Inventory and Evaluation of Information on Delaware Bay

volume I

Prepared Under the Direction of
DENNIS F. POLIS
College of Marine Studies
University of Delaware
Newark, Delaware

for THE DELAWARE RIVER BASIN COMISSION

Funded by Sea Grant No. 1-35377 and the National Geographic Society

November 1972

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GENERAL INTRODUCTION

This project was 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. It was carried out by the University of Delaware under contract to the Basin Commission with Sea Grant funding matched with a baseline study planning grant from the National Geographic Society.

The geographic area covered by the study is Delaware Bay and its immediate environs. Delaware Bay is taken to be the water area bounded by New Jersey and Delaware and extending from a line between Capes Henlopen and May up to Liston Point. Of necessity, the report also concerns itself with the contiguous shore areas and other areas exerting, or likely to exert, a major influence on the bay.

The study was divided into two major portions: a socio-political one, and an engineering and scientific one. The socio-political portion of the study was subcontracted to the Natural and Historical Resource Associates, who were given access to relevant portions of the unpublished report of the Delaware Governor's Task Force on Coastal and Marine Affairs as well as certain supporting materials. These materials had been prepared by State and University of Delaware personnel in response to requests by the Task Force.

The overall project supervision and the scientific and engineering subtasks remained under the direction of Dr. Dennis F. Polis of

the University of Delaware's College of Marine Studies. The College also developed the comprehensive bibliography which is part of this report.

The total report 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.

V. A three part report on the history of the Bay, the laws and regulations governing its use, and the development and ownership patterns of the adjacent areas.

VI. A comprehensive annotated and indexed bibliography on all aspects of the Delaware Bay region.

Acknowledgement: We wish to thank all of those who have co-operated 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. The members of the CMS staff who aided in the production of the report are: (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, I wish to thank Mr. Joel Goodman who backed me up on those occasions when I was forced to be elsewhere.

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.

TABLE OF CONTENTS

APPENDIX I

FIGURES

PLATES

TABLES

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-1: ENGINEERING STRATEGIES FOR DEVELOPMENT OF MARINE-BASED RECREATION

Principal Investigators:
See below.

Objectives:

1) To provide the basis for cost-benefit analyses of competing land use with emphasis upon multiple usage alternatives.

2) To create a regional model for future development of other recreational land.

This project has several sub-projects as follows:

R/T-1a: STRATEGIES FOR COASTAL ROADWAY DESIGN

Principal Investigator:
R. Richards, Jr.

Objectives:

Study new strategies for location and design of roads along the Delaware coast to provide access for recreational uses while preserving the tidal marsh, dune areas, and near shore. Attention will be initially directed toward two possibilities:

1) A "structural ribbon" post-tensioned and slightly

bouyant located between marsh and farmland.

2) A low-profile causeway offshore.

R/T-1b: METHODS FOR IMPROVING RECREATIONAL BEACHES

Principal Investigator:
W. S. Preslan

Objectives:

The proposed work will investigate new methods of improving recreational beaches in areas where coastal geology has precluded natural development of attractive shorelines. Alternative methods for the initial enhancement of natural beaches and for the maintenance of improved beaches will be evaluated in terms of cost and environmental impact. A case study at Bowers Beach, Delaware, will lead to recommendations applicable to the Delaware shoreline and, more broadly, to the whole central portion of the East Coast.

R/T-1c: MARINA DESIGN

Principal Investigator:
H. Wang

Objectives:

The main objective is to develop new engineering practices for the future establishment of marinas in tidal inlets, marsh lands or lagoons. Two schemes will be explored fully:

1) A portable, floating marina complex designed to minimize disturbances to the natural coastal environment and at the

same time, to maintain maximum aesthetic value of the area.

2) A permanent or portable tidal lock system to promote much needed flushing and circulation in the marina.

Initial efforts will be concentrated on two sites selected from the area near Bowers Beach, Kent County, Delaware. This area is typical of many coastal zones along the East Coast.

R/T-1d: ADEQUATE WASTE DISPOSAL SYSTEMS

Principal Investigator:
L. L. Olson

Objectives:

1) To determine if the storage of waste water effluent with appropriate plant modifications and controlled release to the estuary will minimize the contamination of beach areas upstream from the discharge.

2) To determine if the variation in flow and sewage strength caused by the weekly fluctuations in resort town population can be smoothed out by proper treatment plant design.

3) To evaluate the effects of the effluent from the regional waste water treatment plant (now under construction) at Frederica on the surrounding beach areas.

4) In the event that storage and controlled release do not provide adequate protection of the beaches and the estuary, then the feasibility of sewage reclamation and fresh ground water recharge will be investigated.

R/T-1e: HYDRAULIC ANALYSIS OF A COASTAL DEVELOPMENT AND PRESERVATION PROGRAM

Principal Investigator:
A. Vaziri

Objectives:

The purpose of this study is to investigate the hydraulics of the coastal area along Bowers Beach, Delaware, in an attempt to establish new criteria for evaluating the merits of alternate engineering innovations introduced in the development and protection of these coastal lands. This will be accomplished by:

1) An evaluation and characterization of the present hydraulic balance of the area;

2) A study of the long-term shore protection and planning needs of the area;

3) Determination of suitable design configurations for shore protection purposes;

4) Development of hydraulic design criteria supportive to other sub-projects of the present group study; and

5) Development of a quantified scale for evaluating the long-term effects on the hydraulics and ecology of the area caused by implementation of the present recreational development program.

R/C-1: THE ROLE OF METEROLOGICAL AND HUMAN FACTORS IN COASTAL STORM DAMAGE WITH SPECIAL REFERENCE TO THE DELMARVA REGION

Principal Investigators:
J. R. Mather
F. J. Swaye

Objectives:

1) To establish the natural damage potential of Delaware's coastal areas, and

2) To identify those aspects of man's development of the coastal areas of Delaware that when superimposed on natural damage potential contribute materially to the frequency and magnitude of storm damage.

R/G-1: GEOLOGIC HISTORY OF SHORELINE RATES OF CHANGE AND BOTTOM SEDIMENT MORPHOLOGY OF DELAWARE BAY

Principal Investigator:
J. C. Kraft

Objectives:

1) To produce as detailed as possible with framework proposed, a bottom sediment map of the Delaware Bay.

2) To produce a detailed geological analysis of the Delaware Bay sediment pattern.

3) To relate bottom sediment patterns to rates of shoreline change.

4) To determine whether or not the Bay-shoreline sediment patterns are undergoing a rapid evolution or are relatively static and long lived.

R/T-3: PORT DEVELOPMENT AND MANAGEMENT

Principal Investigator:
F. E. Camfield

Objectives:

1) To provide the means of analyzing regional marine transportation facilities, and of optimizing the development of such facilities.

2) To give consideration to minimizing environmental impact.

3) To determine possible means of financing and managing the facilities while considering the influence of commodity flow of offshore terminals, the widening and deepening of the C & D Canal and Christina Basin development plans.

R/G-2: ANALYSIS OF SHOAL DEVELOPMENT PROCESSES AT IMMINENT CONSTRUCTION SITES IN DELAWARE BAY

Principal Investigator:
R. E. Sheridan

Objective:

To interpret from the stratigraphy and structure of the Holocene sediments the major processes of shoal formation in three specific areas hypothesized by industry and government as future construction sites in Delaware Bay. These sites are Brandywine Shoal, Old Bare Shoal, and Crow's Nest Shoal.

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

Principal Investigator:
D. K. Smith

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

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

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/E-2: DEVELOPMENT STRATEGIES FOR MARINE RELATED RESOURCES

Principal Investigators:
R. J. Agnello
L. P. Donnelley

Objective:

It is the objective of this project to identify and analyze the management policies (or lack of them) which cause otherwise unexplained variances between supply and demand function and outputs

of commodities in coastal zone areas of the State and region.

Criteria will be developed for the selection of management policies or strategies that will assure the optimal role of public and private communities interests with respect to the developing Delaware's marine related resources.

R/S-1: SOCIOLOGICAL ASPECTS OF SEASHORE RECREATION

Principal Investigator:
W. Dynes

Objectives:

General - The general objective is the development of estimates of levels of support, both economic and political, for various developments options among the populations that use or may use the western shore of Delaware Bay and the ocean area to the south.

Specific - During the 1972-73 contract year intentions are to:

1) Finish the interviewing of the camper sample should this not have been completed.

2) Analyze the data from the camper sample and produce a report that will give estimates of economic and political support for the development options examined.

3) Draw a sample of local yachtsmen and if feasible, yachtsmen that transit the area.

4) Adapt the interview schedule to the yachtsmen's situation.

5) Collect data pertinent to the yachtsmen's support for development options of concern to them.

R/W-2: ACTIVITY AND VARIATIONS OF TRACE CONTAMINANTS IN ESTUARINE ORGANISMS AND SEDIMENTS

Principal Investigator:
A. M. Thompson

Objectives:

1) Determine environmental activity of hazardous metals in estuarine sediments.

2) Develop analytical and sampling techniques for evaluative bio-accumulation of trace metals in oysters.

3) Scan and establish base levels of trace metals in additional estuarine organisms.

4) Determine systematic variation of pesticides and petrochemicals in estuarine organisms and sediments as a function of source and distance.

R/W-2a: ENVIRONMENTAL ACTIVITY OF METALS

Principal Investigator:
A. M. Thompson

Objectives:

1) To determine the location (e.g. clay minerals, organic matter, carbonates, etc.) of major concentrations of trace metals in sediments.

2) To measure the environmental activity of the identified sources of metals.

R/W-2b: BIOACCUMULATION OF METALS IN OYSTERS AND OTHER ESTUARINE ORGANISMS

Principal Investigator:
T. Ritchie, Department of Resources & Environmental Control

Objectives:

1) To determine base levels and seasonal rates of trace metal accumulation in oysters throughout Delaware Bay.

2) To sample and evaluate trace metal levels in other estuarine organisms in Delaware Bay.

R/W-2c: VARIATIONS IN PESTICIDES AND PETROCHEMICALS AS A FUNCTION OF SOURCE AND DISTANCE

Principal Investigator:
F. M. Swain

Objectives:

1) To measure the levels of pesticides and other organic contaminants in oysters and other filter feeding organisms.

2) To examine the spatial distribution of pesticides for relations to possible sources.

R/M-5: INFORMATION UTILIZATION SYSTEM FOR COASTAL ZONE MANAGERS

Principal Investigator:
D. F. Polis

Objectives:

The objectives of this project are to develop a Coastal Zone Information Management and Utilization System that will provide for reactive and regulatory real time decision making relative to:

1) deployment of emergency environmental control systems,

2) long term trend ecological warning,

3) near term public health closures and near term recreational safety advisories.

The project will also yield a management game for pretesting decisions with potentially adverse environmental impact.

A/I-1: MARINE ADVISORY SERVICES

Principal Investigator:
S. M. Gwinn

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 research is designed to focus on specific and important coastal and estuarine problems. The proposal for this year's work has four groups of projects.

Group I projects focus on the use of geologic methods to predict near term (i.e., one to ten years) coastal changes with particular reference to sandy coasts. This work will be extended to include the development of mathematical models for the geological evolution of shoreline change.

Group II projects are devoted to the analysis of wave spectra and their relationship to sediment transport. Work will continue on the transient wave spectra analysis method. A further application of this method will be to wave-sediment interaction and ultimately to wave-sediment-structure interaction. Lastly, an analytic approach to wave spectral analysis which could improve on the Pierson-Moskowitz method is being explored.

Group III projects use remote sensing as the principal tool in the understanding of coastal and estuarine processes. The first project uses optical Fourier techniques to determine wave energy impinging on a beach. The second is devoted to the differentiation of observed fronts by remote techniques.

Group IV projects are continued exploratory thrusts into two

geochemical areas. The first is aimed at characterizing marsh gas from all types of coastal marshes. The second is to establish the mechanism by which stabilizes marine soils.

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

MATHEMATICAL MODELS FOR GEOLOGICAL SHORELINE EVOLUTION

Principal Investigators :
H. Wang
J. C. Kraft

Objectives:

1) To establish time trend functions for geological evolution along the Delaware Coast;

2) To test the sensitivity of the time trend functions with respect to various governing geologic processes;

3) To examine the variation of time trend functions due to high intensity, short term events such as storms and artificial shoreline changes.

STATISTICAL MODELS OF WAVE-SEDIMENT INTERACTION

Principal Investigators:
H. Wang
C. Y. Yang

Objectives:

Statistical models to predict short-term coastal sediment motion due to major storms will be developed. Delaware coastal areas

will be delineated into sub-zones according to the geographical-meteorological peculiarities so that within each sub-zone the gross wave characteristics are expected to be similar under a typical storm. Initial efforts will be concentrated on establishing a model for sub-zones outside the breaking area where the effects of long-shore currents and rip currents are negligible and the sediment motions are governed mainly by tides and waves.

TWO-DIMENSIONAL SPECTRAL ANALYSIS OF SHALLOW WATER WAVES

Principal Investigators:
V. Klemas
H. Wang

Objectives:

This project will develop optical fourier transform techniques for shallow water waves and should provide wave data of use in the planning and design of coastal engineering projects in the Delaware Bay region.

CLASSIFICATION AND IDENTIFICATION OF FRONTAL SYSTEMS AND BOUNDARIES IN COASTAL AND ESTUARINE WATERS BY REMOTE METHODS

Principal Investigators:
V. Klemas
S. Kupferman
D. Polis
K. Szekielda

Objectives:

1) Identify and classify observed boundaries and frontal

types. This will require the examination of existing imagery and discussions with users of coastal and estuarine imagery for related purposes.

2) Develop, where necessary, methods to provide positive ground truth to characterize both sides of boundaries or fronts.

3) Create small scale frontal situations to verify ground truth tests, ranges of lighting and sun angles, and selection of appropriate wave lengths.

4) Extend work into the field where clearly identifiable boundary situations can be found and examined. (Several types of fronts are readily observed in Delaware Bay.)

5) Determine geometric characteristics of boundaries and fronts as supplementary interpretive information.

6) Prepare and publish an interpretive system of classification and identification for all known types of boundaries and fronts which may be found in coastal and estuarine situations.

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 is shown below:

Work Group & Chairman	Academy	Delaware	Rutgers*
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**

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* 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, Glouster, 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 adminstrative 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 Chesapeak and 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.

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 and climatological data (wind speed

and direction, air temperature, pressure, precipitation, evaporation, dew point and sky cover), sedimentation, salinity and water temperature.

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

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 phemonena. 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.

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.

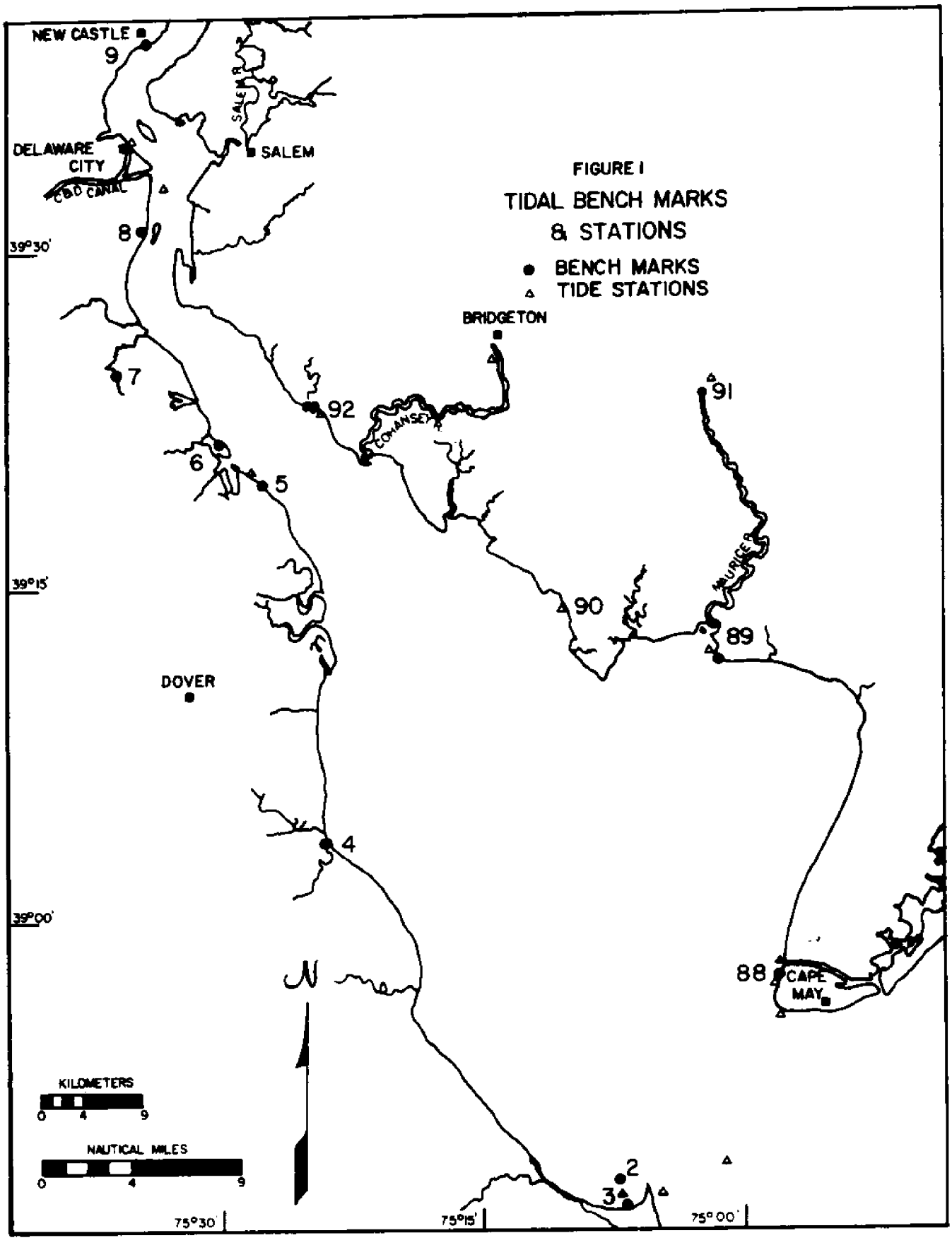
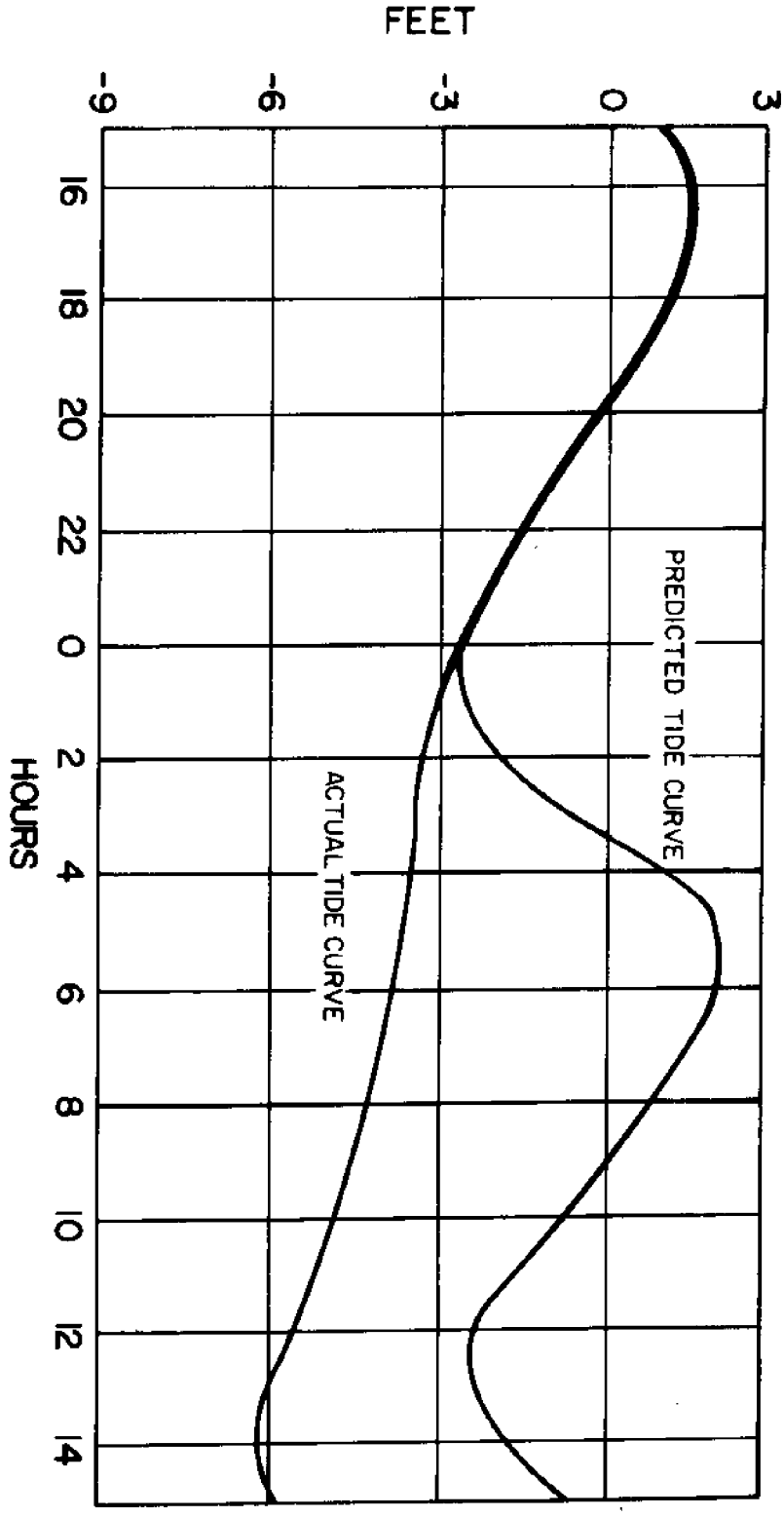


FIGURE I

TIDAL BENCH MARKS & STATIONS

● BENCH MARKS

△ TIDE STATIONS

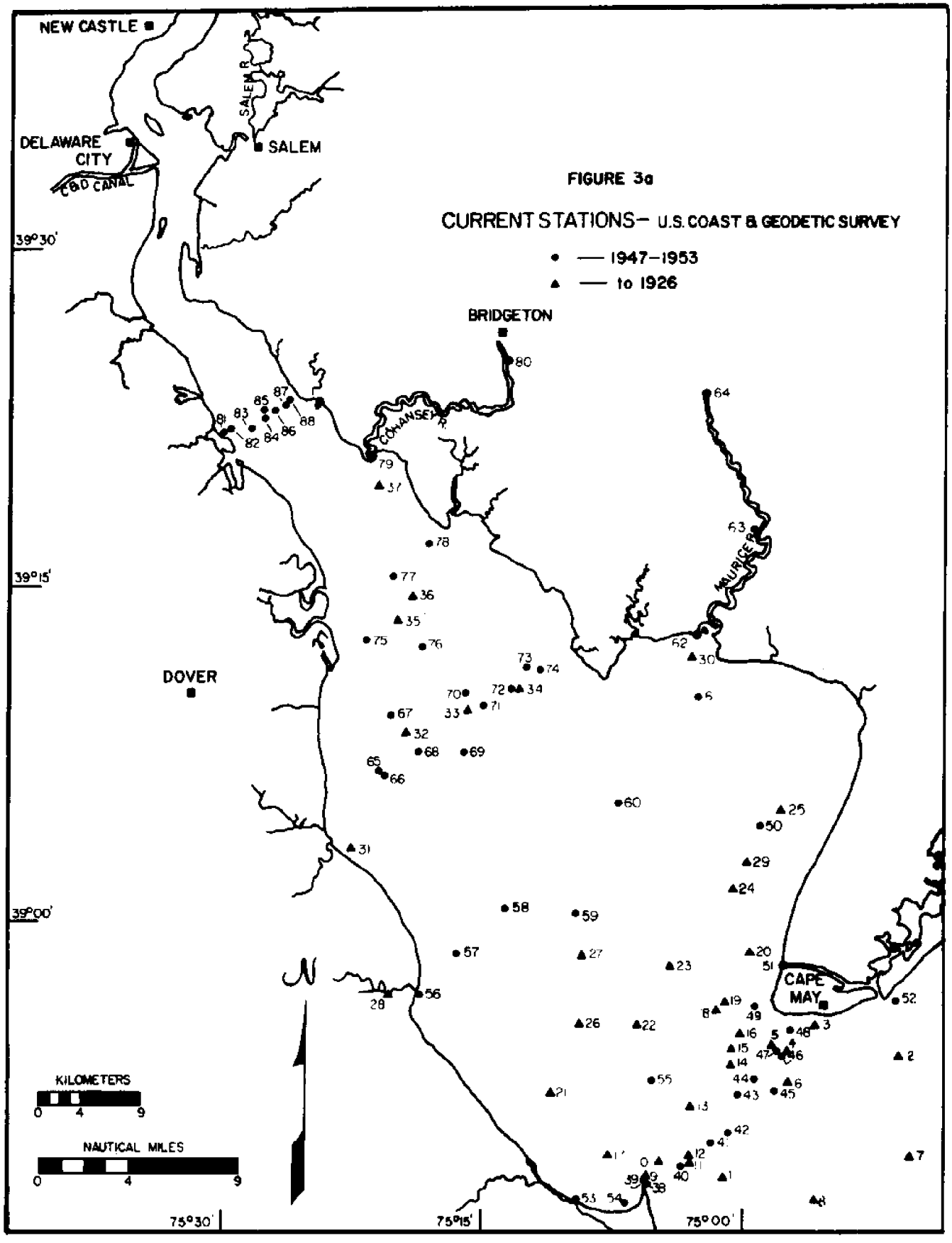


PREDICTED AND OBSERVED TIDE CURVES, PHILADELPHIA

MARCH 1–2, 1914

after ZESKIND AND LeLACHEUR
1926

FIGURE 2


NEW CASTLE
SALEM R.
DELAWARE CITY
C&D CANAL
SALEM
FIGURE 3a
CURRENT STATIONS– U.S. COAST & GEODETIC SURVEY
● — 1947–1953
▲ — to 1926
BRIDGETON
COHANSEY R.
MAURICE R.
DOVER
CAPE MAY
39°30'
39°15'
39°00'
75°30'
75°15'
75°00'
KILOMETERS
0 4 9
NAUTICAL MILES
0 4 9

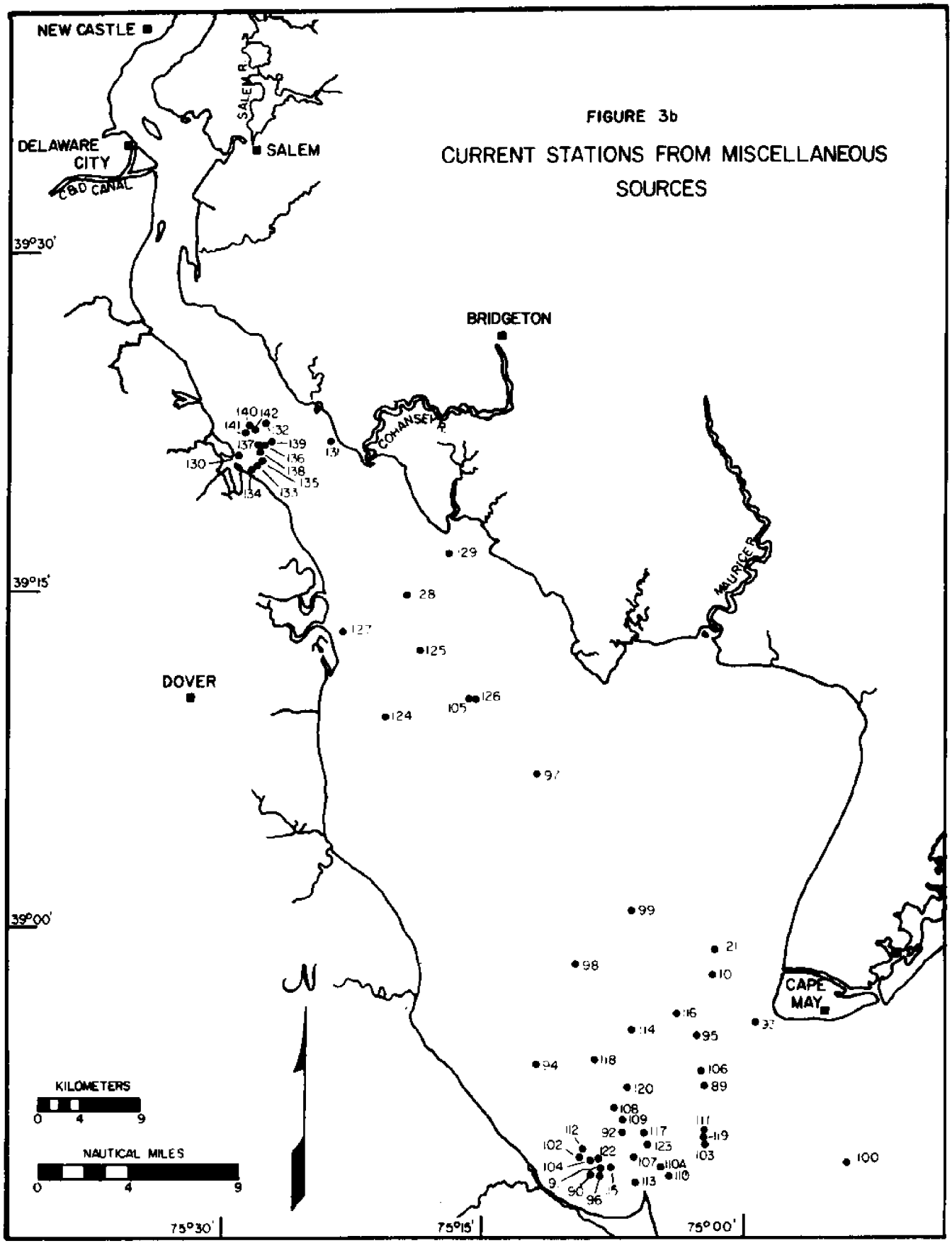


FIGURE 3b

CURRENT STATIONS FROM MISCELLANEOUS SOURCES

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	U S C & G S	A
				1 Jan. 1922 - 5 Jan. 1923		
				30 Mar. 1932 - 31 Mar. 1939		
				Scattered to 1957		
5.	Lewes	38 47	75 08	28 July 1931 - 1 Nov. 1932	U S C & G S	B
				May 1936 - Dec. 1939		
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	U S C & G S	B
				Aug. 1956 - Dec. 1966		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° '	LONG. W° '	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.

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 <u>total</u> 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-

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.

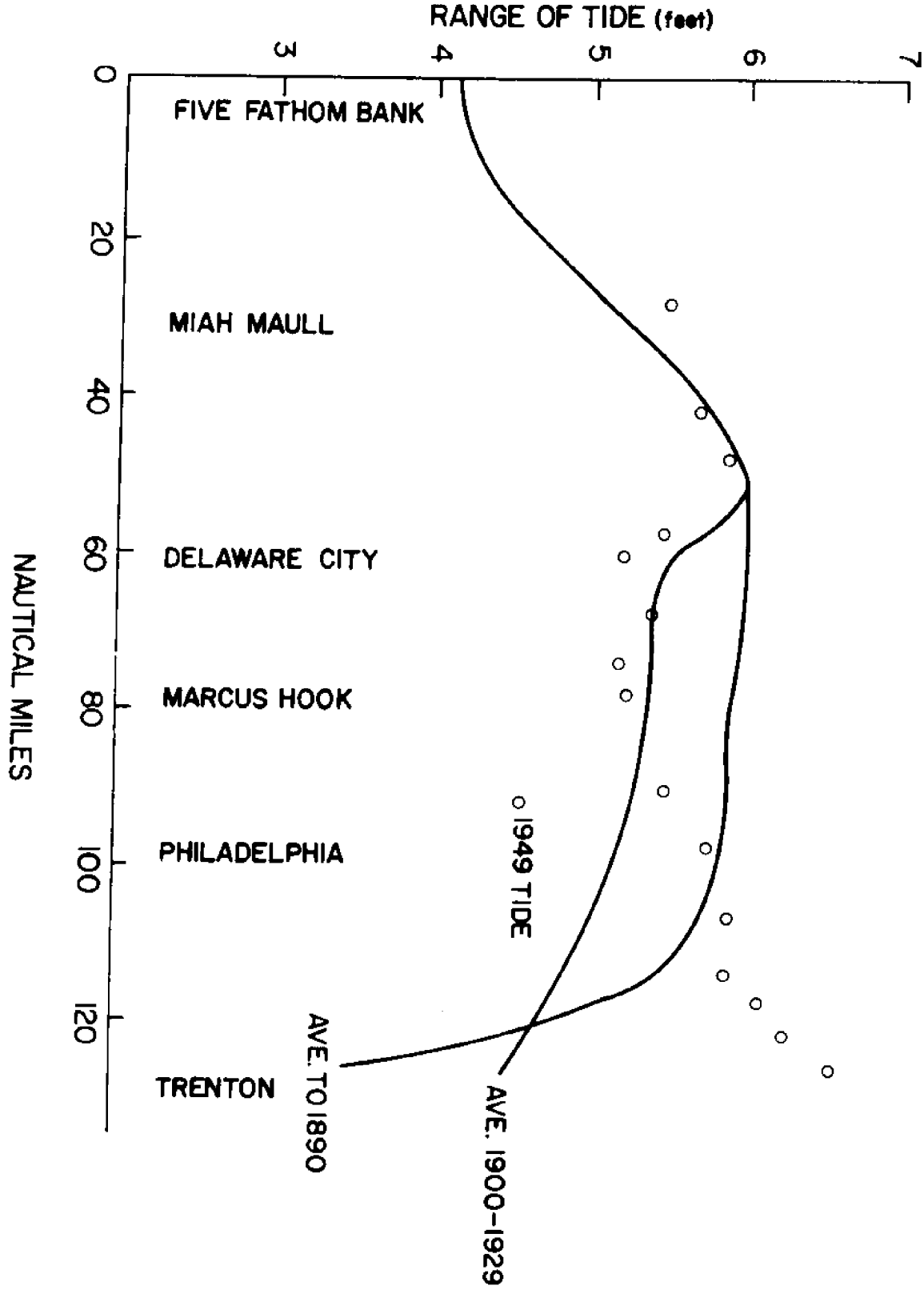
In addition to these difficulties, there is considerable doubt as to the usefulness of historical current data in describing the circulation of a rapidly changing area such as Delaware Bay. To be more specific it is known that:

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 accompained 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 itself. 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.

TABLE II

CURRENT DATA SUMMARY

#	Ref.#	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		o	'	o	'				
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	'				
1	7a	38	48.9	75	01	Aug 18-22,1925	4	PM	7,15,35,55
						1912-13, 1918-21 1925, 1940-41 See Table IIa	1552	P	7
2	9a	38	54.2	74	51.2	Sept 15-16, 1847	½	P	7
3	10a	38	55.5	74	56.0	Aug 26, 1847	½	P	7
4	11a	38	54.5	74	57.5	Sept 6-7, 1847	½	P	7
5	12a	38	58.2	74	54.6	Aug 27, 1847	½	P	7
6	13a	38	53	74	57.5	Sept 8-9, 1847	½	P	7
7	14a	38	49.8	74	50.5	Sept 16-17, 1847	½	P	7
8	15a	38	47.8	74	56	Sept 18, 1847	½	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	½	P	7
12	4a	38	49.7	75	03.3	Aug, 1886	2½	P	7

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)
		o	'	o	'				
26	18a	38	55.5	75	09.4	Aug, 1847	½	P	7
27	19a	38	58.6	75	07.4	Aug, 1847	½	P	7
28	20a	38	56.4	75	20.0	Aug 25, 1924	½	P, PM	7,3
29	21a	39	02.8	74	59.8	Aug 27-28, 1924	½	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	½	P	7,5,11,18
36	28a	39	14.6	75	19.2	Aug 20, 1924	½	P	7,8,15,24
37	29a	39	19.4	75	21	Sept 8, 1924	½	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)
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)
		o	'	o	'	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)
		o	'	o	'				
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	½		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	¼		
94	31c	38	53.9	75	11.9	Spring (1969?)	?		
95	84c	38	55.2	75	02.5	May 2, 1970	¼		
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)
		o	'	o	'				
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)
		o	'	o	'				
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	½		1,6,11,20,25,30,34
120	82c	38	52.9	75	06.5	May 2, 1970	½		
121	702c	38	59.0	75	01.5	Feb 7-8, 1970	½+		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	?	½?		M
125	21d	39	12.3	75	18.5	?	½?		M
126	22d	39	10.1	75	15.4	?	½?		M

TABLE II

CURRENT DATA SUMMARY

#	Ref.#	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		o	'	o	'				
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	½		5,10.25,35,40
108	405c	38	52.0	75	07.2	July 30, 1969	½		
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	½+		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)
		o	'	o	'				
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 ($\simeq$ 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 II

CURRENT DATA SUMMARY

#	Ref.#	N. Lat		W. Long		Date	Period Days	Method	Depth (ft)
		o	'	o	'				
127	24d	39	13.1	75	22.9	?	½?		M
128	25d	39	14.7	75	19.4	?	½?		M
129	26d	39	16.7	75	17.0	?	½?		M
130	28d	39	20.8	75	29.0	?	½		M
131	29d	39	21.7	75	23	?	½		M
132	30d	39	22.3	75	27.5	?	½		M
133	9A	39	20.5	75	27.0	July 8-18, 1952	½		T,M,B
134	9B	39	20.4	75	27.2	July 8-18, 1952	½		T,M,B
135	9F	39	20.6	75	26.8	July 8-18, 1952	½		T,M,B
136	8A	39	21.4	75	27.5	July 8-18, 1952	½		T,M,B
137	8B	39	21.35	75	27.7	July 8-18, 1952	½		T,M,B
138	8C	39	21.3	75	27.7	July 8-18, 1952	½		T,M,B
139	8F	39	21.5	75	27.1	July 8-18, 1952	½		T,M,B

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	"

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

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).

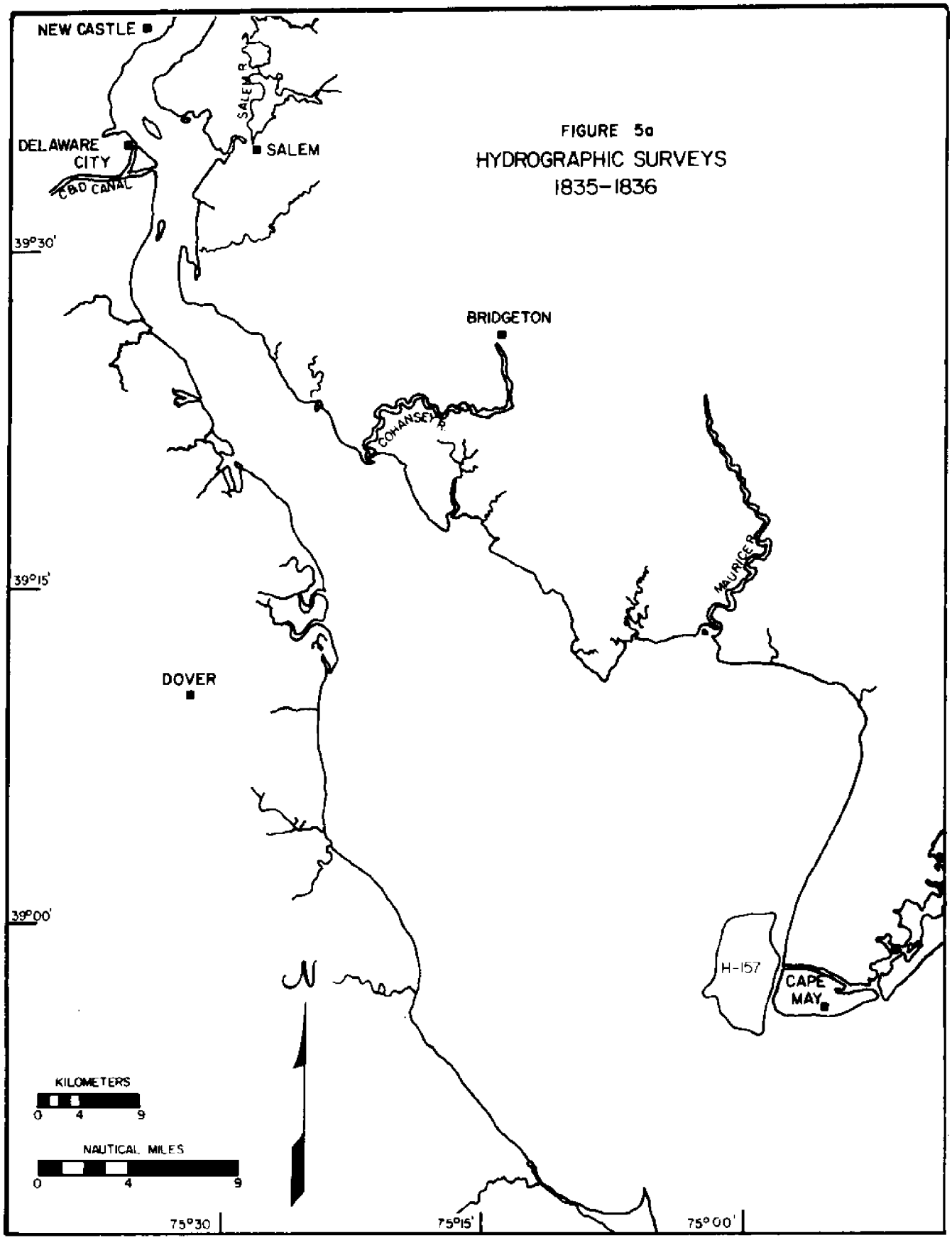


FIGURE 5a
HYDROGRAPHIC SURVEYS
1835–1836

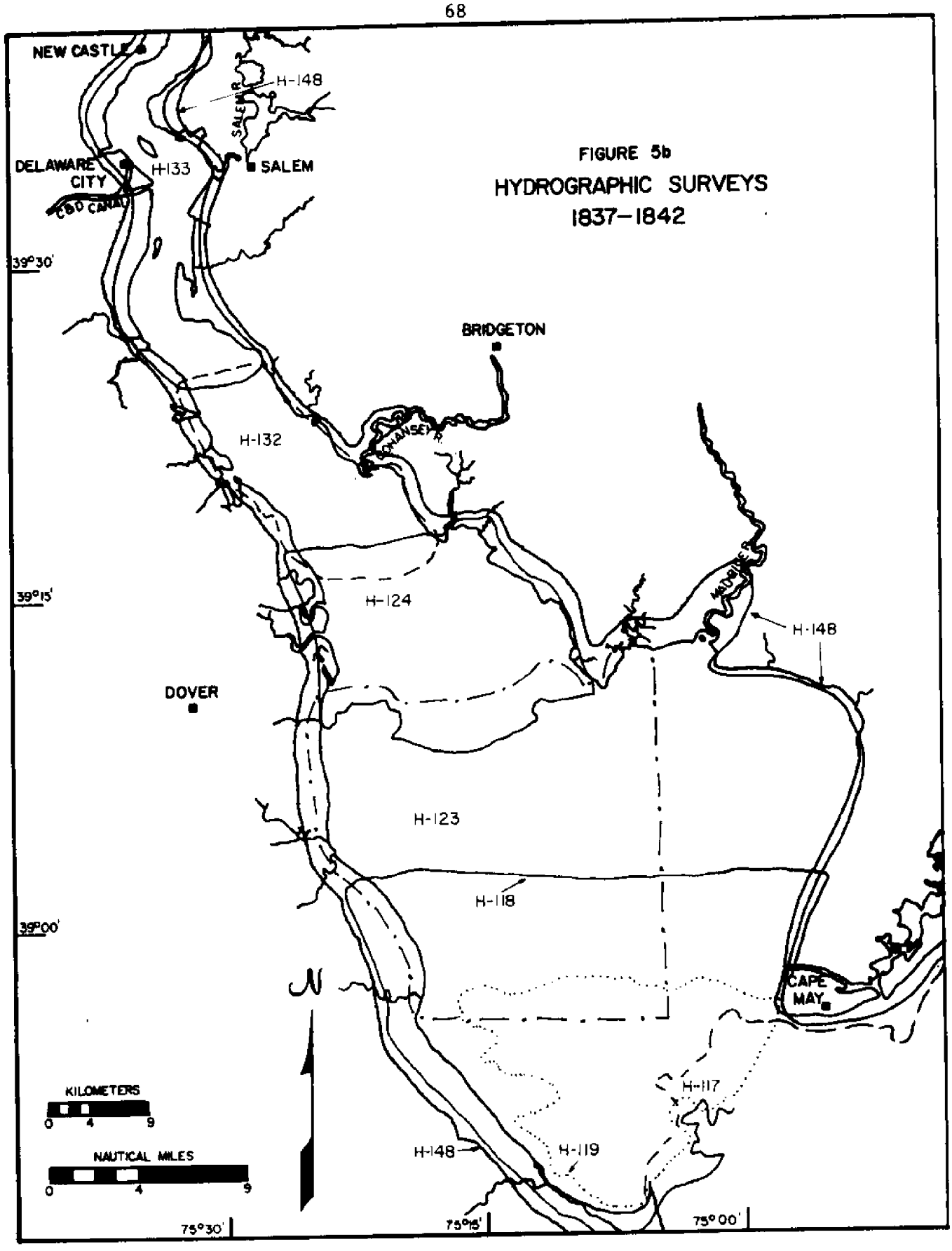


FIGURE 5b
HYDROGRAPHIC SURVEYS
1837–1842

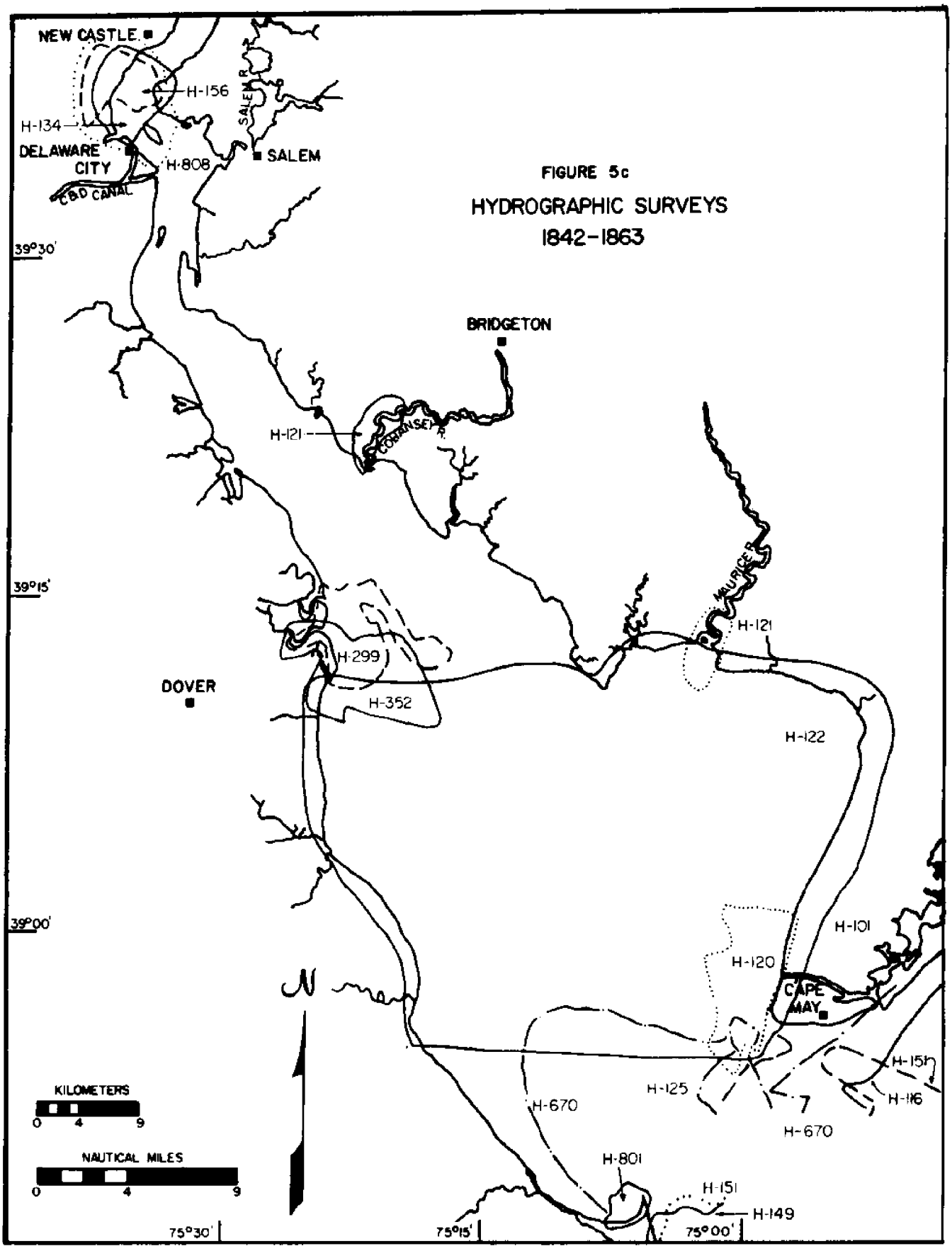


FIGURE 5c

HYDROGRAPHIC SURVEYS

1842-1863

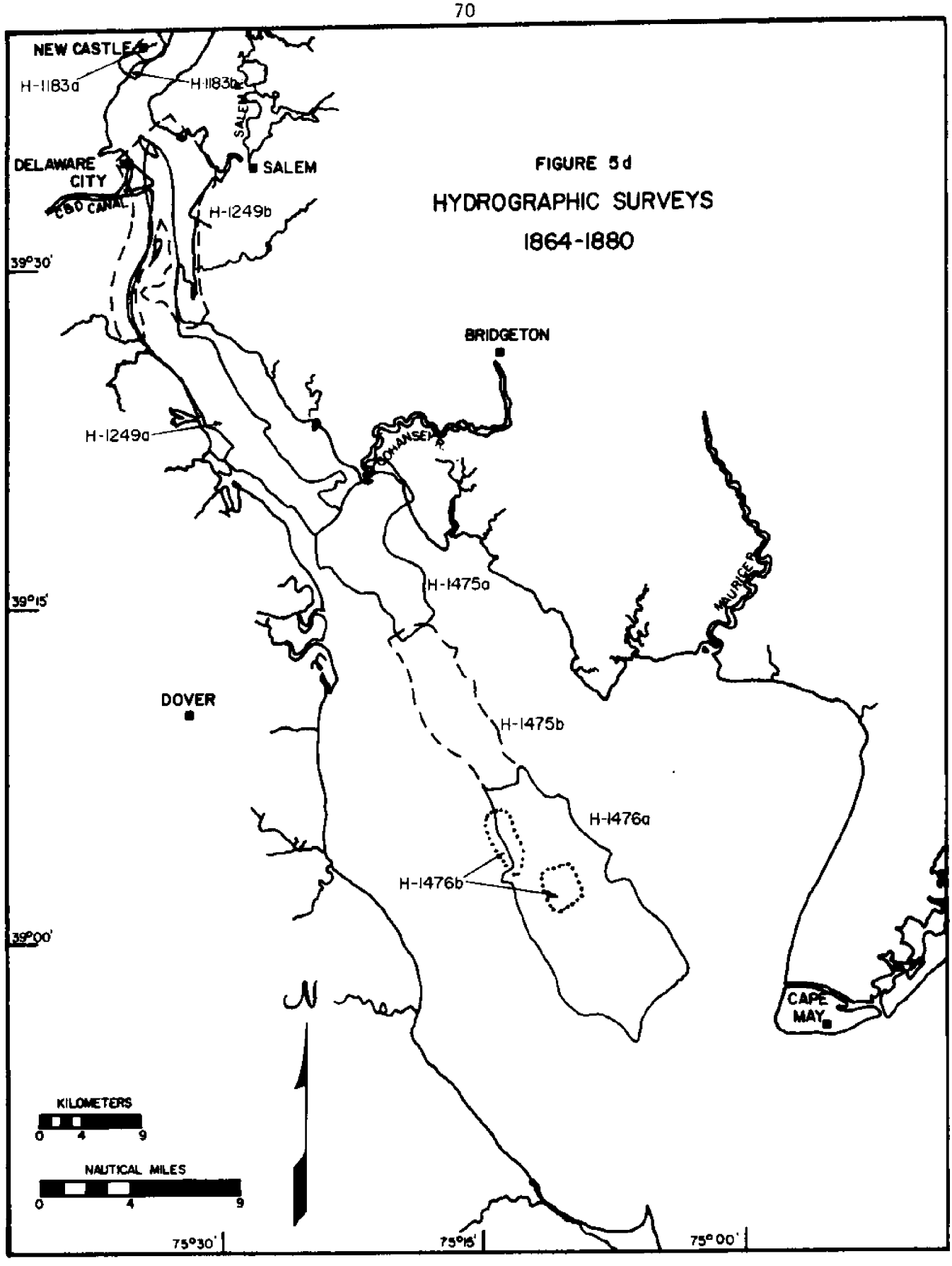


FIGURE 5d

HYDROGRAPHIC SURVEYS

1864-1880

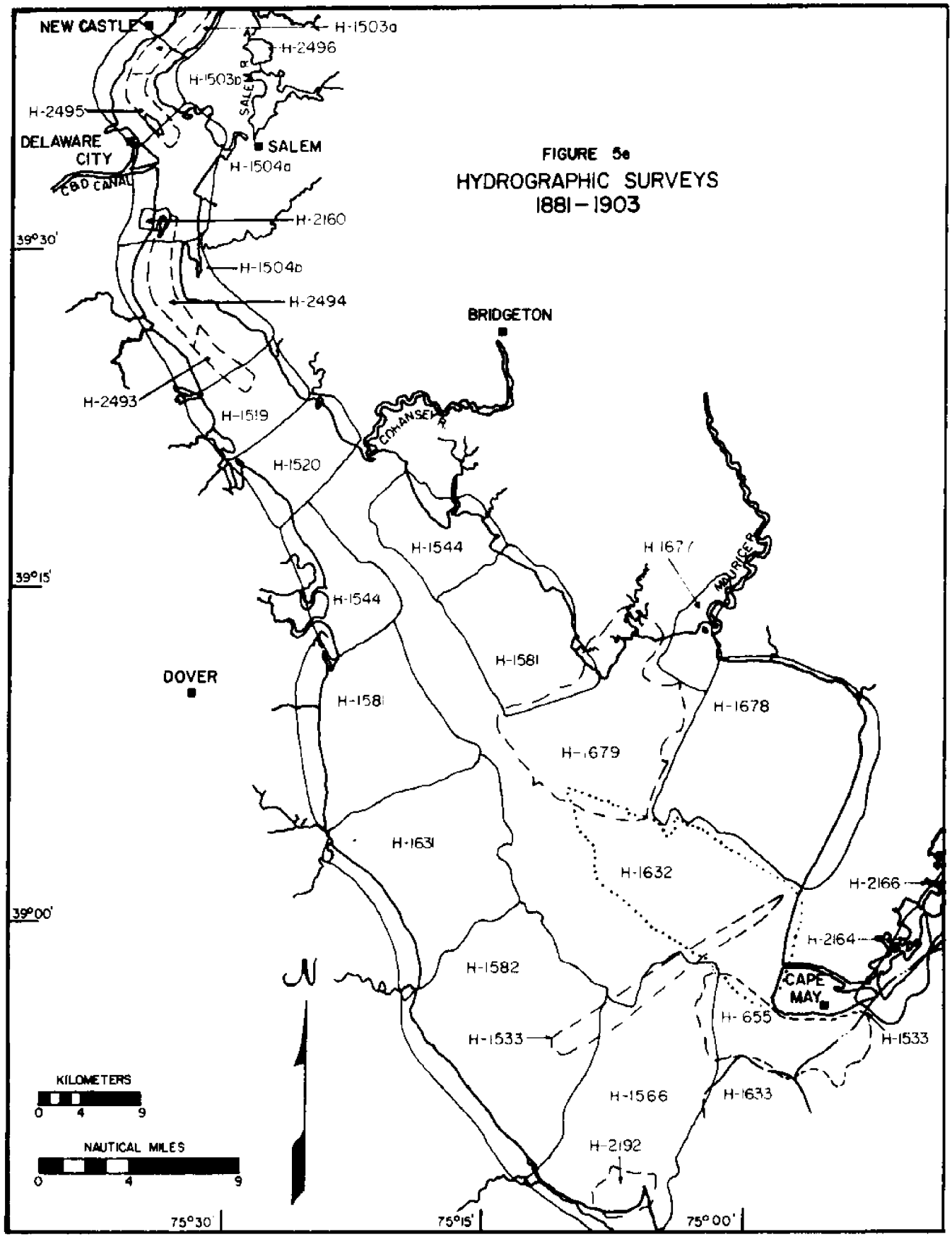


FIGURE 5a
HYDROGRAPHIC SURVEYS
1881 – 1903

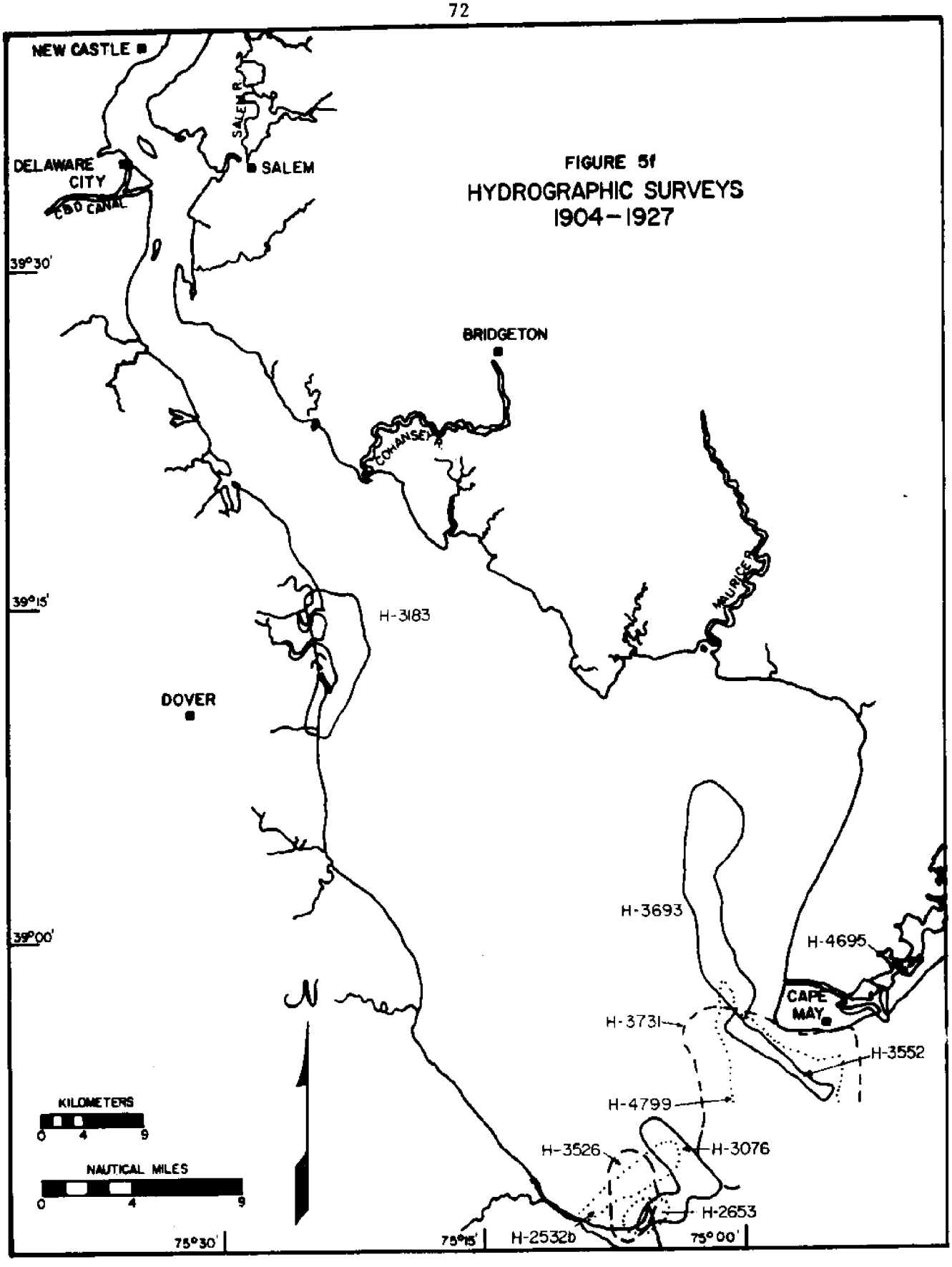


FIGURE 51
HYDROGRAPHIC SURVEYS
1904–1927

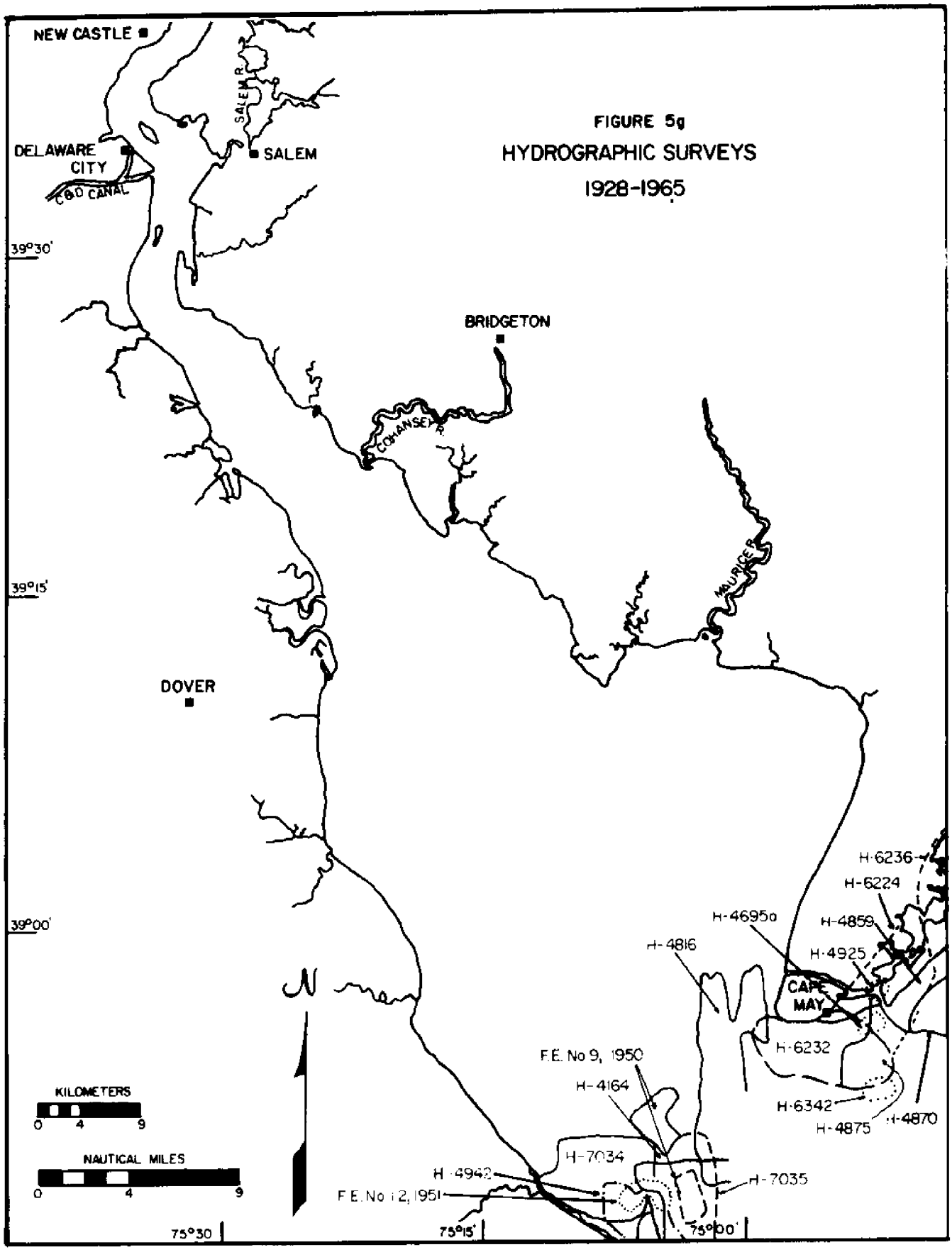


FIGURE 5g
HYDROGRAPHIC SURVEYS
1928-1965

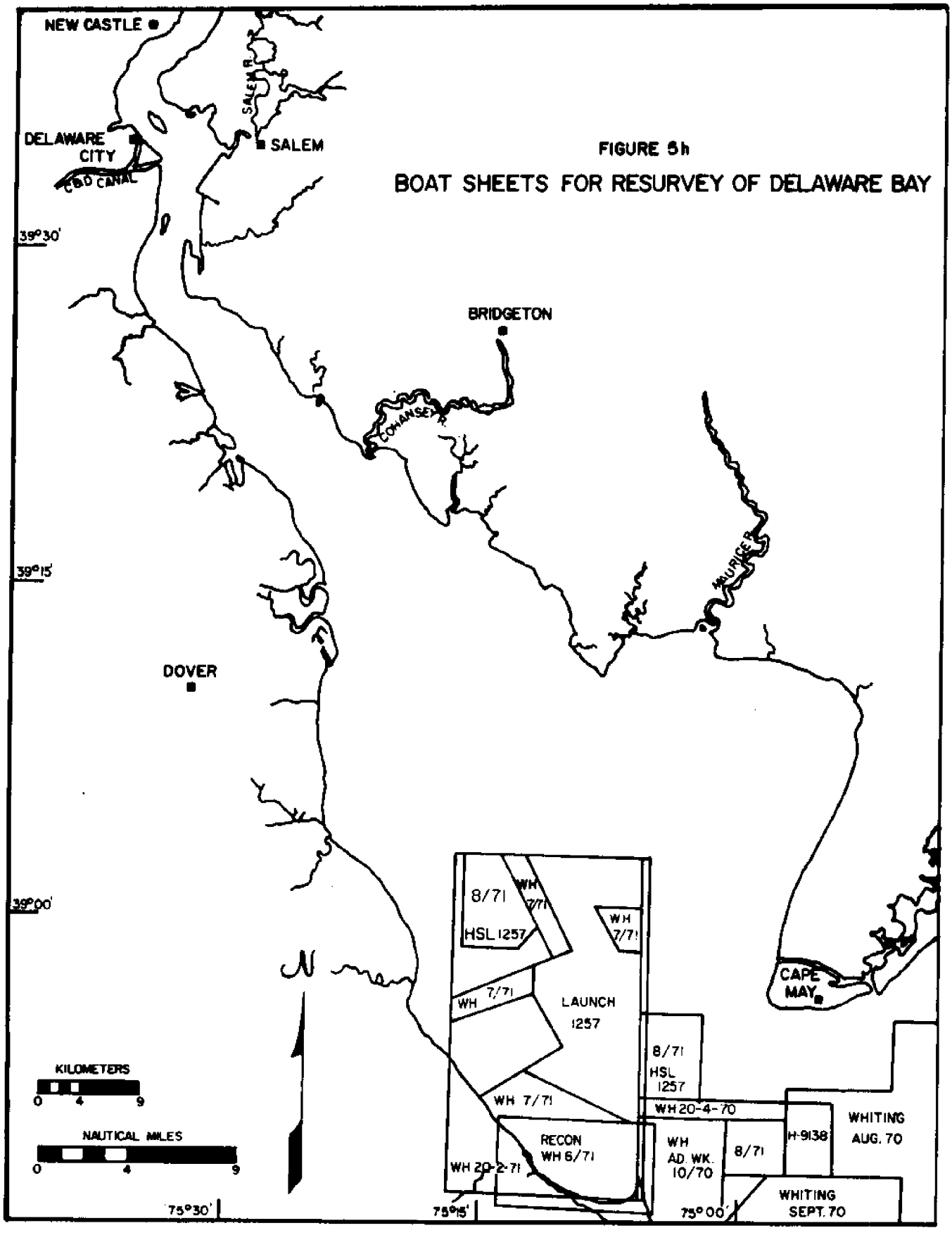


FIGURE 5h

BOAT SHEETS FOR RESURVEY OF DELAWARE BAY

TABLE III*

BATHYMETRIC SURVEYS

Survey No.	Year	Scale	Hydrographic Index Sheet Nos.
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

Survey No.	Year	Scale	Hydrographic Index Sheet Nos.
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
H-3076	1910	10,000 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

Survey No.	Year	Scale	Hydrographic Index Sheet Nos.
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 DELZOOP, 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

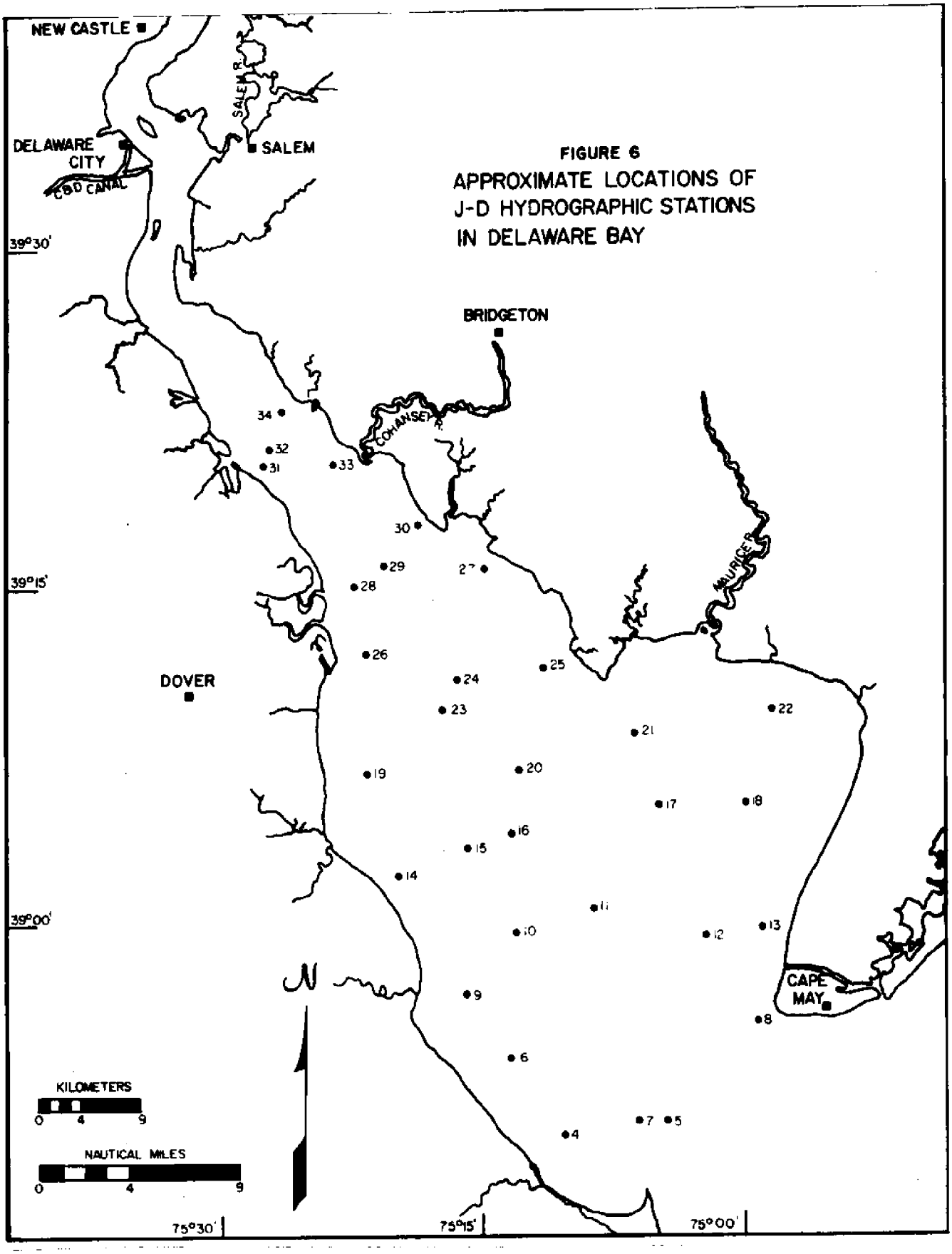


FIGURE 6
APPROXIMATE LOCATIONS OF
J-D HYDROGRAPHIC STATIONS
IN DELAWARE BAY

TABLE IV

HYDROGRAPHIC CRUISES IN DELAWARE BAY

Cruise	Date
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. 1953
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 phenomenom--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 (Szekielda, Klemas, Polis and Kupferman-to be published). These systems are discontinuous breaks in the horizontal

salinity pattern observed in the bay. 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 DELZOOP, 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

The amount of biological knowledge for Delaware Bay is far in excess of the amount of physical knowledge, but in view of the greater complexity of the biological aspects of the Bay ecosystem, it is far less adequate to develop an integrated view of the system. At the same time, the sources and types of biological data available are more familiar to the Basin Commission staff. Given this greater familiarity, this inventory highlights the biological data for the Bay, rather than treating it in exhaustive detail. A more comprehensive treatment is forthcoming in a report to the Council on Environmental Quality being prepared by D. Maurer, in connection with a preliminary study of the ecological impact of a deep-draft terminal in Delaware Bay.

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	Phytoplankton	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 quite a bit 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 being prepared at the College of Marine Studies as part of the National Geographic Report Series on Delaware Bay. These will be available shortly. Entrance to the literature may be gained through the comprehensive bibliography in Volume 3 of this report 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

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*Prepared by D. Maurer

the bay almost to Trenton. At present a private research group, Ichthylogical 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

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* 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 meterological 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 meterological 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*

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

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

TABLE V

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

TABLE V

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

TABLE V

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

TABLE V

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

TABLE V

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

TABLE V

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

TABLE V

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

TABLE V

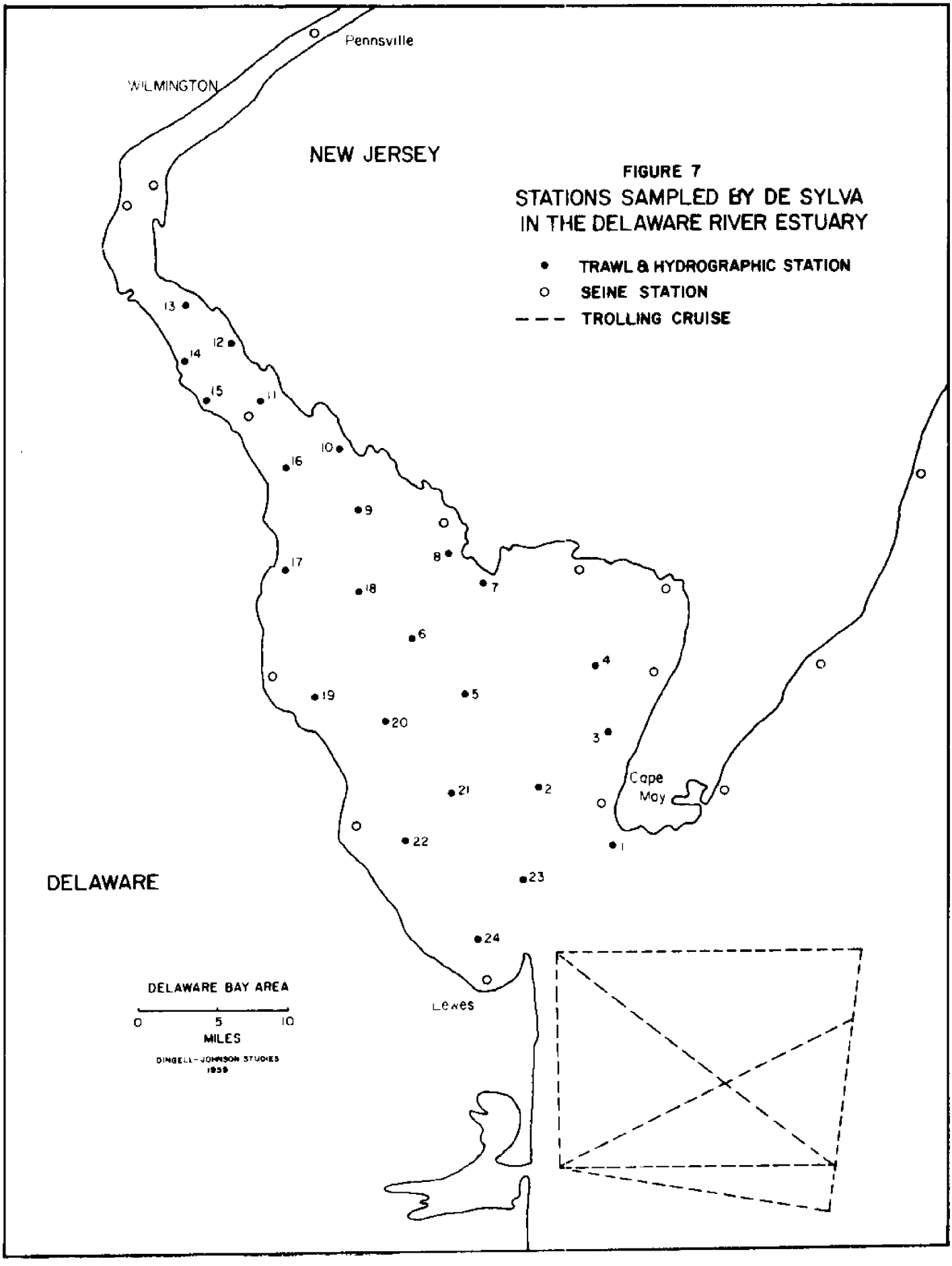
COMMON NAME	SCIENTIFIC NAME	REFERENCES & NOTES
STICKLEBACKS	GASTEROSTEIDAE	
Fourspine stickleback	Apeltes quadracus	dS
Threespine stickleback	Gasterosteus aculeatus	dS
CORNETFISHES	FISTULARIIDAE	
Bluespotted cornetfish	Fistularia tabacaris	dS (as: Cornetfish)
SEAROBINS	TRIGLIDAE	
Armored searobin	Peristedion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

TABLE V

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

TABLE V

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


Pennsville
WILMINGTON
NEW JERSEY
FIGURE 7
STATIONS SAMPLED BY DE SYLVA
IN THE DELAWARE RIVER ESTUARY
TRAWL & HYDROGRAPHIC STATION
SEINE STATION
TROLLING CRUISE
13
12
14
15
11
10
16
9
8
17
7
18
6
4
19
5
20
3
21
2
Cape
May
22
1
23
DELAWARE
24
Lewes
DELAWARE BAY AREA
0
5
10
MILES
DINGELL-JOHNSON STUDIES
1959

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

DEL-SG-5-73

The Influence of the Climatic Water Balance
on Conditions in the Estuarine Environment

John R. Mather, Frank J. Swaye, and Bruce J. Hartmann

Note:

The horizontal scales on Figures 8 and 9 (Part I) which now read "Outflow Cape May-Lewes (x10,000 cfs)" are actually the values of outflow appearing in the far right-hand column of Table 3 (headed Balance), multiplied by the number of days in the month and summed for a two month period. The study reported in Figures 8 and 9 covered only the four years from 1965-1968.

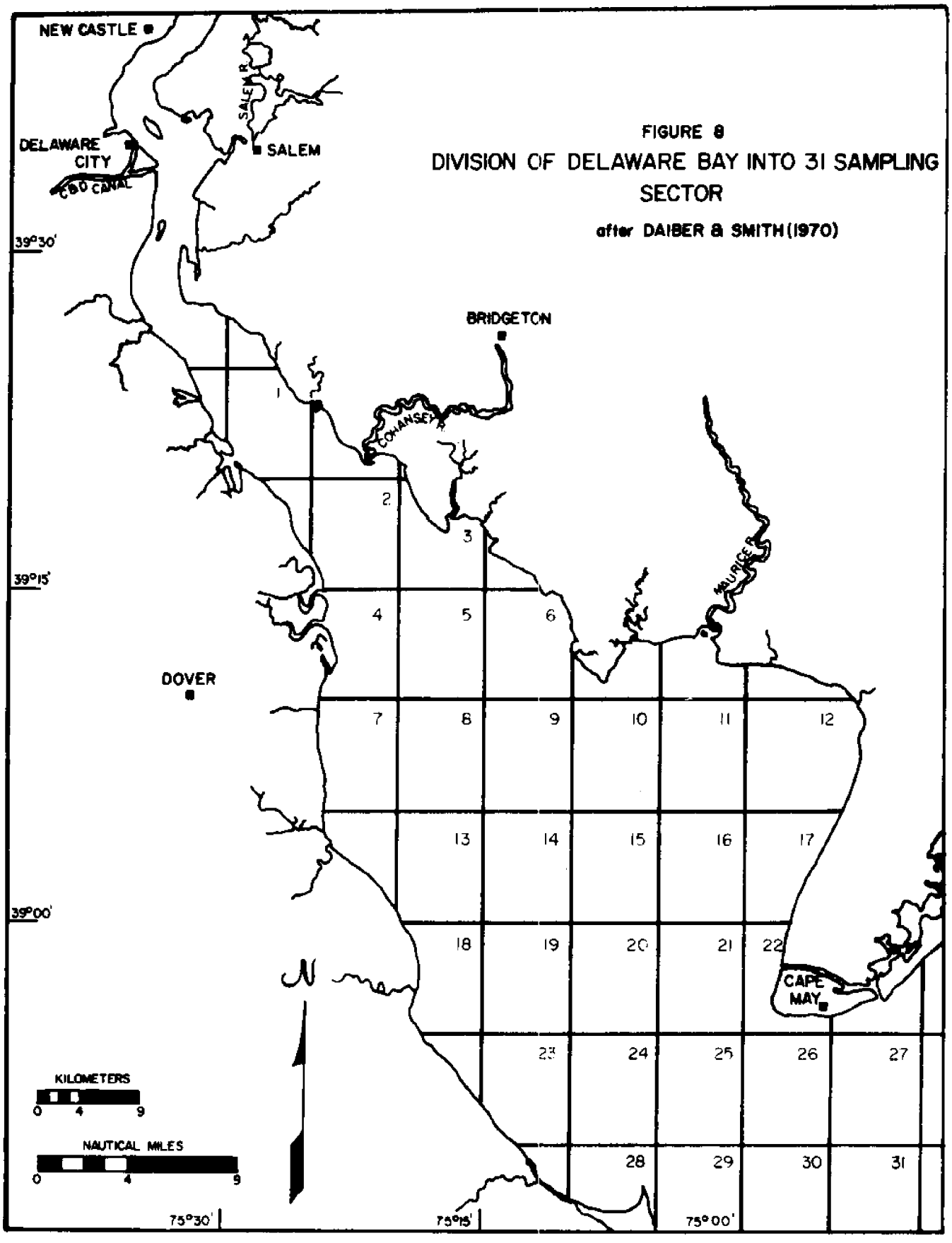


FIGURE 8
DIVISION OF DELAWARE BAY INTO 31 SAMPLING SECTOR
after DAIBER & SMITH (1970)

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.

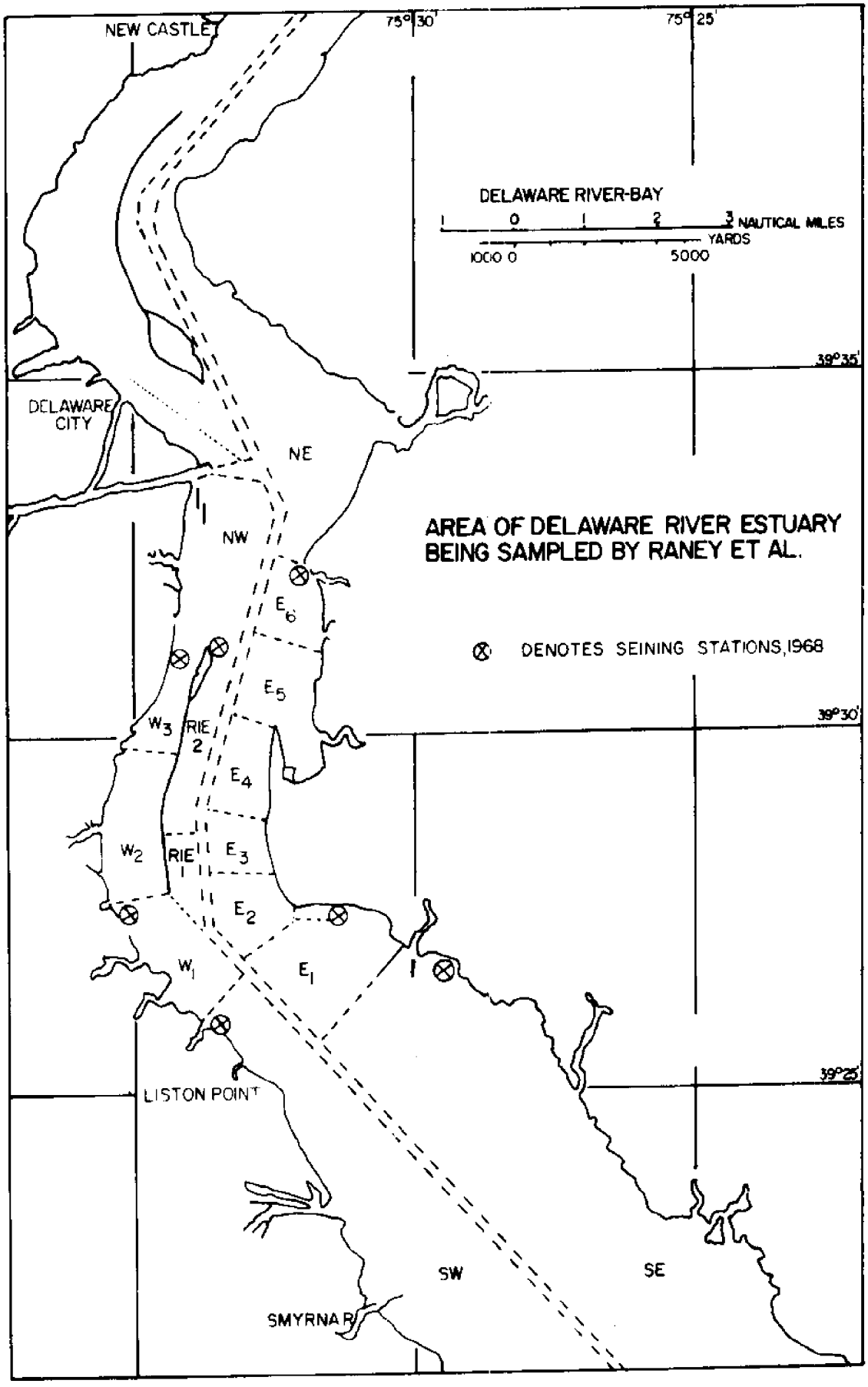

NEW CASTLE
75° 30'
75° 25'
DELAWARE RIVER-BAY
1 0 1 2 3 NAUTICAL MILES
YARDS
10000 5000
39°35'
DELAWARE CITY
NE
NW
AREA OF DELAWARE RIVER ESTUARY
BEING SAMPLED BY RANEY ET AL.
DENOTES SEINING STATIONS, 1968
E6
E5
39°30'
W3
RIE 2
E4
W2
RIE 1
E3
E2
W1
E1
LISTON POINT
39°25'
SW
SE
SMYRNA R.

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.

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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 literaure 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 Icthyological 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.

Plate 1

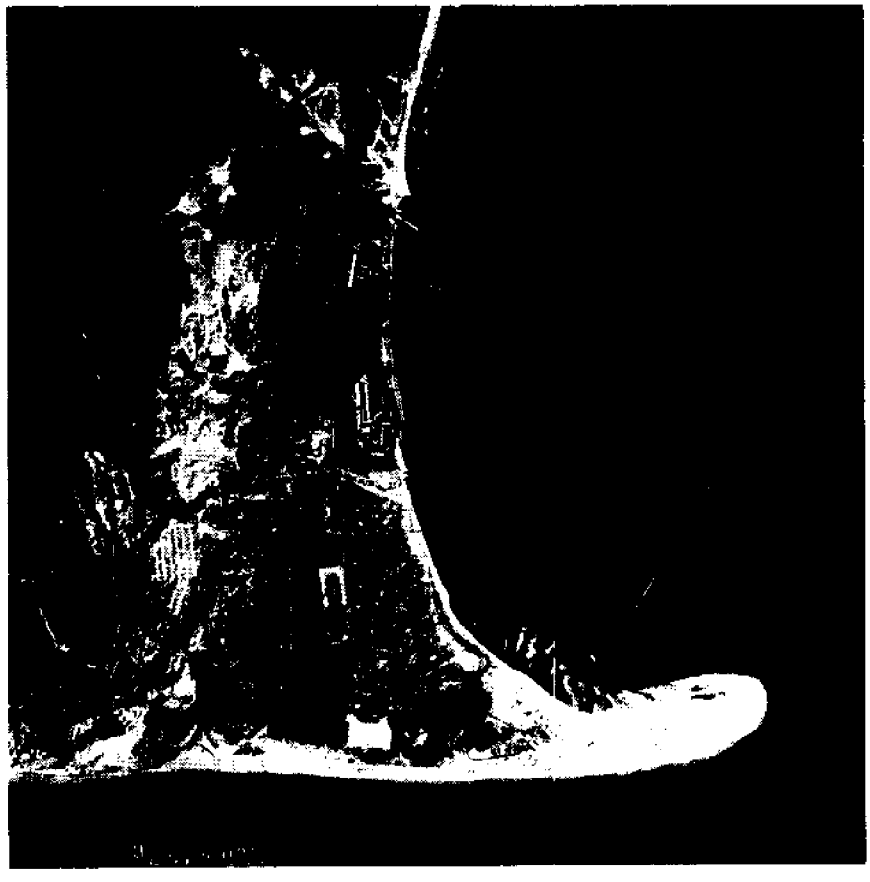
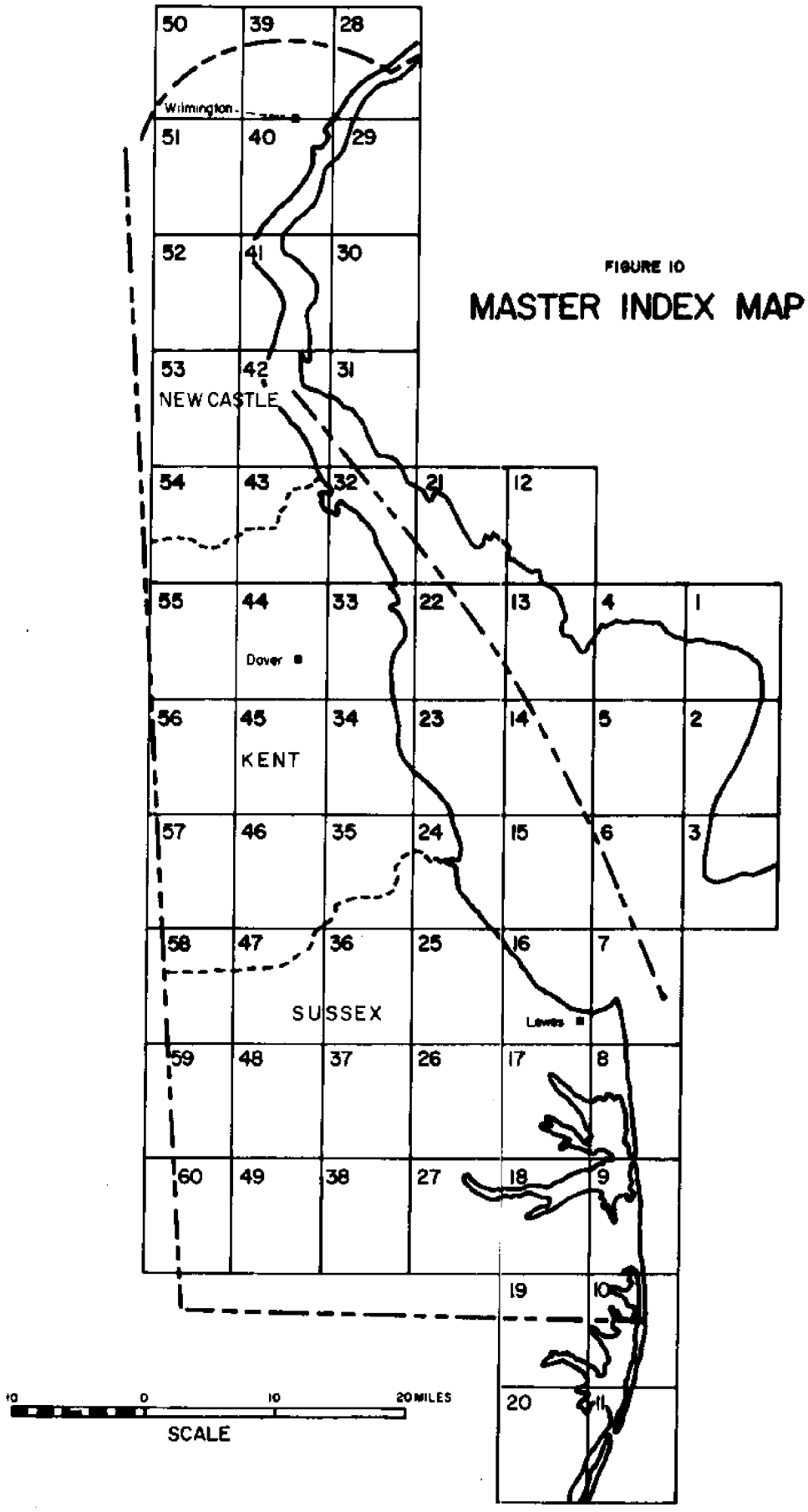


Plate 2

FIGURE 10

MASTER INDEX MAP



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 in 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.

TABLE VI

Agency Photo-Type Index*

TABLE VI

Agency Photo-Type Index*

* See Table VII 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
						CMS, Coll. of Agriculture and Geography Dept. all refer to University of Delaware.	coast of Delaware
Entire Region	1960-61	1:20,000			9" x 9"	Same as 1946 and V. Klemas, CMS and L. Cotnoir, Agr. Dept. and F. Swaye, Geog. Dept.	CMS - Sussex Co. coast. Area numbers: 7-10,16-19,24-27 see Index sheets (on order-6/26/72) Agr. Dept. - Kent Co. coast Area numbers: 23,33,34 Geog. Dept. - Entire State of Delaware
					9" x 9"	Same as 1946 and V. Klemas, CMS	CMS - 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
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, CMS and F. Swaye, Geog. Dept.	CMS - Sussex Co. coastal area. Area numbers: 7-10,16-19, 24-27 see Index sheets Geog. Dept.- 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, CMS and L. Cotnoir, Agr. Dept.	CMS - Sussex Co. coast. Area numbers: 7-10,16-19,24-27 see Index sheets Agr. Dept. - 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
Northern New Castle Co.	1959	1:24,000			9" x 9"	F. Swaye, Geog. Dept.	New Castle Co. coast Area numbers: 28,39-41
Northern New Castle Co. coast	1963	1:12,000			9" x 9"	F. Swaye, Geog. Dept.	New Castle Co. coast Area numbers: 28,39-41
Northern New Castle co. coast	1968 & 1969	1:36,000			9" x 9"	F. Swaye, Geog. Dept.	New Castle Co. coast Area numbers: 28,39-41

TABLE VIIa

FILM AND PRINTS

U.S. Department of Agriculture

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

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
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 (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.)
Color

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

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		CMS - V. Klemas	Type Photo & Roll # Color - #19
Entire Region	9/23 1970	1:120,000	RC84L	2443 12		CMS - V. Klemas	Color I.R.-#20
Entire Region	9/23 1970	1:60,000	Zeiss 5L	2443 D		CMS - V. Klemas	Color I.R. -#21
Entire Region	9/23 1970	1:458,000	Hass sR1	2402 25A		CMS - V. Klemas	B & W - #22
Entire Region	9/23 1970	1:458,000	Hass sR2	2402 58		CMS - V. Klemas	B & W -#23

TABLE VIIb

FILM AND PRINTS

NASA (cont.)
I.R. & Multispectral

Area	Date	Scale	Camera	Film type Filter type	Film Format	

Multispectral Lines

Date	Lines
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 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	
Delaware	1959-1960	1:60,000				Atlantic Region Engineer U.S. Geol. Survey 1109 N. Hyland St. Arlington, Va. 22210	
Northern New Castle 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
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 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 Commerece 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, CMS	CMS -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 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 VIIe

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: 1) Wetlands mapping 2) Land use mapping 3) Water boundary indentification 4) Frontal system identification 5) Shallow water wave study 6) Water pollution study 7) Dye dispersion study 8) Oil slick detection			CMS - V. Klemas	Types of photography used: 1) Black & White 2) Color 3) Color I.R. 4) Multispectral 5) Ultra violet

TABLE VIII

Agency Map-Type Index

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 Geog. Dept. F. Swaye	CMS - Sussex, Kent and New Castle Co. coast- see Index sheet (same map as master Index for map & phto file). Geog. Dept. 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 CMS - V. Klemas	CMS - Sussex, Kent and New Castle County coast. Same area numbers as above Geo. Dept. Entire Region
Entire Region	Geologic Maps			Wash. Distrib. Section Geologic Survey Wash., D.C. 20242 and Geo. Dept.- Geol. Survey	

TABLE XIb

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 CMS - V. Klemas	CMS - Entire Region-see Index map.
Entire Region	Hydrographic Survey Maps	1:10,000 or 1:20,000	1835 - 1965	C. & G.S.	CMS - Has Index sheets for all surveys.

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 CMS- V. Klemas	CMS - Entire Region
Del. & Penn.	Index map of Bench Marks		1954	C. & G.S. and CMS - V. Klemas	CMS - Ordered, June 1972
N. J.	Index map of Tidal Bench Marks		1956	C. & G.S. and CMS - V. Klemas	CMS- Ordered, June 1972

TABLE XIc

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	Superintendant of Documents U.S. Gov. Printing Office Wash., D.C. 20402	Not in print until Sept. 1972

TABLE XId

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"=½ mi.	Recent	Delaware State Highway Department	

TABLE XId

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 Recommended Highway Plan	1"=½ mi.	Recent	Delaware State Highway Department	
Cities	City maps	-	Recent	Delaware State Highway Department	

TABLE XIe

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 CMS - V. Klemas	CMS - 1954 & 1957 Maps
U.S.A.	United States in 1783		1783	CMS - V. Klemas	CMS- 1783
U.S.A.	Pop. Density Maps		1960	Geography Division Bureau of the Census and CMS- V. Klemas	CMS- 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 is 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. Freiberger, 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

Q. 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.

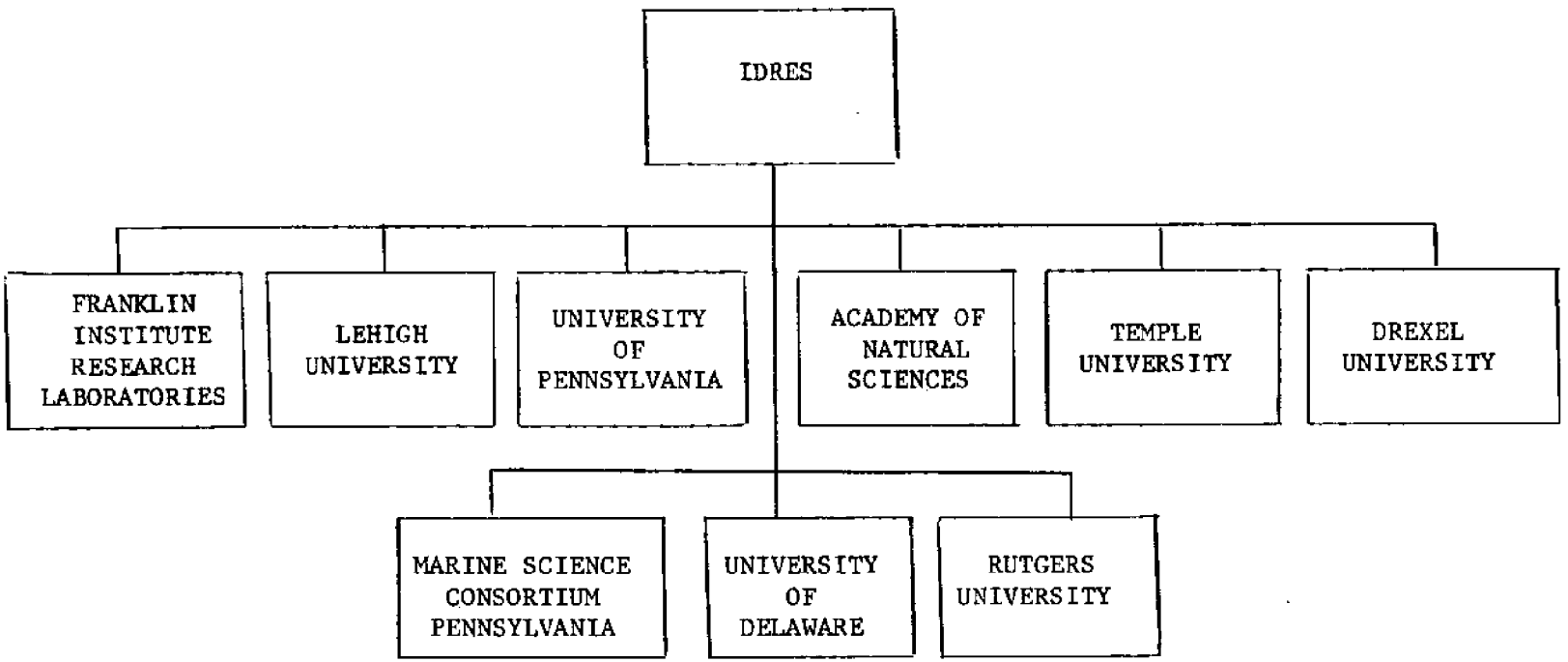


Figure 11. IDRES Consortium Members

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. Icthyological 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 ectinomycetes.

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 1B, 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

Delaware River Comprehensive Navigation Study

1. 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 baseline 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.

6. APPLICATION OF ENHANCED ERTS-A IMAGES TO COASTAL POLLUTION-EPA/NASA

Contact: V. Klemas

This work is proposed with a start date in Fall 1972. It is believed to have a good chance at funding.

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 tranfer 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:

	Place	Dimensions Deep	Wide	Status
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 DRBC 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. I 19.16 575 — Professional paper 575-D, pp. 247-252. Moody and von Reenon (1967). High resolution sub-bottom seismic 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

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

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

Delaware, Maryland summary	New Jersey
Wilmington-New Castle	Cape May
Dover	
Lewes	

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

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

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Source and Transportation of Shoaling Materials in Delaware Estrary, 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, pyrocenes, 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 Estrary, 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 Estrary. Pint samples taken at 3 depths in tributary streams in spring, summer and fall of 1969.