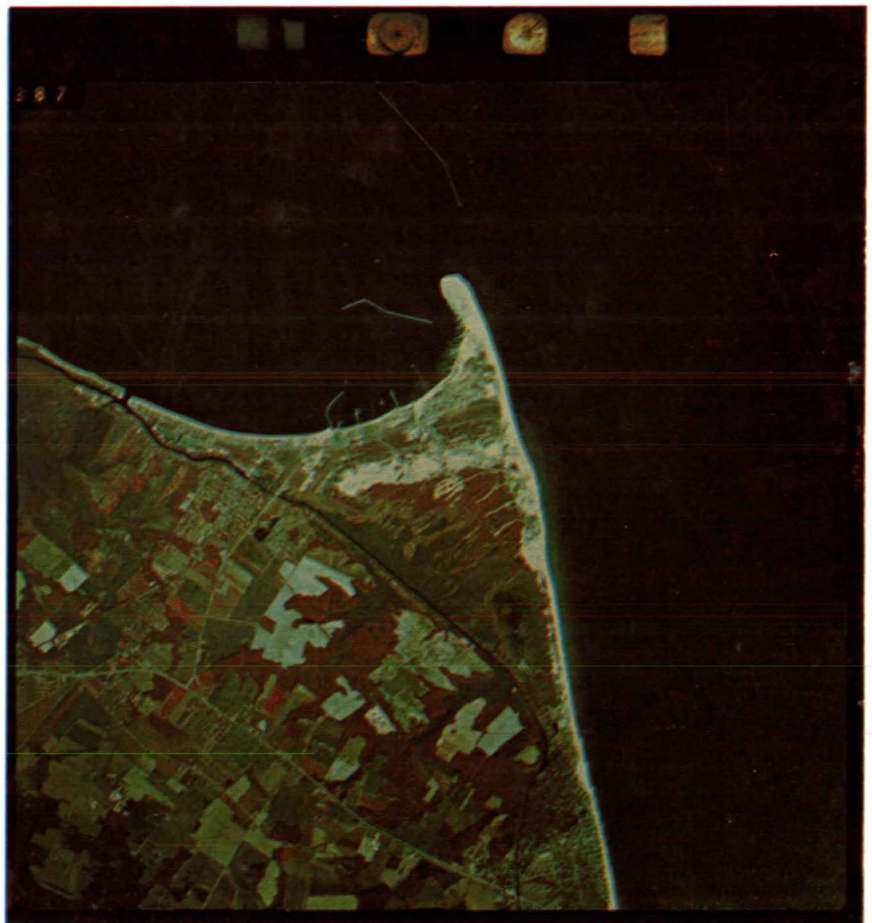


Plate 2

Plate 3



Plate 4



certain species of vegetation. Coniferous and deciduous trees, for example, are quite distinct in their infrared reflectance whereas they look quite similar in panchromatic photographs. This technique is also quite useful in identifying precise water-land boundaries. (See Plate 2)

c. Color Photography

Improvements in the quality of color film have increased its use in recent years although processing costs restrict availability. It is very useful in identifying rock outcrops and soil types and also in delineating underwater features. (See Plate 3).

d. Color - Infrared Photography

Color - infrared photos are probably the best available for identifying fine distinctions in reflectance, allowing discrimination of plant species, plant diseases, insect outbreaks, water pollution, etc. Color - infrared may also prove very useful in land use mapping. (See Plate 4).

e. Multispectral Photography

Multispectral imagery usually refers to several photos of the same area, taken at the same time, each displaying reflectance in a single, narrow, spectral band. The bands used are generally chosen for a specific study so this technique has the advantage of eliminating a great deal of extraneous material and zeroing in on specific features under study. In general, availability is limited and this technique is best used in conjunction with a specific study.

3. REMOTE SENSING PROGRAMS AND RECENT AIRCRAFT AND SATELLITE
IMAGERY

Tables 1, 2 and 3 present active remote sensing programs at the University of Delaware, recent aircraft overflights, and ERTS-1 satellite overpasses. The Earth Resources Satellite (ERTS-1) passes over Delaware Bay every 18 days. The aircraft photography is performed in conjunction with the remote sensing programs outlined in Table 1.

TABLE VIa
REMOTE SENSING ACTIVITIES
AT THE COLLEGE OF MARINE STUDIES
UNIVERSITY OF DELAWARE

Project Title	Supporting Agency	Contract Number
1. Two-dimensional Spectral Analysis of Shallow Water Waves	ONR-Geography Programs	N00014-69-A0407
2. Classification and Analysis of Frontal Systems and Boundaries in Coastal and Estuarine Waters	ONR-Geography Programs	N00014-69-A0407
3. The Delaware Estuary System, Environmental Impacts and Socio-Economic Effects	NSF-RANN*	Grant GI-33369
4. Application of Geological, Ecological and Oceanographic ERTS-A Imagery to Delaware's Coastal Resources Planning	NASA-ERTS-1	NAS5-21837
5. Skylab/EREP Application to Ecological, Geological and Oceanographic Investigations of Delaware Bay	NASA-Skylab	NAS1-12304
6. Chlorophyll Measurements in Upwelling Regions by Remote Sensing	NASA-ERTS-1 NASA-Skylab	NAS5-21784
7. Analysis of Economic Structure, Land Use Patterns, and Ecological Impact in Delaware's Coastal Zone	NOAA-Sea Grant**	GH-30 (NOAA)

* Marsh mapping

** Land use and land use change mapping

TABLE VIb
AIRCRAFT OVERFLIGHTS
OF DELAWARE BAY TEST SITE

<u>DATE</u>	<u>AIRCRAFT AND ALTITUDE</u>
September 14, 1970	RB-57 at 60,000 ft. altitude
November 4, 1971	U-2 at 65,000 ft. altitude
August 26, 1971	9 Inch Color IR at 11,500 ft.
September 15, 1972	U-2 at 65,000 ft. altitude
October 27, 1972	C-130 at 10,000 ft. altitude
December 3, 1972	U-2 at 65,000 ft. altitude
March 24, 1973	U-2 at 65,000 ft. altitude
April, 1973	C-130 at 10,000 ft.
April, 1973 - August, 1973	Sidelooking Radar Overflights
June 1, 1973	Color, red & green bands at 11,500 ft.
Summer, 1973	Laser Wave Profiling Overflights
Summer, 1973	Laser Chlorophyll and Oil Detection Overflights
Fall, 1973	RB-57 at 60,000 ft.

TABLE VIc
IMAGERY FROM
ERTS-1 SATELLITE OVERPASSES*
OF DELAWARE BAY REGION

<u>Date of Pass</u>	<u>Region</u>	<u>I. D. Number</u>	<u>Center Point Coordinates</u>	<u>Bands</u>	<u>Format</u>
8/16/72	DO	1024-15073	38.926N 73.925W	M	MSTP9
9/3/72	DO	1024-15074	38.752N 73.998W	M	MSTP
10/9/72	DB	1078-15075	38.915N 73.955W	M	MSTP9
10/10/72	DO	1079-15133	38.883N 75.346W	M	MSTP
10/27/72	DO	1096-15081	38.794N 74.016W	M	MSTP
12/2/72	DO	1132-15083	38.786 74.036W	M	MSTP
12/3/72	DB	1133-15141	38.798N 75.474W	5,6,7	MSTP9
1/26/73	DB	1187-15140	38.883N 75.346W	M	MSTP9
2/13/73	DB	1205-15141	38.960N 75.486W	M	MSTP-9

Bands M = 4, 5, 6, 7
 4 = 0.5 - 0.6 microns
 5 = 0.6 - 0.7 microns
 6 = 0.7 - 0.8 microns
 7 = 0.8 - 1.1 microns

Format M = 70 mm negative
 S = 70 mm positive transparency
 T = 9.5 in positive transparency
 P = 9.5 in paper print
 9 = 9-track tape 800 (bpi)

Region DB = Delaware Bay
 DO = Delmarva Coast

* This list shows only imagery containing less than 60% cloud cover.

TABLE VII

Agency Photo-Type Index*

	PAGE
a. U.S. Department of Agriculture (ASCS)	155
Black & White Prints 1:20,000	
b. NASA (ERTS)	159
Black & White 1:60,000; 1:120,000	
Color 1:60,000; 1:120,000	
Color I.R. 1:60,000; 1:120,000	
I.R.	
Multispectral	
c. U.S. Geological Survey	165
Black & White 1:20,000; 1:24,000; 1:28,000; 1:60,000	
d. National Oceanic & Atmospheric Administration	166
Color 1:60,000	
Infra-Red	
Black & White	

TABLE VII

Agency Photo-Type Index*

	PAGE
e. New Castle County Planning Department	170
Black & White 1:4800	
f. University of Delaware Oblique only	171
Black & White	
Color	
Color - Infra-Red	
Multispectral	
Ultra-violet	

*See Tables VIIa-f for addresses of agencies.

TABLE VIIa

FILM AND PRINTS

U.S. Department of Agriculture
Black & White

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
Entire Region	1938	1:20,000			9" x 9"	Nat. Archives & Record Service Cartographic Branch G.S.A. 8th St. & Penn Ave., N.W., Wash., D.C. - 20408 and V. Klemas, <u>CMS</u> and F. Swaye, Geog. Dept. -----	<u>CMS</u> - Sussex Co. coastal area. Area numbers: 7-10,16-19, 24-27 see Index sheets <u>Geog. Dept.</u> - New Castle and part of Kent Co. coast. Area numbers: 39-43 see Index sheets
Entire Region	1946	1:20,000			9" x 9"	Eastern Laboratory Aerial Photo. Div. ASCS - USDA 45 S. French Broad Ave. Ashville, N. C. 28802 -----	
Entire Region	1954	1:20,000			9" x 9"	Same as 1946 and V. Klemas, <u>CMS</u> and L. Cotnoir, <u>Agr. Dept.</u>	<u>CMS</u> - Sussex Co. coast. Area numbers: 7-10,16-19,24-27 see Index sheets <u>Agr. Dept.</u> - Entire

TABLE VIIa

FILM AND PRINTS

U.S. Department of Agriculture
Black & White

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
Entire Region	1960- 61	1:20,000			9" x 9"	CMS, Coll. of Agriculture and Geography Dept. all refer to University of Delaware. Same as 1946 and V. Klemas, <u>CMS</u> and L. Cotnoir, <u>Agr. Dept.</u> and F. Swaye, <u>Geog. Dept.</u>	coast of Delaware CMS - Sussex Co. coast. Area numbers: 7-10, 16- 19, 24-27 see Index sheets (on order-6/26/72) <u>Agr. Dept.</u> - Kent Co. coast Area numbers: 23, 33, 34 <u>Geog. Dept.</u> - Entire State of Delaware -----
					9" x 9"	Same as 1946 and V. Klemas, <u>CMS</u>	<u>CMS</u> - New Castle, Kent and Sussex Co. coast. Area numbers: 28, 29, 32- 35, 39-43-see Index sheets

TABLE VIIa

FILM AND PRINTS

U.S. Department of Agriculture

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
New Castle & Kent Co.	1937	1:15840			9" x 9"	L. Cotnoir, <u>Agr. Dept.</u> F. Swaye, <u>Geog. Dept.</u> L. Cotnoir, <u>Agr. Dept.</u>	Agr. Dept. - same as CMS Geog. Dept. -Kent & Sussex Co. coast. Area numbers: 7-10,16- 19,23-27,32-35 Agr. Dept. - New Castle & Kent Co. Area numbers: 23,24,32-35,- 39-43 -----

TABLE VIIa

FILM AND PRINTS

U.S. Department of Agriculture
Black & White

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
North- ern New Castle Co.	1959	1:24,000			9" x 9"	F. Swaye, <u>Geog. Dept.</u>	New Castle Co. coast Area numbers: 28,39-41
North- ern New Castle Co. coast	1963	1:12,000			9" x 9"	F. Swaye, <u>Geog. Dept.</u>	New Castle Co. coast Area numbers: 28,39-41
North- ern & New Castle co. coast	1968 & 1969	1:36,000			9" x 9"	F. Swaye, <u>Geog. Dept.</u>	New Castle Co. coast Area numbers: 28,39-41

TABLE VIIb
FILM AND PRINTS
NASA
Black & White

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
Entire Region	9/23 1970	1:60,000	RC-8 Zeiss Hass		9" x 9" and 70 mm.	Earth Resources Observation System Data Center Sioux Falls, S. Dakota V. Klemas, CMS 57198 -----	Catalogue (CMS) Mission 144, Sites 167, 168 & 244 Flight (3)
New Castle Co.	9/25 1970	1:60,000 or 1:120,000	RC-8 Zeiss Hass		9" x 9" and 70 mm.	Earth Resources Observation system Data Center Sioux Falls, S. Dakota 57198 -----	Mission 144 Site 244 Flight (5)

TABLE VIIb
FILM AND PRINTS

NASA
Black & White

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
Sussex Co. & N.J. coast	5/18 1970	1:60,000 or 1:120,000	RC-8 Zeiss Hass		9" x 9" and 70 mm.	Earth Resources Observation System Data Center Sioux Falls, S. Dakota 57198 -----	Mission 166 Site 244 Flight (6)
Sussex Co. & N.J. coast	5/19 1970	1:60,000 or 1:120,000	RC-8 Zeiss Hass		9" x 9" and 70 mm.	Earth Resources Observation System Data Center Sioux Falls, S. Dakota 57198	Mission 166 Site 244 Flight (7)

TABLE VIIb
FILM AND PRINTS

NASA (cont.)
Color

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
				SAME AS NASA	BLACK & WHITE		

TABLE VIb
FILM AND PRINTS

NASA (cont.)
Color I.R.

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
Entire Region	9/23 1970	1:60,000	Zeiss	2443 D	9" x 9"	Same as B & W and CMS - V. Klemas	CMS- Sussex, Kent & New Castle Co. coast. Area numbers: 7-10,23,24,82,29-35, 39-43
Entire Region	9/23 1970	1:60,000	RC-8	2443 12	9" x 9"	Same as B & W and CMS - V. Klemas	

TABLE VIIb
 FILM AND PRINTS
NASA (cont.)
 I.R. & Multispectral

Area	Date	Scale	Camera	Film type Filter type	Film Format		
							<u>Multispectral Lines</u> <u>Date</u> <u>Lines</u> 9/23/70 - 3,4,5,6 9/25/70 - 1 5/18/71 - 5,6,7 5/19/71 - 5,7 (also I.R. Scanner on this flight)

TABLE VIIb

FILM AND PRINTS

NASA
Film Rolls Available at CMS

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
Entire Region	9/23 1970	1:120,000	RC84R	2445 2E		<u>CMS</u> - V. Klemas	<u>Type Photo & Roll #</u> Color - #19
Entire Region	9/23 1970	1:120,000	RC84L	2443 12		<u>CMS</u> - V. Klemas	Color I.R. - #20
Entire Region	9/23 1970	1:60,000	Zeiss 5L	2443 D		<u>CMS</u> - V. Klemas	Color I.R. - #21
Entire Region	9/23 1970	1:458,000	Hass sR1	2402 25A		<u>CMS</u> - V. Klemas	B & W - #22
Entire Region	9/23 1970	1:458,000	Hass sR2	2402 58		<u>CMS</u> - V. Klemas	B & W - #23

TABLE VIIc
 FILM AND PRINTS
U.S. Geological Survey
 Black & White

Area	Date	Scale	Camera	Film type	Film	Key Contact	Additional Information
				Filter type	Format		
Sussex Co. coast	1953	1:20,000				Atlantic Region Engineer U.S. Geol. Survey 1109 N. Hyland St. Arlington, Va. 22210	
Sussex Co. coast	1963	1:24,000				Atlantic Region Engineer U.S. Geol. Survey 1109 N. Hyland St. Arlington, Va. 22210	
Cape May & Cumber- land Co. coast	1954	1:28,400				Atlantic Region Engineer U.S. Geol. Survey 1109 N. Hyland St. Arlington, Va. 22210	
Salem Co. Coast	1965	1:24,000				Atlantic Region Engineer U.S. Geol. Survey 1109 N. Hyland St. Arlington, Va. 22210	

TABLE VIIc
 FILM AND PRINTS
U.S. Geological Survey
 Black & White

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
New Jersey	1956- 1958	1:60,000				Atlantic Region Engineer U.S. Geol. Survey 1109 N. Hyland St. Arlington, Va. 22210	
Dela- ware	1959- 1960	1:60,000				Atlantic Region Engineer U.S. Geol. Survey 1109 N. Hyland St. Arlington, Va. 22210	
North- ern New Castle Co. coast	1965	1:24,000				Atlantic Region Engineer U.S. Geol. Survey 1109 N. Hyland St. Arlington, Va. 22210	

TABLE VIId

FILM AND PRINTS

National Oceanic and Atmospheric Administration (U.S.C. & G.S.)
Black & White

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
Sussex Co. coast	1/1 1971	1:10,000 or 1:20,000				Nat. Oceanic and Atmospheric Administration Dept. of Commerce Washington, D.C.	
Kent and New Castle Co. coast	1/1 1971	1:10,000 or 1:20,000				Nat. Oceanic and Atmospheric Administration Dept. of Commerce Washington, D.C.	
Cape May coast	1/1 1971	1:10,000 or 1:20,000				Nat. Oceanic and Atmospheric Administration Dept. of Commerce Washington, D.C.	

TABLE VIId
 FILM AND PRINTS
NOAA (cont.)
 Color

Area	Date	Scale	Camera	Film type Filter type	Film Format		
Sussex, Kent, New Castle and Cape May Co. coast.	1/1 1971	1:10,000 or 1:20,000				Same as black & White and V. Klemas, <u>CMS</u>	<u>CMS</u> -Intermittent coverage of Del. & N. J. coast see color Index sheets 133 C,D,G

TABLE VIId
 FILM AND PRINTS
NOAA (cont.)
 I.R.

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
				SAME AS FOR NOAA COLOR			See I.R. Index sheets-133C,D & G

TABLE VIIe

FILM AND PRINTS

New Castle Co. Planning Dept.
Black & White

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
New Castle Co.	1962	1"=400' 1"=200' 1"=100'				New Castle Co. Planning Dept. Engineering Bldg. Newark, Delaware	CMS - Has two of these at 1"=400'
New Castle Co.	1964	1"=400' 1"=200' 1"=100'				New Castle Co. Planning Dept. Engineering Bldg. Newark, Delaware	
New Castle Co.	1968	1"=400' 1"=200' 1"=100'				New Castle Co. Planning Dept. Engineering Bldg. Newark, Delaware	

TABLE VIIIf

FILM AND PRINTS

University of Delaware

Area	Date	Scale	Camera	Film type Filter type	Film Format	Key Contact	Additional Information
				Intermittent coverage of coast and wetlands taken for the following type studies:		<u>CMS</u> - V. Klemas	Types of photography used: 1) Black & White 2) Color 3) Color I.R. 4) Multispectral 5) Ultra violet
				1)	Wetlands mapping		
				2)	Land use mapping		
				3)	Water boundary indentification		
				4)	Frontal system indentification		
				5)	Shallow water wave study		
				6)	Water pollution study		
				7)	Dye dispersion study		
				8)	Oil slick detection		

TABLE VIII

Agency Map-Type Index

	<u>PAGE</u>
a) U.S. Geological Survey	172
Geological Maps	
Topographic Maps	
Water Table, Surface Drainage	
and Engineering Maps	
b) National Ocean Survey (NOAA)	173
Tidal Current Charts	
Index Map of Tidal Bench Marks	
Soundings in Feet (Navigation Charts)	
Hydrographic Survey Index Maps	
c) U.S. Department of Agriculture (SCS)	175
Agriculture Soil Maps	
d) Delaware Highway Department	176
Road Maintenance Maps	
e) Miscellaneous Maps	178

TABLE IXa
MAPS
U.S. Geological Survey

Area	Map Type	Scale	Date	Key Contact	Additional Information
Entire Region	Topographic	1:24,000 or 1:62,500	1948-56	Wilm. Blueprint 817½ Tatnall St. Wilm., Del. and CMS - V. Klemas and <u>Geog. Dept.</u> F. Swaye	CMS - Sussex, Kent and New Castle Co. coast- see Index sheet (same map as master Index for map & phto file). <u>Geog. Dept.</u> same as above Area numbers: 7-10,16,23,24, 32-34,40-43 -----
Entire Region	Hydrologic Survey (Water Table, Surface Drainage & Engineering Soils Maps)	1:24,000	1964	Wash. Distrib. Section Geological Survey Wash., D.C. 20242 and <u>CMS</u> - V. Klemas	CMS - Sussex, Kent and New Castle County coast. Same area numbers as above ----- <u>Geo. Dept.</u> Entire Region
Entire Region	Geologic Maps			Wash. Distrib. Section Geologic Survey Wash., D.C. 20242 and <u>Geo. Dept.</u> - Geol. Survey	

TABLE IXb

MAPS
National Ocean Survey (NOAA)

Area	Map Type	Scale	Date	Key Contact	Additional Information
Entire Region	Tidal Current Charts	1" 5na.mi.	1960	Envir. Services Admin. Coast & Geodetic Survey, Rockville Md. 20852 and <u>CMS</u> - V. Klemas	<u>CMS</u> - Entire Region
Del. & Penn.	Index map of Bench Marks		1954	C. & G.S. and CMS - V. Klemas	<u>CMS</u> - Ordered, June 1972
N. J.	Index map of Tidal Bench Marks		1956	C. & G.S. and <u>CMS</u> - V. Klemas	<u>CMS</u> - Ordered, June 1972

TABLE IXb

MAPS
National Ocean Survey (NOAA)

Area	Map Type	Scale	Date	Key Contact	Additional Information
Entire Region	Soundings in Feet - Mercator (Navigation Charts)	1:40,000 and 1:80,000	1970-71	C. & G.S. and <u>CMS</u> - V. Klemas	<u>CMS</u> - Entire Region-see Index map.
Entire Region	Hydrographic Survey Maps	1:10,000 or 1:20,000	1835 - 1965	C. & G.S.	<u>CMS</u> - Has Index sheets for all surveys.

TABLE IXc
MAPS
U.S. Department of Agriculture

Area	Map Type	Scale	Date	Key Contact	Additional Information
New Castle, Kent & Sussex Co.	Agriculture Soil maps	1:15,840	1970	Superintendent of Documents U.S. Gov. Printing Office Wash., D.C. 20402	Not in print until Sept. 1972

TABLE IXd

MAPS

Delaware State Highway Department

Area	Map Type	Scale	Date	Key Contact	Additional Information
New Castle, Kent and Sussex Co.	Highway	1"=2 mi.	Recent	Delaware State Highway Department and CMS - V. Klemas	Area numbers 7-10,16-19,23-27,32-60
New Castle, Kent and Sussex Co.	Highway	1"=1 mi.	Recent	Delaware State Highway Department and CMS - V. Klemas	
Entire State	Highway	1"=2 mi.	Recent	Delaware State Highway Department and CMS - V. Klemas	Area numbers 7-10,16-19,23-27,32-60
New Castle, Kent Co.	Sheet "A"	1"= $\frac{1}{2}$ mi.	Recent	Delaware State Highway Department	

TABLE IXd

MAPS

Delaware State Highway Department

Area	Map Type	Scale	Date	Key Contact	Additional Information
New Castle, Kent and Sussex Co.	County Hundreds	1"=2 mi.	Recent	Delaware State Highway Department	
Entire State	1985 Recom- mended Highway Plan	1"=½ mi.	Recent	Delaware State Highway Department	
Cities	City maps	-	Recent	Delaware State Highway Department	

TABLE IXe

MAPS
Miscellaneous Maps

Area	Map Type	Scale	Date	Key Contact	Additional Information
New Castle Co.	Zoning Maps		1954 & 1957 & ?	New Castle Co. Regional Planning Comm. and <u>CMS</u> - V. Klemas <u>CMS</u> - V. Klemas	<u>CMS</u> - 1954 & 1957 Maps
U.S.A.	United States in 1783		1783		<u>CMS</u> - 1783
U.S.A.	Pop. Density Maps		1960	Geography Division Bureau of the Census and <u>CMS</u> - V. Klemas	<u>CMS</u> - 1960

III. DESCRIPTIVE LISTING OF RESEARCH,
TECHNICAL AND ADVISORY GROUPS

The following is a descriptive listing of groups judged to have an immediate research interest or capability, technical competence, or an advisory role with respect to Delaware Bay. Cross references are provided to Parts I and IV of this volume where more important information as to current or planned research may be found.

The list is compiled from many sources, including consulting work by R. E. Fothergill and by the Natural and Historical Research Associates, as well as proposals, descriptive material, etc., generated by the group described.

- A. Academy of Natural Sciences
19th and The Parkway
Philadelphia, Pennsylvania 19103
Contact: R. Patrick

The Academy of Natural Sciences has been engaged in collecting and studying species of invertebrates and fish in the Delaware River for over 100 years. However, it is only since the beginning of the Limnology department of the Academy of Natural Sciences that ecological studies, which are also in part systematic, have been carried out. These studies have been carried out for Incodel and for the Delaware River Basin Commission. The Incodel studies were carried out between 1957 and 1959 and were involved with determining the condition of the river by the use of diatometers and benthic algae studies between Trenton and Delaware Bay.

At the present time they are carrying out a detailed study of Cedar Creek Marsh in Delaware together with less extensive studies of the Bombay Hook marsh area. These studies deal with the chemical characteristics of the water, the fauna and flora that live in these marshes, and the use of these marshes by various forms of aquatic life as feeding grounds for migratory fish and invertebrates.

The Academy's participation in NSF/RANN is considered in Part IA,

3. See also IB, 16.

- B. Arthur D. Little, Inc.
Cambridge, Massachusetts
Contact: B. Putnam

This group acted as consultants on the environmental impact of a deep draft terminal in Delaware Bay.

- C. Bechtel, Inc.
Contact: F. F. Watters

The Pipeline Division of this company is carrying out the study required by the Delaware Bay Oil Transport Committee (Part IB, 3).

- D. College of Marine Studies
University of Delaware
Newark, Delaware 19711
Contact: W. S. Gaither, Dean

The College of Marine Studies was founded on July 1, 1970. It incorporated existing efforts in marine biology, marine geology, and ocean engineering, and added to them groups in physical oceanography, marine chemistry and the broad area of marine affairs.

Extensive facilities for marine research are located on the main campus in Newark and at the Field Station in Lewes, Delaware. The colleges at Newark support studies of shellfish culture, oyster pathology, salt marsh ecology, physiological ecology of marine organisms, marine pollution, coastal vegetation, benthic invertebrates, plankton, fishes, breakwater and cofferdam design, harbor construction, design

and structural analysis of deep submergence test facilities, systems analysis of marine problems, dynamics of sediments in estuaries, coastal sedimentary processes, and organic geochemistry.

The Field Station laboratories have direct access to a variety of marine habitats--including the Atlantic Ocean, sand beaches, dunes, the Delaware Bay, rock jetties, mud flats, barrier islands, tidal streams, salt marshes--and the full spectrum of estuarine water conditions--within five miles. A variety of equipment is available, supported by a fleet of small boats, a 42-foot aluminum-hulled craft designed for hydrographic and plankton studies, and a 48-foot wooden-hulled trawler used for exploratory fishing with trawl and dredges, geological sampling, and hydrographic work. Research and sampling continue all year on projects which coordinate with those in progress at Newark.

The College's involvement in Sea Grant, Office of Naval Research, and NSF/RANN research is discussed in Part IA. Other projects of concern to this study are found in IB, 1, 2, 4, 6, and 17; IVA, 4, 5, and 6.

E. Council on Environmental Quality
Contact: S. D. Jellinek

This Presidential Council is seeing to the preparation of a report on the environmental impacts of deep draft terminal facilities in order to aid in a site-selection decision (Part IB, 2).

- F. Delaware Bay Marine Sciences Institute
 Fort Christina Laboratory
 Wilmington, Delaware 19081
 Contact: A. M. Ostheimer

This is a new group with an unknown potential. They have recently acquired the *Cheriton*, an obsolete sea-going tug 150' long with 4,000 rated horsepower and 12,000 mile range. The ship is in bad need of repairs, but they have hopes of making it into a research vessel for coastal and estuarine work with the help of contributions and volunteers.

- G. Delaware Bay Oil Transportation Committee
 Contact: W. S. Gaither, Chairman

The committee is charged to find the safest way to move petroleum up the Delaware Bay and River to existing refineries and is overseeing a study designed to provide this information (Part IB, 3).

- H. Delaware Department of Natural Resources
 and Environmental Control, NREC
 Contact: A. Heller, Secretary

The plans of this agency are dealt with in Part IVB, 4.

- I. Division of Fish and Wildlife, NREC
 Contact: D. Louder, Director

Division research interests include the following:

1. An oyster management survey.
2. Study of oyster management experimental techniques.
3. Hard clam survey.
4. Blue crab investigation.
5. Biological investigation of the Chesapeake and Delaware Canal.

6. Biological evaluation of tidal streams.
7. Fish population index.
8. General studies on tidal marsh areas.
9. Delaware Bay Study (through the Academy of Sciences).
10. Study of the effect of metallic substances on shellfish.

J. Delaware Governor's Wetlands Action Committee
Contact: W. K. DuPont, Chairman

See Part IVB, 6.

K. Delaware River and Bay Authority
Contact: J. C. Volk, Project Engineer

The Authority is funding environmental studies of the effects of dredging at its ferry terminals at Cape May, N. J., and at Lewes, Delaware (See Part IB, 1).

L. Delaware River and Bay Council

This New Jersey Governor's Commission is discussed in Part IV B, 3.

M. Delaware River Basin Commission

Since the Commission is a co-sponsor of this report, its activities, responsibilities, and capabilities have not been detailed.

N. Delaware State Planning Office
Contact: D. R. Keifer, Director

The office's coastal zone planning research is outlined in Part IB, 18. Plans are covered in IVB, 5.

O. Drexel University

Contacts: Dr. Flaser and Dr. Suffet, co-principal investigators

Current Projects:

1. Base Line Study of Soil Cores and Inflow Water Samples for Two Future Impoundments. The impoundments will be at March Creek and Nockamixon. The project is ongoing and connected with IDRES.
2. Addition of bacterial growth to the Delaware Estuary Model, Dr. Glaser.
3. Analysis of Pesticides Transport in the Estuary, Dr. Suffet.

P. Environmental Protection Agency

Contacts: R. Rhodes, Director of Research and Monitoring Office, Philadelphia.

A. Freiburger, Office of Research and Monitoring, New York.

Research and Development Projects in Delaware. This list includes only those projects listed in the computer prior to April 11, 1972.

As of April 11, 1972, as entered in computer files:

#11023 EYC - Development of a Flocculation-Flotation Module
Contract 14-12-855
Hercules, Inc.
Site: Wilmington, Delaware

#12020 EAW - Ocean Disposal of Industrial Wastes
E. I. DuPont
New Castle, Delaware

#12050 GXP - Treatment of Oil Refinery Wastewaters for Reuse
Using a Sand Filter Activated Carbon System
B. P. Oil Corp.
Marcus Hook, Delaware

#15020 HJI - Devices for On-Board Treatment of Wastes From Vessels
Contract #68-01-0137
Hercules, Inc.
Wilmington, Delaware

#16090 DCL - Delaware Estuary and Bay Water Quality Sampling
and Mathematical Modeling Project
Delaware River Basin Commission
Delaware, New Jersey, Pennsylvania

#17030 FKD - Investigation of Amphipathic Waste Soluble Polymers
as Flocculents and Flotation Aids in Domestic Waste
Water Treatment
Contract #14-12-430
Standard Brands Chemical Industries, Inc.
Dover, Delaware

In addition, there is a proposal dealt with in Part IVA, 8.

Research and Development Projects in New Jersey:

#12020 DJI - Waste Treatment Facilities for Polyvinyl Chloride
Manufacturing Plant
B. F. Goodrich Chemical Company, Cleveland, Ohio
Project site in Salem County

#11060 DRO - Deep Water Pilot-Engineering and Interceptor
Feasibility
Delaware River Basin Commission, Trenton, New Jersey
Project site in Salem County

9. Franklin Institute
Contact: Dr. Erb

Sewage Sludge Disposal at Bay Mouth. Study was terminated at the
end of last year. Dr. Erb knows of no new projects at the Franklin
Institute concerned with Delaware Bay.

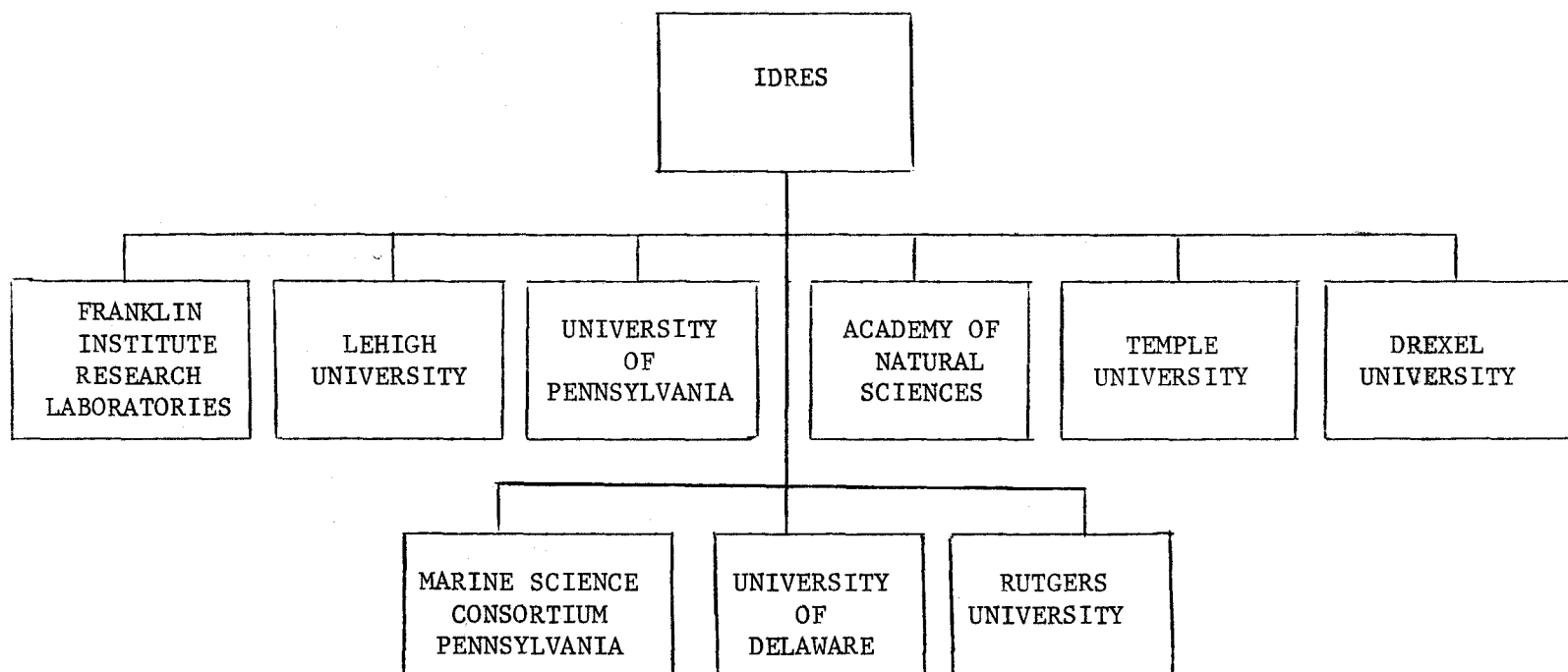


Figure 11. IDRES Consortium Members

- R. Institute for the Development of Riverine and Estuarine Systems (IDRES)
Contact: V. Hardy, Executive Secretary

IDRES is a consortium of research institutions, shown in Figure 11. It has been expanded since its initial establishment to include those principal institutions in the States of Pennsylvania, New Jersey, and Delaware with special responsibilities and interests in research concerning the region of the Delaware River watershed. Each has for a number of years carried on strong research programs oriented to the needs of the basin and estuary. All have recognized the advantages and long-term productive results of the consortium method of operation in this area of research.

Some ongoing work of the IDRES consortium is mentioned in Part IB, 16. Their proposal to NSF/RANN is described in Part IVA, 3.

- S. Ichthyological Associates
Contact: W. Basen, Project Leader, Upper and Lower Delaware
V. J. Schuler

The main project of concern is covered in Part IB, 5. There is similar work being carried out in Eddystone, Pennsylvania. It is an inventory of species as a check on possible effects of proposed expansion of the Eddystone Plant.

- T. Lehigh University
Contact: E. MacNamara

E. MacNamara is currently conducting the following studies on marsh land in Salem County. He remarked that he has three other research proposals submitted which relate to the Delaware Bay, but

preferred not to give the titles.

1. Distribution of neo-benthos in a tidal marsh environment.
2. Soil structures and plant community relations in a tidal marsh environment.
3. The effect of sewage effluent disposal on a tidal marsh.

U. Marine Sciences Consortium
Contact: B. Oostdam, President

Recently Completed Projects:

Suspended Solid Transport

Sewage Sludge Disposal at Bay Mouth

The Consortium is working on no new major projects on Delaware Bay. There are some minor offshore student projects on the continental shelf, strictly educational in intent.

V. Nathan Associates
Washington, D. C.
Contact: P. Cheney

This group is studying deep draft terminal problems for the Corps of Engineers.

W. National Aeronautics and Space Administration

This agency, like the U. S. Geological Survey, has a strong interest in remote sensing techniques, and is actively exploring with NSF specific areas of cooperative research in earth resources. Its Central Atlantic Regional Test Site is discussed in Part IB, 11. Other programs are dealt with in Part IB, 17 and Part IVA, 5 and 6.

X. National Oceanic and Atmospheric Administration

1. Sea Grant
Contact: H. McLellan

The University of Delaware's Sea Grant Program is described in Part IA, 1.

2. National Marine Fisheries Service
Contact: A. Merrill, Director, Oxford Laboratories,
Oxford, Maryland

The Service is funding shellfish studies in Delaware Bay (Part IB, 6).

3. National Ocean Survey
Contact: G. Lill, Deputy Director

The Survey is recharting Delaware Bay (Part IB, 10). They also have a large amount of tide data (contact R. A. Cummings, Chief, Tides Branch), tidal harmonics (contact D. C. Simpson, Acting Chief Predictions Branch) as well as information on the level net surrounding the Bay (contact S. P. Hand).

Y. New Jersey Bureau of Statewide Planning
Contact: D. Stanfield, Chief

The Bureau's activities are covered in Part IVB, 2.

Z. New Jersey Department of Environmental Protection
Trenton, New Jersey

1. Management Plans
Contact: R. Sullivan, Secretary

These are dealt with in Part IVB, 1.

2. Bureau of Marine Lands Management
Contact: H. Barker, Chief

Mapping Activities: The language of the Wetlands Act of 1970 states that regulations concerning the areas defined by the Act may be promulgated only after these areas have been mapped. The Bureau's mapping activities have been discussed in Part IB, 12.

Management Procedures: The Bureau employs four Deputy Attorney Generals who deal with matters concerning riparian land.

3. Bureau of Water Pollution Control
Contact: C. Kaushik, Chief Environmental Engineer

Management Procedures: According to C. Kaushik, water pollution control on the Delaware Bay falls under the jurisdiction of the Delaware River Basin Commission. Surveillance and monitoring procedures are carried on, on behalf of the Commission by the Coast Guard and the State of Delaware in the Bay.

4. Section of Wetlands Ecology
Contact: F. Ferrigno, Head

The research program of this group is described in Part IB, 14.

5. Division of Parks and Forests
Contact: L. Schmidt

See IVB, 1, for the Division's plans.

AA. New Jersey Marine Sciences Consortium
Contact: Dr. Ridlon, Chairman of the Board

Recently Completed Projects:

Review of existing literature on the Marcus Hook anchorage
for the Environmental Protection Agency.

Current Project:

Study of tributaries and tidal portions of Raccoon Creek and
Old Man's Creek on the New Jersey side.

BB. Rutgers University
New Brunswick, N. J.

1. Water Resources Research Institute
Contact: W. Whipple
2. Marine Sciences Center
Contact: H. Haskin

Rutgers has had programs of research related to shellfish and general biology dating back many years, and more recently has become a strong center of expertise related to rivers and water pollution generally, especially the dynamics of biochemical oxygen demand, the mathematical modeling of river system pollution situations, and the economics of water resource development.

Two groups have capability with respect to estuarine and bay work: The Water Resources Research Institute and the Marine Sciences Center. W. Whipple is director of the Water Resources Research Institute and H. H. Haskin is acting director of the Marine Sciences Center. There is considerable overlapping of personnel engaged in programs of the two groups.

The Marine Sciences Center of Rutgers University, organized last year, has forwarded an application for a large grant from NOAA and has already received state funding. Although new as a center, the marine science teaching and research activities are already soundly established. The principal research objectives during the next few years are expected to be:

1. Problems of shellfish production (H. H. Haskin and R. C. Ahlert).
2. Productivity in the New Jersey marshlands.
3. Environmental studies in the Island Beach - Barnegat Bay area.
4. Ecology of marine ectinomyces.

The Center operates an Oyster Research Laboratory at Bivalve, New Jersey.

Rutgers is participating in the NSF/RANN project dealt with in Part IA, 3. Other Rutgers projects are covered in Part IB, 1, 7-9, and 15.

CC. Soros Associates
New York, New York
Contact: P. Soros

This group has a contract with the Maritime Administration to study the deep draft port problem for the U. S. (See Part IB, 13).

DD. Stevens Institute of Technology
Contact: R. Hires, Associate Professor, Department of Ocean Engineering.

Current Projects:

Dye study of industrial effluent from the Rollins Purle Company, Bridgeton, New Jersey, on Raccoon Creek.

R. Hires knew of no research proposals with reference to Delaware Bay.

EE. U. S. Army Corps of Engineers
Contact: C. Grider, District Engineer, Philadelphia

The central mission of the Corps of Engineers as it relates to regional environments is management and planning of specified water resource development, including navigation, flood control and hydro-electric power. The Corps also has the responsibility for evaluating the environmental consequences of coastal zone construction.

The Corps' Baltimore District is funding a study on the ecological effects of navigation improvements on the Chesapeake and Delaware Canal (Part IB, 4). The Philadelphia District submitted a proposal to Congress for a \$5,000,000 Delaware River Comprehensive Navigation Study. This is dealt with in Part IVA, 1. Other activities are in Part IVB, 7. The Corps' deep draft terminal study is covered in Part IB, 19.

As is well known, the Corps runs a physical model of the Bay at the Waterways Experiment Station in Vicksburg, Miss.

Long Range Spoil Disposal Study This study consists of seven sections, six of which are published. The seventh is an ongoing cooperative effort with the Rutgers School of Agriculture on the use of dredge material for farming. This project is representative of a variety of Corps research programs which may have an indirect applicability to Delaware Bay.

- FF. United States Coast Guard
Contact: Mr. Dux, Assistant to the Senior Inspector

The Coast Guard monitors water quality violations on the part of marine vessels and enforces marine regulations. They are also responsible for the upkeep of lighthouses, buoys, etc.

Mr. Dux knew of no future research or engineering plans on Delaware Bay.

- GG. U. S. Maritime Administration
Contact: R. Blackwell, Assistant Secretary for Maritime Affairs

The Administration is considering various port sites for deep draft vessels. Locations in and just off of Delaware Bay are considered prime candidates. (See Part IB, 13).

- HH. U. S. Navy - Office of Naval Research

The ONR funded research of the University of Delaware is detailed in Part IA, 2.

- II. University of Pennsylvania
Department of Landscape Architecture and Environmental Planning
Contact: N. Muhlenberg, Associate Professor

The Department Program maintains a set of student studio projects on the Delaware Bay region each year. New projects build on the information gathered in previous studies and cover a variety of interests including bed-rock geology, historical and land use studies. Of special concern is the development of a community health index for the area, and the department has received a National Institute of Health grant toward this end.

IV. FUTURE PLANS AND PROPOSALS*

*Natural and Historical Research Associates acted as consultants in the preparation of this part.

Plans for future scientific and management-engineering projects in the Delaware Bay Region are difficult to identify. Researchers and administrators are willing to discuss past projects and certain aspects of present projects, but they hesitate to divulge information about those which have not been funded or authorized. This is particularly true of research proposals and land acquisition programs, since precipitous public exposure might weaken the agency's position vis-à-vis potential competition or obstruction. The Survey of Future Plans, therefore, suffers from the interviewees' reticence to disclose their aspirations and is not complete where such reticence was obvious, however it has been so noted.

This report divides plans and proposals into two categories: (A) scientific and engineering research, and (B) engineering works and management.

A. SCIENTIFIC AND ENGINEERING RESEARCH

1. DELAWARE RIVER COMPREHENSIVE NAVIGATION STUDY --
CORPS OF ENGINEERS

Contact: R. Kaign, Assistant Chief, Planning Board

The Corps of Engineers has submitted a proposal to Congress for a Delaware River Comprehensive Navigation Study. The focus of this study will be the relationship between port development and land use, including a sociological analysis of effects. It will commence upon completion of the Deep Water Port Study, around June 1973. The proposal asks for a \$5,000,000.00 appropriation.

2. INSTITUTE FOR THE DEVELOPMENT OF RIVERINE AND ESTUARINE SYSTEMS (IDRES) - NSF/RANN Proposal

Contact: V. Hardy, Executive Secretary

The following are sections of a multi-part research proposal to the National Science Foundation. The Pennsylvania Science and Engineering Foundation will provide matching funds.

1. Five year study of natural marine bio-toxins.
Contact: T. C. Cheng, Lehigh
2. Study of means for maintaining dredged ship channels without continual dredging.
Contact: J. M. Parks, Lehigh
3. Economic evaluation of proposed water reuse.
Contact: C. W. Clump, Lehigh
4. Toxic effects of water-born refinery wastes.
Contact: R. B. Biggs, University of Delaware
5. Redesigns of cooling towers.
Contact: A. Kalnins, Lehigh

6. Magnitudes of direct atmosphere fall-out as a source of estuarine pollution.

Contact: R. B. Biggs, University of Delaware

7. Effects of herbicides on aquatic plants.

Contact: I. H. Suffet, Drexel & N. H. Prichard, Lehigh

3. DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL-
COLLEGE OF MARINE STUDIES JOINT RESEARCH AND MANAGEMENT PLAN

Contact: W. S. Gaither, Dean, CMS

This plan is detailed in section B of this part.

4. BASELINE STUDY OF DELAWARE BAY-CMS

Contact: D. Polis

The objectives of the planned investigation are to provide base-line data on the biology, chemistry, physical oceanography, climatology, hydrology and geology of the Delaware Bay and to use this data to develop predictive models. The study would supply governmental agencies with the information needed for sound management of the bay and adjacent lands.

The plan for the Baseline Study was adopted by NOAA as the basis for their proposed environmental quality study of Delaware Bay. This was incorporated in budget proposals, but was not approved by the Bureau for the Management of the Budget. Certain portions of the study plan have been incorporated into the RANN project, while other portions are being pursued by NOAA agencies.

5. SKYLAB/EREP APPLICATION TO ECOLOGICAL, GEOLOGICAL AND OCEANOGRAPHIC INVESTIGATIONS OF DELAWARE BAY-NASA

Contact: V. Klemas

This project is funded and work will begin in the Spring of 1973.

B. FUTURE PLANS AND PROPOSALS - ENGINEERING WORKS AND MANAGEMENT

1. NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Water Pollution Control
Contact: F. Salkie, Facilities Management Branch

Sewage Treatment Plants: The Bureau is responsible for examining and evaluating proposals for sewage treatment.

In the next year there are no proposed treatment facilities in Cape May, Cumberland or Salem Counties. A combined project for the Townships of Alloway, Elker, Quinton and Pillsgrove, has been proposed to commence around 1975. This proposal will involve a groundwater recharge station, a pumping station and a sewage treatment plant.

Division of Parks and Forests
Contact: L. Schmidt

Acquisition: This Division has put forth a proposal to acquire 23,000 acres of wetlands adjacent to the state-owned fish and game lands at Egg Island, Turkey Point and Cadwalder. This acreage is located in Downe, Commercial and Maurice River Townships. An application has been made for federal matching funds.

Management: No management plans for this area exist at the present time.

2. NEW JERSEY BUREAU OF STATEWIDE PLANNING

Contact: D. Stanfield, Chief

This Bureau completed a background study on Delaware Bay in 1966. It has no immediate plans to update it.

Research Proposal: Criteria Standard and a Procedure for Evaluating the Environmental Impact of Proposed Manufacturing Land Uses in the Coastal Zone.

3. DELAWARE RIVER AND BAY COUNCIL, NEW JERSEY GOVERNOR'S COMMISSION

Contact: J. Holland, Chairman

The Council has no paid staff. Its purpose is to recommend long-range policies for the Bay. It has just finished holding hearings and is now involved in sifting through information preliminary to making recommendations at the end of the year. The Council will not initiate any independent research studies.

4. DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

Overall Departmental Plans

Contact: A. Heller, Secretary

Ecological Warning System: The department is developing a methodology for a proposed ecological warning system for the state which will seek to interrelate air and water quality and their effect on biota. This project will seek federal funding.

CMS-NREC Cooperative Research-Management Project: In a unique venture, the College of Marine Studies is preparing a joint budget with the Department of Natural Resources and Environmental Control to carry out research directly relevant to the management of the State's coastal zone resources. Among the projects being considered are:

1. The development of plans for coastal recreation centers
2. The development of models to aid in the management of the Bay

3. The planting of oysters and clams on natural seed beds
4. The construction and investigation of artificial reefs
5. The development of an organizational structure for the management of the Bay
6. An investigation of financial incentive for coastal zone development
7. An investigation of strategies for engineering development with ecological integrity in a coastal environment

Division of Environmental Control
Contact: J. Bryson, Director

Mapping Activities: There are no new mapping activities planned for this area. Most of it has already been mapped.

Management Procedures: The Department continues to make water quality checks for the Delaware River Basin Commission on the stretch of the Delaware between Reedy Island and Trenton. One Deputy Attorney General is employed to assist in water pollution control cases.

Beach Erosion: The responsibility for beach erosion control is in the process of transfer from the Department of Transportation to the Department of Environmental Protection. There are no current projects.

Sewage Treatment Plants: Regional Sewage Treatment Systems are scheduled for either expansion or construction in the Wilmington-New Castle area, in Kent County and in Sussex County.

Division of Parks, Recreation and Forestry
Contact: R. Jass, Director of Planning and Construction

Acquisition: The state recently acquired 2,000 acres of wetland

including a large area adjacent to Bombay Hook. Plans continue for future acquisition, but R. Jass declined to give any details. There is a proposal to transfer 250 acres at Cape Henlopen from federal to state ownership.

Management Projects: Management projects for the coming year include:

1. Launching ramp and boat platform repair on the Mispillion.
2. Parking lot construction adjacent to the C & D Canal at Delaware City.
3. Relocation of 300 families living in shacks on Burton Island, on newly acquired state park land.
4. Construction of a launching ramp at Port Mahon.

5. DELAWARE STATE PLANNING OFFICE

Contact: D. R. Keifer, Director and J. Sherman, Planner IV

State Comprehensive Development Plan: The office is updating the State Comprehensive Development Plan, including plans for the area around Delaware Bay. The plan should be completed in September, when it will be reviewed by state and federal agencies as well as the DRBC.

Coastal Zone Planning and Management Program: This program which is required of the Planning Office by the Coastal Zone Act was begun in April and is due to be completed in March of 1973. The research described in Part IB, 18 is in support of this planning.

6. DELAWARE GOVERNOR'S WETLANDS ACTION COMMITTEE

Contact: W. K. Dupont

The Governor has newly appointed a Wetlands Action Committee whose purpose is to recommend controls for residential development on the shoreline. The Chairman is William K. Dupont. Their report is due next February.

7. U.S. ARMY CORPS OF ENGINEERS, PHILADELPHIA DISTRICT

Contact: R. Krech, Assistant Chief of Operations, Philadelphia

Dredging Projects:

	<u>Place</u>	<u>Dimensions</u>		<u>Status</u>
		<u>Deep</u>	<u>Wide</u>	
Delaware	Appoquinimink			Inactive
	Smyrna	7'	100'	Last dredged 1949
		7'		
	Leipsic			Inactive
	Little Run	5'	40-60'	Inactive 1966
	St. Jones	7'	50-60'	Inactive 1937
	Murderkill	7'	60'	Inactive 1972
	Mispillion	6'	60-80'	Inactive 1964
	Broadkill	6'	40'	Inactive 1965
	Harbor of Refuge	15'	300'	Inactive 1951
	Roosevelt Inlet	10'	200'	No Information
New Jersey	Cohansey River	12'	75-100'	No Information
	Maurice River	7'	60'	Inactive 1941
	Dennis Creek			Inactive
	Gochen Creek			Inactive
	Cape May Canal	10'	100'	Dredging Now
Main Ship Canal			1,000'	Dredge every 3-4 years

Beach Erosion Projects: Two beach erosion projects are in the study stage at Broadkill and Lewes. It is anticipated that both projects will be authorized. Both projects call for less than \$500,000 in funding.

8. ENVIRONMENTAL PROTECTION AGENCY

Contact: R. Salkie, Facilities Management Branch, New York City

Because of its recent reorganization, detailed program plans of this agency must be considered as being in flux. While it is apparent that EPA will need comprehensive research to support its specific pollution abatement thrusts, it appears that these will not be developed through direct sponsorship of research methodology studies.

Under the recent reorganization, the Delaware River constitutes the boundary between regions, so that the prospects of completion of the long-delayed comprehensive water quality study for this basin now appear even more remote.

The EPA has an extensive grant assistance program for the construction of water pollution control facilities, but they have little knowledge of future plans. The state prepares the preliminary proposal and then submits it to EPA for approval. Proposed sewage treatment facilities are listed in this report under the programs of the individual state resource agencies.

APPENDIX I

DATA COLLECTED FOR INFORMATION INVENTORY (THROUGH MAY, 1972)*
Available from College of Marine Studies

From Corps of Engineers (Philadelphia - J. Phillips)

Salinity observations	1930-39	
Salinity observations	1931-34	(Vidette runs)
Salinity observations	1932	(Liston runs)
Salinity study	1940	(Ship John, Miah Maull, & Brandywine)
Del. Bay tides	1931-40	(Ship John & Miah Maull)
Del. Bay tides	1931-32	Ship John, Miah Maull,
Del. Bay tides	1931-38	Brandywine & Breakwater
Del. Bay tides	1921-38	Reedy Island

Del. River Salinity Studies 1949

Effect of Del. River flow on oysters in natural seed beds of
 Delaware Bay. Engle, U. S. Fish and Wildlife Service; Contains
 data on river flow 1907-1951 and 1935, 1936, 1951, 1952.

Del. River Model Study River Flow, 1949. Fresh water flows at
 various stations (incl. Miah Maull).

U. S. Geological Service. Water Supply Paper 681 (1929).

New Jersey Bulletin. 33 1913-28.

Delaware River Basin report. 1960, Vol. VI, App. M, pp. 16-17.

Maj. Deakyne report 1908. U. S. Army - Engineers office.

Effect of dredging on oyster culture in Delaware Bay
 (Sedimentation Data)

*Prepared by R. E. Fothergill

Data on sediment from Neiheisal Reports. June & Sept. 1970.

53 large graphs of tides, currents, & salinity at channel stations

303 and higher (down-bay from Ship John Lt.) 1931-1933.

Pennsylvania Sanitary Water Board. Delaware River Salinity

Survey, Appendix A, 12 large charts.

From CERC (Coastal Engineering Research Center)

Beach erosion control and hurricane protection along Delaware coast, 1966.

Map showing locations of geophysical track lines and core location of vibracores and high resolution seismic reflections obtained in Inner Continental Shelf (ICONS) program.

From NOS (National Ocean Survey)

Current data in 1947 and 1953 from U.S.C.G.S. report of March 1955.

From U. S. Geological Survey

U. S. Doc. Professional paper 575-D, pp. 247-252. Moody and von

I 19.16 Reenon (1967). High resolution sub-bottom seismic

575 profiles of the Del. Estuary & Bay Mouth.

Surface water supply of the United States, Part I. North Atlantic slope Basins. Water Supply Papers: 681, 696, 711, 726, 741, 756, 781, 801, 821, 851, 871, 891, 921, 951, 971, 1001, 1031, 1051, 1081, 1111, 1141, 1171, 1202, 1232, 1272, 1332. (Years 1928-29 through 1953-4).

U. S. Geological Survey, Current Records Center, Philadelphia

Machine data cards on hourly temp. and sp. conductance at Ship

John Light (Station 1-412350) from beginning in 1969 to the

present (Feb. 1972).

Delaware River Basin Commission

Seventh water resources program, 1970.

Interstate Commission on the Delaware River Basin

Physical facts, 1939.

Delaware River Master Reports (U. S. Geological Service)

Flow at Del. River at Trenton for years 1954-5 through 1969-70.

Rutgers University Thesis R. E. Good 1965

Salt marsh vegetation, Cape May, N. J. (Also pub. in N. J.

Academy of Science 10, No. 1., pp. 1-11, 1965).

Journal of the Hydraulics Division, Proceedings of the American Society

of Civil Engineers, 95, No. HYI, January 1969.

N. J. State Board of Shell Fisheries

The story of an oyster (1931).

National Oceanographic Data Center

Machine data cards for Delaware Bay (Marsden Sq. 116) 5 stations giving bathythermograph (BT) data, 87 stations giving chemical analyses, 30 stations giving geological data.

Delaware River Basin Physical Facts

Hydrographic chart of Delaware River at Trenton for 1936.

DATA FOR INFORMATION INVENTORY CONTAINED IN
COLLEGE OF MARINE STUDIES LIBRARY, UNIVERSITY OF DELAWARE

Kraft, J. C., *A Guide to the Geology of Delaware's Coastal Environments*,

ONR-N00014-69-A0407. CMS Pub. 2 GL039 (1971).

Biggs, R. B., *Sedimentation on Shell banks in Delaware Bay*, Geological descriptions of sediment samples taken in 1971 at 90 stations in Delaware Bay. Also in pp. 79-92 of Sea Grant Report DEL-SG-1-72, March 1972.

Kraft, J. C., *Geologic History of Shoreline Changes*, Sea Grant Report DEL-SG-1-72. Nine detailed study sections of variants in the geology of Delaware Bay's western coastal area, pp. 66-71.

Sheridan, R. E. *Paleoecology of the Oyster Beds of Delaware Bay*, Sea Grant Report DEL-SG-1-72. Seven cross bay transects of two mile intervals between Kitts Hummock and Smyrna River, and several longitudinal tie lines run with a 7KH₂ seismic reflection profile.

CLIMATOLOGICAL DATA AVAILABLE IN
UNIVERSITY OF DELAWARE MORRIS LIBRARY
(Gov. Document Section)

U. S. DOC. Climatological data - monthly summaries. Years 1969-
C 56 present, in boxes on shelves. Prior years at bindery
(April 1972).

<u>Delaware, Maryland summary</u>	<u>New Jersey</u>
Wilmington-New Castle	Cape May
Dover	
Lewes	

These contain data on daily precipitation, temperature, and snowfall. Monthly summaries.

U. S. DOC. Climatological Data National Survey (National Weather
 C 30.51: Service) Monthly summaries for Wilmington, Del.
 20/969 Data on pressure, temperature, precipitation, wind,
 clouds, etc.

U. S. DOC. Local climatological data (National Weather Service)
 C 30.56: Daily records at Greater Wilmington Airport.
 968/70
 964/67
 961/63
 961/60

WATER RESOURCES DATA AVAILABLE IN
 UNIVERSITY OF DELAWARE MORRIS LIBRARY

U. S. DOC. Water Resources Data, Part I. Maryland-Delaware
 I 19.53: surface water records, 1967. Also available pam-
 Md.-Del. phlet for 1961 through 1967.

968 Water Resources Data, Part I. Pennsylvania, 1970.

I 19.53: Other volumes available 1962-1969. One volume
 Penn. (special report 31) cover years 1960-65.

969

DATA IDENTIFIED BUT NOT YET AVAILABLE

From Corps of Engineers (Philadelphia - B. Vibel)

Preliminary unpublished reports prepared by the Corps of Engineers
 South Atlantic Division Laboratory.

Source and Transportation of Shoaling Materials in Delaware Estuary, J. Neiheisel, September 15, 1970

This report contains geological data of bottom sediment samples taken all over the Bay. Samples of suspended sediment taken during tidal cycles were analyzed by a Phillips X-ray diffraction unit. Analyses show organic matter, amorphous hydrous iron compounds, clay minerals, quartz and feldspar, mica, detrital heavy minerals, and other materials.

Delaware Bay Suspended Samples in Vicinity of Ship John Lighthouse and at the Capes, Appendix C, August 8, 1968 and May 1, 1969.

This report gives data on load, in ppm., salinity, in ppt., velocity in ft/sec., silt in ppm., and kaolinite, in ppm. Samples were taken at several depths ranging from 1 to 50 feet above bottom, on 8/8/68, 4/16/69, 5/1/69, and 8/7/68.

Heavy Minerals as Indicators of Transport of Sand Size Sediment in Delaware Estuary and Vicinity

This report contains geological data on parts of Delaware Bay. Data given for magnetic and non-magnetic opaque heavy minerals, transparent heavy minerals, amphibole, garnet, micas, zircon, sillimanite, staurolite, tourmaline, pyroclenes, epidote, and chloritoid.

Composition and Load of Suspended Sediment from Tributary Streams to Delaware Estuary

Gives data on suspended load, crystalline materials, clay minerals and organic matter in streams flowing into Delaware Bay.

Limited Investigation of the Concentration and Sources of Diatoms in Delaware Estuary and Vicinity, J. Neiheisel, March 1970.

Suspended Sediment of Delaware Estuary, J. Neiheisel, July 15, 1970.

Many pages of tables giving data obtained in May, July, and December 1969 at various stations in the Delaware River from Pigeon Point to Marcus Hook.

Feldspar Distribution in Delaware Bay and Vicinity as Indicator of Sand Transport Direction, J. Neiheisel, November 12, 1970.

Gives feldspar content of 39 Bay bottom samples, 18 Continental Shelf samples and 5 beach sands.

Composition and Load of Suspended Sediment from Tributary Streams to Delaware Estuary, Appendix A.

This report describes the composition and load of suspended sediment from tributary streams to Delaware Estuary. Pint samples taken at 3 depths in tributary streams in spring, summer and fall of 1969.

