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**Recommendations For  
A Research Program  
Responsive To Management Needs  
For Information To Ensure  
The Values And Uses  
Desired For The  
Delaware Estuary in 2020**



**MARINE SCIENCES RESEARCH CENTER**

STATE UNIVERSITY OF NEW YORK

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Responsive To Management Needs  
For Information To Ensure  
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Desired For The  
Delaware Estuary in 2020**

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of the  
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**J.R. Schubel, Director**

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"The future never just happened. It was created."

Will and Ariel Durant  
The Lessons of History

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## Preface

This report is based upon the results of two workshops. The goal of the first workshop (March 30 & 31, 1990) was to identify the uses and values desired for the Delaware estuary in the year 2020. The uses and values were identified by representatives of diverse user groups. The goal of the second workshop (May 18 & 19, 1990) was to identify the data and information needed to ensure that the values and uses desired for the estuary of 2020 are achieved and sustained. The required scientific and technical data and information were identified by scientists and managers. This report integrates the results of those two workshop reports and expands upon them.

In preparing the reports of the first two workshops, we made a special effort to report the views of the participants without adding our own. In this report, we offer some of our own opinions; opinions based on extensive experience in a variety of capacities with other estuary programs in the National Estuary Program.

We thank Susan Schubel and Jihyun Lee for their assistance in preparing the two workshop reports; Jonathan Sharp, Marria O'Malley and Mary Downes Gastrich for organizing the workshops and for advice and guidance throughout the project; Trudy Bell, Doreen Monteleone, Joseph Ohla and Ajit Subramanian for serving as rapporteurs; Marria O'Malley, William Johnson, Marjorie Crofts, Barbara Finazzo and Mary Gastrich for serving as facilitators; and Gina Anzalone and Donna Bruno for typing the many drafts of the several reports.

This report was prepared through the Coastal Ocean Action Strategies (COAST) Institute of the Marine Sciences Research Center.

J.R. Schubel  
W.M. Eichbaum  
1 October 1990



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## I. INTRODUCTION

On July 18, 1990 the Delaware Estuary was designated by the Administrator of the U.S. Environmental Protection Agency (EPA) to the National Estuary Program for special attention pursuant to Section 320 of the Clean Water Act. Since that designation, a management structure has been developed which involves the Federal EPA, the states of New Jersey, Pennsylvania and Delaware, as well as the Delaware River Basin Commission (DRBC), the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers (COE). A component of that structure is the Scientific and Technical Advisory Committee (STAC) which has part of its charge, *inter alia*, to develop a forward-looking research agenda for the Delaware Estuary. In that context relevant research questions not only are those which address questions of "hard" science, but also those that grapple with problems of public administration.

Two workshops were organized. The objective of the first was to identify uses and values desired by the public for the Delaware Estuary in the year 2020. The objectives of the second were (1) to assess how closely the present estuary matches the desired estuary of the future, (2) to determine what modifications, if any, of present management strategies -- policies and practices -- would be required to ensure the desired estuary of the future, and (3) to identify what new information is needed by managers to conserve and, when necessary, to rehabilitate the present Delaware estuary to match the uses and values desired for the Delaware estuary of 2020. The pervasive goal of the two workshops was to develop a template to shape the research agenda of the Delaware Estuary Program.

This report summarizes and expands upon the results of the two workshops held in the spring of 1990 sponsored by the Scientific and Technical Advisory Committee (STAC) of the Delaware Estuary Program. A very slightly modified version of the original statement of goals of those workshops which was sent to all workshop participants is presented below.

## **GOALS OF STAC WORKSHOPS**

Two workshops have been scheduled for March 30-31 and May 18-19, 1990 by the Scientific and Technical Advisory Committee of the Delaware Estuary Program. This statement is written to clarify the expectations of these workshops.

### **Purpose**

The two separate sessions are scheduled as a two-part process. For the first workshop, the invitation list includes primarily individuals who could be considered users of the Delaware River and Bay. They are diverse, ranging from environmental artists and bird watchers to waterfront developers and industrial dischargers. The major question to be addressed to this assembled group involves the current and projected future uses of the estuary. The second workshop will have scientists, engineers, resource managers, and regulators as its major invitation group. They will be charged with the question of what further information is needed as a background for rational present and future management of the estuarine resources. Central to this question are the uses identified by the first workshop.

### **Expected Results of the Workshop**

The Delaware Estuary Program is in the five-year phase of developing the Comprehensive Conservation and Management Plan. Several rather general considerations (e.g. toxic substances, living resources, etc.) have been identified as areas for public concern. However, it is felt that a clearer delineation are needed from the users of the Delaware Estuary of the values of this aquatic system. Therefore, a group of users is being assembled in this first workshop that are much broader in interets than the public who responded last year in the original planning sessions for the program. This clearer delineation of estuarine uses is needed to formulate information needs for management. The following are expected results.

From the first workshop, a list of uses with some priorities and delineation of key locations to support those uses; identification of present and potential conflicts; and a preliminary exploration of strategies to reduce conflicts to "acceptable" levels -- levels consistent with the desired uses.

From the second workshop, identification of information gaps for management that aid in research planning for the immediate fiscal year and the following three years of the first phase of the program.

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This statement is a very slightly modified version of the statement prepared by Jonathan H. Sharp on March 16, 1990.

The results of the two workshops were summarized in detail in separate reports (Schubel et al. 1990 a, b). Copies of those reports are available from the COAST Institute, Marine Sciences Research Center. This report integrates the findings of the two workshop reports.

## **II. SUMMARY OF THE DATA AND INFORMATION NEEDED FOR MANAGEMENT**

This summary is based upon the results of the two workshops. It identifies the participants' views of the information needed by managers to develop strategies to ensure that the values and uses desired for the estuary in 2020 are attained. The desired uses and values and the management strategies to attain them are summarized in Appendix A. The research needed is summarized in the body of the report. The research program should place a special focus -- one of several -- on the urbanized portion of the system. Metropolitan areas have had the greatest impact on the system, they have the greatest political clout and they stand to benefit most from cleaning up the system.

The Delaware estuary has a number of advantages for developing a carefully crafted research program responsive to management issues; advantages shared by few other major U.S. estuaries -- estuaries of national significance.

The Delaware estuary is relatively small and has a relatively simple geometry. The majority of the freshwater input to the estuary enters at its head. The estuary serves a rich variety of users and uses, but none seems to dominate. Except for the tidal reaches of the river between Trenton and Wilmington, the system both farther upstream and farther downstream, is in generally good condition. The lower Delaware has an especially extensive and rich system of wetlands. Although these have been modified extensively over a long period of time, they constitute a habitat of extraordinary importance to a variety of resident and migratory species of birds and fish, as well as mammals and invertebrates.

The primary challenges to management are (1) to conserve those parts of the system that are still in good shape and (2) to improve the tidal portion of the river. Both will require new initiatives in addition to continuation of ongoing programs. Cleaning up and restoring the tidal reaches of the river will require additional controls on point and non-point sources, industrial pre-treatment, and re-creation of tidal wetlands. Conserving the portions of

the system farther upstream and downstream will require comprehensive land use planning and management.

The problems confronting the Delaware system today are similar to those of a decade or even half a century ago. They differ in degree; not in kind. This should not be used as an excuse for delaying informed, decisive management actions. It does mean, however, that there is time to think the solutions through carefully and thoughtfully. The first priority should be to protect those parts of the system that are still in good condition. Preventive environmental medicine is a more effective strategy than restoration and remediation. Once an environment has been seriously degraded, efforts to remediate it are costly and the results often uncertain. The second priority should be to tackle problems which are tractable and whose solution will result in effective management responses -- responses that restore and retain important values and uses.

### **General Principles**

- o A number of the areas of research identified by workshop participants are themes that have come up in a number of estuaries included in the National Estuary Program and in summaries of unresolved problems of the nation's estuaries.
  - o Wetlands
  - o Anoxia/Hypoxia
  - o The Exchange of Contaminants Between Sediments and Overlying Waters
  - o Hydrocarbons
  - o Relationship Between Land Use and Water Quality
  
- o It is clear that these themes are pervasive and important in many of the nation's estuaries. They pop up on everyone's list of priority areas for research. It also is clear that the level of investment in fiscal and human resources that is possible through the Delaware Estuary Program is not likely to lead to a significant advance in our

fundamental understanding of them. If any of these topics is tackled by the Delaware Estuary Program, it should be given a carefully designed Delaware "spin," a spin with a management objective.

- o We recommend that the Delaware Estuary Program emphasize research on problems that are expressed with particular clarity in the Delaware system and that are of identified management importance. The problems selected for research support should be important and tractable given the fiscal resources available and the duration of the study. They also should be clearly linked to management needs and opportunities.
- o Further refinements of the research topics outlined in this report will be required. Several mechanisms should be employed. A coherent multi-year program should be thought through before individual projects are funded. The small group of scientific and technical advisors described elsewhere in this report is one useful mechanism. Another is the proposal mechanism. In the RFPs, respondents should be strongly encouraged to discuss in their proposals the potential values of the results of their research to management.
- o Once projects are selected for funding, a special effort should be made to integrate the projects into a coherent program. The principal investigators must be willing and committed participants in this process and actively involved throughout. It cannot be accomplished by the STAC and it cannot be left to the end. Broad consultation and active outreach efforts to involve a large number of representatives of diverse stake holders have been hallmarks of the National Estuary Program. It has been a strength of the program in galvanizing interest among citizens in conserving and, where necessary, in rehabilitating estuaries. These same characteristics have been a weakness in crafting research and monitoring programs that are scientifically and technically rigorous and that effectively respond to management's needs for information.

In the following sections, we summarize the data and information needed for development and implementation of management strategies to ensure the uses and values desired for 2020. The management strategies and the important values and uses of the estuary are included in Appendix A.

**ECOLOGY AND LIVING RESOURCES:  
RESEARCH NEEDED**

Information needs identified in this area by workshop participants fell into three categories: (1) fishability and human health, (2) fishability and the health of fish stocks and (3) fishability and ecosystem health.

1. To increase fishability with regard to human health, additional information is needed:
  - o To assess levels of toxicants in fish and shellfish; coordinated tri-state management practices need to be continued and expanded.
  - o To determine if toxicants perceived to have an effect on human health from the consumption of contaminated fish and shellfish health really do.
  - o To determine the locations and strengths of primary and secondary sources (such as resuspended sediments) of toxicants; the routes and rates of transport of toxicants; the patterns of accumulation and the availability and ultimate fates of toxicants and pathogens.
  - o To manage changes in the quantity of freshwater to the system without producing unanticipated and undesirable effects.
  - o To assess the inputs of toxicants on a regional level and to develop the information needed to formulate effective strategies for reducing them.
  - o To determine if and where contaminated sediments from the river and bay bottom are contributing to accumulations of toxins in living marine resources.
  - o To develop and use modelling to predict impacts of toxicants on the ecosystem.
  - o To develop aquaculture to enhance food quantity and quality.
  
2. To increase fishability with regard to the health of stocks, additional information is needed:
  - o To identify the status and trends of living resources through stable, intercalibrated monitoring programs.



- o To identify limiting factors (spatial and temporal changes in habitat and water quality), and the effects of diseases and stock removal (fishing, entrainment and impingement by power plants) on the health of stocks.
  - o To prevent unintentional introduction of exotic species.
  - o To restock the oyster population with MSX-resistant seed.
  - o To develop bi-state (NJ/DE), and in some cases tri-state (NJ/DE/PA), fishery management plans consistent with coast-wide management plans.
3. To increase fishability with regard to ecosystem health, additional information is needed:
- o To establish the spatial and temporal distributions, abundances, production, species diversity and composition of each important benthic and planktonic community.
  - o To establish the spatial and temporal distributions of important physical and chemical environmental parameters.
  - o To identify the effects of oil spills, dredging and pollution on the ecosystem.
  - o To use aquaculture to reintroduce species and to reestablish existing species to desired levels.

**PORT ISSUES AND DREDGING:  
RESEARCH NEEDED**

- o To assess the ecological and economic impacts of dredging and dredged material disposal.
- o To develop possible beneficial uses of dredged materials, including the possibility of their use for wetland creation and enhancement, and for beach nourishment.
- o To assess the risks associated with the increase in maritime traffic, such as spills of oil or other toxic substances, and the impacts of ships' wakes on coastal areas.
- o To determine the ecological and socio-economic impacts of port growth and the impacts of the development of secondary infrastructure and industry in support of expanded port activities.
- o To develop strategies to prevent the accidental introduction of exotic species by shipping activity.
- o To assess the advantages and disadvantages of a variety of different organizational models for the Port and to select the model most appropriate for the "Ports of Delaware Bay."

**RECREATION:  
RESEARCH NEEDED**

- o To assess the economic benefits of tourism and low impact recreational activities such as swimming and birding.
- o To define the terms "swimmable" and "fishable" in measurable, quantifiable ways.
- o To assess the levels of toxicants in fish and shellfish, and to assess how these affect fish and fisheries.
- o To assess the potential impact of birdwatching on bird behavior and success.
- o To assess the value and potential impacts of various kinds of recreation.
- o To identify, characterize, and catalog important recreational areas and their uses, benefits and impacts -- existing and potential.

## **WATER QUALITY AND USE: RESEARCH NEEDED**

Information needs identified in this area by workshop participants fell into five categories: (1) water resources, (2) system-wide waste disposal, (3) status of the health of the system, (4) environmental crises management, and (5) applied economic research.

### **1. *Water Resources***

Additional information is needed:

- o To identify present and projected water budgets.
- o To assess the effects of freshwater inputs on flushing rate, salinity distribution, patterns and rates of sedimentation, habitats, and living resources.
- o To identify and assess impacts of an increase in future water needs on the estuary and its living resources.

### **2. *System-Wide Waste Disposal***

Additional information is needed:

- o To determine pollutant loadings, including hydrocarbons and metals, from the atmosphere, from point sources and from non-point sources (present and projected).
- o To determine the assimilative capacity of different segments of the system for different kinds of wastes.

### **3. *Status of Health***

Additional information is needed:

- o To determine the levels of human pathogens in the estuary.
- o To assess ecosystem health and diversity.

### **4. *Environment Crises Management***

Additional information is needed:

- o To establish the frequency and impacts of episodic CSOs.
- o To develop effective management controls for spills of oil and other toxic substances.

### **5. *Applied Economic Research***

Additional information is needed:

- o To assess relative values of competing uses of Bay resources.

**WETLANDS:  
RESEARCH NEEDED**

- o To effectively define and develop the information needed to implement a "no net loss" policy.
- o To develop diagnostic indices of the function, health and value of wetlands on a variety of spatial scales.
- o To assess the relative importance of the different functions that wetlands serve in different segments of the system.
- o To clarify the roles of wetlands and their importance to the Delaware Bay system.
- o To assess the effectiveness of present regulatory and enforcement programs that deal with wetlands and to ensure that there is an appropriate level of consistency among the requirements of the several states and the federal government.
- o To inventory wetlands throughout the Delaware Bay system. The effort should start with existing information, be supplemented as appropriate and be updated periodically.
- o To determine why some artificial wetlands succeed and others fail, and to use that knowledge to develop a framework for creation of wetlands and mitigation of impacts.
- o To assess the roles that hydrologic processes play in the formation, functioning and evolution of wetlands.

**HUMAN CARRYING CAPACITIES:  
RESEARCH NEEDED**

- o To assess the carrying capacity of the system for different levels and mixtures of uses and management strategies.
- o To develop criteria for allocating permissible levels of human uses of the river and estuary and its drainage basin.
- o To establish wasteload allocations consistent with the desired uses and values identified in the report.

**FRESHWATER SUPPLY:  
RESEARCH NEEDED**

- o To assess the effects of different withdrawal rates of freshwater on (1) salinity, (2) circulation, (3) sedimentation, (4) habitat and (5) living resources.
- o To assess the effects of a rising sea on each of the characteristics identified above.
- o To develop models that can be used by managers to evaluate the ecological consequences of different freshwater allocation schemes.

**TRIBUTARIES AND SUBTRIBUTARIES:  
RESEARCH NEEDED**

- o To assess the importance of the tributaries and subtributaries to the system -- their functions, uses and values -- need to be assessed.
- o To assess the importance of the system's largest tributary -- the Delaware River -- in developing information needed for management of the system.
- o To establish what additional field research is needed on the tributaries. (The starting point should be a synthesis of existing data and information. The data and information for the tributaries and subtributaries have not been synthesized, analyzed and interpreted. This effort is needed to formulate an appropriate research effort.)



**POPULATION AND DEMOGRAPHICS:  
RESEARCH NEEDED**

- o To assess the effects of a changing population: changes in the total population in the drainage basin and changes in its character and distribution: suburbanization in the north; tourism and second homes in the south.
  - Will these trends increase?
  - Will the distribution change?
  - Will per capita water consumption continue to increase?
  - Will use of lawn fertilizers continue to increase?
- o To assess the change in total population in the drainage basin over the past several decades, as well as population projections out to 2020.
- o To assess changes of the distribution of population within the drainage basin over the past several decades and projections of changes in distribution out to 2020. Population in the drainage basin allegedly has increased only slightly in the past decade, but there has been a major redistribution with suburban areas gaining and inner city areas, particularly in Philadelphia, losing.
- o To assess whether or not the projected changes in population distribution are consistent with desired uses and values of the estuary for 2020 and, if not, what strategies should be pursued to ensure a better match. A number of these questions will be answered by the 1990 census and by Dr. Ruth Patrick's forthcoming book.
- o To establish criteria for guiding development consistent with other uses and values. One should expect increasing pressure for some kind of development within the coastal zone. The statement was made that population in the Bay region had increased two-fold in the past few decades, but it was low to begin with. Not all development is bad. For example, second homes can provide significant economic benefits to communities with little demand for services and little impact on the environment.

### III. DISCUSSION OF SELECTED ISSUES

#### Data and Information: Analysis/Synthesis/Interpretation

*Historical data should be collected, evaluated for their quality, analyzed, synthesized and interpreted. The rich data bases of utilities should not be overlooked in this effort. Potentially valuable data are being lost, or at least not utilized, and they should be exploited.*

*A regional data/information center should be established through a partnership among the several states with stakes in the Delaware system. The center should focus on transforming data into information. The time lag between data collection and analysis, synthesis and interpretation should be shortened. A centralized directory of data, information and specialists is an important first step.*

*A comprehensive Geographic Information System should be created for the Delaware system.*

New Jersey has a GIS for its portion of the Bay, but Delaware does not. A single comprehensive system is needed. It should be accessible to diverse audiences (users) and should be capable of developing a variety of informational products tailored to the specific needs of different user groups. The GIS should be "tied into" PCs either directly or through a diskette service. Remote sensing technology and data should be used where appropriate.

*The existing data and information for the system should be synthesized, analyzed and interpreted:*

- o To establish the current status of the system and its living resources.
- o To chronicle the changes in the condition of the system and its living resources.
- o To document past and present research and monitoring efforts and to use the information from these activities to identify research and

monitoring priorities.

- o To prepare a comprehensive directory of past and present data, information, investigations and investigators.
- o To identify which existing data sets are good and which are not.
- o To develop appropriate strategies for combining historical data sets with data from more recent initiatives.
- o To recommend a range of standardized methods of sampling, analysis and data reporting to be used for the Delaware Estuary Program and for future activities.

*Among the specific topics that should be focused on in this synthesis effort are:*

- o What have been the patterns and rates of wetland loss and how have these losses impacted the system and its living resources? Attempts should be made to allocate losses among different causes: human activities, erosion, sea level rise and other causes.
- o What has been the history of freshwater input (and withdrawal) and how have variations in input impacted the system and its living resources?
- o What have been the cumulative impacts of impingement and entrainment of organisms by power plants and other water users?
- o What have been the changes in land use patterns throughout the drainage basin and what impacts have these changes -- including point and non-point sources -- had on the system and its living resources?
- o What have been the patterns of fisheries (stocks, landings, etc.) and what factors -- natural and anthropogenic -- have contributed to the fluctuations?

### **Models**

Some of the earliest, successful coastal hydrodynamic models were developed for the Delaware. These were used in prescribing management strategies to rehabilitate the environment and were successful.

*All existing models should be inventoried and assessed for their potential for addressing unresolved management questions throughout the Delaware system. This assessment should be the basis for any future development of hydrodynamic and water quality models for the system.*

The Delaware presents interesting opportunities for development of a new generation of models to guide the management of the system and its living resources. This potential is enhanced by the recognition of the need for a number of modest, specialized models rather than a single, large, all-purpose model. Among the potential areas for model development are:

- o Forecasting loadings of nutrients and contaminants including those from non-point sources, and associated with different land use patterns; and assessing the effects of different loadings on the Delaware and its living resources.
- o Guiding the levels and kinds of development throughout the drainage basin to achieve and sustain desired use patterns and values of the river and estuary. Models must be capable of assessing impacts of point and non-point sources.
- o Managing the hydrology of the Delaware system; surface waters and groundwaters; the effects of different withdrawal rates on the system and its living resources; the effects of hydrology on wetlands.
- o Fate and effects of hydrocarbons, including polychlorinated hydrocarbons, their routes and rates of transport, their patterns and rates of accumulation, and their effects on living resources.
- o Incorporation of plankton dynamics into simple models of the Delaware Estuary.

### **Habitats**

The Delaware Bay is rich in diversity and quality of its natural habitats, particularly its wetlands. *The system's important habitats should be characterized, inventoried, mapped and their values and functions assessed. This will require not only the use of existing knowledge, tools and techniques, but the development and application of new knowledge and*

*diagnostic tools.* These must come through research. They do not exist. A study now being sponsored by the National Research Council to evaluate strategies to protect and enhance wetland habitats may be of value. This should be followed carefully.

*New knowledge is needed to develop strategies to conserve existing habitats in the face of conflicting uses and increasing pressures from development.*

*Research is also needed to evaluate and develop strategies to create new habitat. One focus of this research should be on the development of beneficial uses of dredged materials to create wetlands in the tidal reaches of the river and to nourish saltmarshes so that they can keep pace with an acceleration in the rate of rise of sea level.*

The Delaware is rich in wetlands. The wetlands have a long history of manipulation; and a considerably shorter history of thoughtful management.

*One essential component of a comprehensive habitat management plan is a clear, unambiguous assessment of the needs of important species during different life cycle stages.* Once this information is available the conservation and restoration of critical habitats will be facilitated. In the workshops, the system was subdivided into three zones. Zone I -- Trenton to the Delaware-Pennsylvania border (see Appendix A) -- was identified as the region that should receive a priority for studies of habitat requirements by important species.

There is no historical record of submerged aquatic vegetation (SAV) in the estuarine portion of the Delaware system; appropriate analyses of sediment cores have not yet been carried out to provide an unequivocal assessment. There is an historical record of the presence of SAV in the tidal reaches of the river, however. The coverage of SAV may be more extensive now than in the 1800s.

## **Nutrient Loading and Eutrophication**

Over the past several decades, there has been a successful reduction of oxygen demand of the waters in the tidal river through a major program to upgrade sewage treatment plants and to reduce industrial effluent impacts. Most of the sewage treatment plants discharge between Chester and Philadelphia (Pennsylvania) where the vast majority of the point source loading occurs. The program of rehabilitation was begun in the 1960s with massive federal support beginning in the 1970s in response to the Clean Water Act and was designed primarily to increase levels of dissolved oxygen. The dissolved oxygen content of the tidal river has increased significantly with annual average content more than doubling in the areas of greatest stress. Over this same period, the nutrient nitrogen content has decreased, but only slightly and the total phosphorous has dropped dramatically. In the past 10 years, the dissolved phosphate of the total phosphorous pool has increased. The large, longer-term decrease in total phosphorus and more recent increase in the dissolved phosphate fraction may both be the result of changes in riverine water quality. These changes emphasize the complexity of the biogeochemistry which must be considered in the management of these aquatic resources.

There is significant disagreement between managers and scientists as to the need, or even the desirability, of further reductions in nutrient levels. A number of scientists who have had long and distinguished careers studying nutrient dynamics of the Delaware system argue that a decrease in the levels of nutrients might not be beneficial, at least to the estuarine portion of the system and to the adjacent shelf waters. A large fraction of the nutrients that reach the estuary are transferred to the shelf with relatively little delay. These sewage-derived nutrients may enhance biological productivity in the lower estuary and in open coastal waters. However, the assimilation of the nitrogen components has a significant impact on dissolved oxygen in the tidal river (D. Pollison, personal communication).

The Delaware Bay is a turbid estuary and the high levels of suspended sediment may be the limiting factor in primary productivity. Reductions in

suspended load might lead to undesirably high levels of productivity (eutrophication).

*More research clearly is needed to understand the roles and interactions of nutrients and suspended sediments in determining the level of primary productivity in the Delaware Estuary. In addition, the high suspended sediment loads appear to scavenge potentially toxic metals and organic contaminants from the water column. The importance of this process needs clarification.*

*The interactions between primary and secondary productivity, including fisheries, is an important and fruitful area for fundamental research.*

The existing data indicate high levels of primary productivity, levels which are not reflected in the fisheries data. Fisheries yields are lower than would be expected from the primary productivity. Are fisheries yields underestimated? Is primary productivity overestimated? Or do the conventional relationships between primary productivity and fisheries yields not hold for the Delaware? The answers are not clear. *More research is needed to better understand the fate of primary production, and the transfer from primary production to secondary production, including fisheries harvests.*

Although there are no low D.O. problems in the Delaware estuary and levels in the tidal reaches of the river have shown dramatic improvement over the past decade, D.O. levels in the lower river sometimes still fall below 4.0 ppm during the summer. Studies have shown that fish show signs of stress when levels of D.O. fall below 4 ppm. Stress may interfere with spawning success and may contribute to other problems associated with contaminants.

The Delaware River Basin Commission (DRBC) in cooperation with the U.S. Environmental Protection Agency and the states of Delaware, New Jersey and Pennsylvania recently completed a feasibility study of bringing D.O. levels in the Delaware River between Camden (NJ) and Philadelphia (PA) to the standard of 4 ppm on a sustained basis. Point sources (treatment plants)

dominate oxygen-demanding loads in this stretch of the river, but urban runoff also contributes significant amounts of nutrients. The conclusion was that compliance with the D.O. standard (4 ppm) could be achieved.

Point and non-point sources contribute to the low D.O. problem and the major contributors to the problem vary in different parts of the system. Non-point sources may not be the dominant factor on the main stem of the river.

*While significant advances in understanding and quantifying the specific causes of the low D.O. problem have been made, the secondary effects in the river are not adequately understood. Further research should be done before putting in place any additional expensive corrective measures that may have uncertain consequences. In addition, the full impact of recent improvements in sewage treatment plants should be documented to reflect the current status of the river.*

Several scientists in the workshop questioned the proposed changes in DRBC standards. They pointed out that below Trenton, in the region of Philadelphia, primary productivity is low and that there is an alkalinity sag in the river. They questioned whether removal of nitrogen is the best strategy. Part of the system is phosphorus limited in the spring and summer.

*Nutrients must also be examined in the tributaries in terms of their levels, their sources -- both point and non-point -- and their fates.*

### **Hydrology of the Delaware System**

The importance of groundwater to the Delaware estuary system is poorly known. Historically, groundwater flowed into the estuary from the Potomac-Raritan-Magothy aquifer. Withdrawals have lowered the head and at least in some local areas, such as Philadelphia, have reversed the direction of flow. *The uncertainty in the magnitude of the groundwater source should be reduced through a carefully designed measurement program.* The quality of the groundwater input may also be important in



determining water quality and habitat in the estuary, depending upon the strength of the groundwater signal.

*Existing models must be improved and used to predict the effects of a range of levels of consumptive uses of water from the Delaware River on salinity distribution. The models must be capable of predicting the effects not only on the salinity distribution, but also on habitat and on living resources.*

### **Fisheries**

The development of fisheries management plans for important resident species and for important anadromous and catadromous species should be given a priority.

Plans for resident species will require the cooperation and collaboration of Delaware, New Jersey and Pennsylvania. Plans for migratory species will require cooperation and collaboration with other states and federal fisheries management councils and should lead to the development of plans consistent with the coastal plans already in existence. Regional management plans should be developed for each of the important fishes that utilize the Delaware system during a portion of their life cycle. These include: summer flounder, bluefish, weakfish, striped bass, shad, blue crab, short-nosed sturgeon and eel. Integrated, bay-wide management plans need to be updated and, in some cases, developed *de novo* for important resident species that spend their entire lifecycles within the Delaware system. These include: catfish, white perch, oysters, hard clams and large mouth bass.

Integrated, regional management plans also need to be developed for important birds and mammals including: ospreys, falcons, piping plover, Peregrine falcon, bald eagle, turtles and a number of other important species.

Fish in more urbanized stretches of the system exhibit a variety of diseases. The causes of the diseases are believed to be contamination, but evidence for

cause and effect relationships is lacking.

Several other factors were identified by workshop participants as being important to fisheries:

- o The Delaware River Cooperative Fishery Management Plans should be utilized in developing any new fishing plans.
- o Habitat and water quality are important, but the effects of fishing pressure on stocks should not be underestimated and should be accurately assessed locally and regionally.
- o Better estimates are needed of fisheries yields (landings).
- o The effects need to be assessed of the impacts of impingement and entrainment by powerplants on fish stocks.

Participants in the first workshop stated a goal of increasing fishery landings by two-fold by the year 2020. *This will require research and the development of effective management strategies.* It also may require the use of aquaculture to supplement natural stocks, to develop disease-resistant strains and to directly supplement seafood in the marketplace. *Integration of fishery programs with other components of the estuary program will require a broad understanding of the environmental mechanisms that control population abundance.*

### **Birds and Wildlife**

The Delaware Bay is unusual, if not unique, among the nation's estuaries in its importance to migrating waterfowl, to shorebirds and to a variety of other birds. It also provides important habitat to a number of species of mammals and reptiles. *The importance of these uses should be assessed; the habitats that support them should be identified and conserved; the role of transfer of primary productivity to birds and wildlife should be investigated.*

### **Fishable/Swimmable**

Participants in the first workshop identified as a goal for 2020 to have the entire Delaware Bay estuary and river fishable and swimmable. Participants

in the second workshop indicated the need to define with specificity and clarity what the terms "fishable" and "swimmable" mean.

Are there legal definitions of fishable and swimmable? Are these definitions what the public wants and expects? Coliform standards now determine swimmable. To what extent do aesthetic qualities -- for example, the presence of obnoxious, but innocuous floatables -- enter into the public's perception of "swimmable?" Should there be standards for toxicants (e.g. metals) and chlorinated hydrocarbons in certifying bathing areas?

Fishable should mean that all areas are of a quality to support natural stocks of commercially and recreationally important fish and of other species that are ecologically important. Fishable also should mean that fish and shellfish that are harvested throughout the system are safe for consumption without limits or advisories on the number, or amount, that can be eaten safely.

Where do toxics enter the system? How do they affect the health of the fishery and the edibility of fish?

#### IV. ON THE NEED FOR A UNIFYING THEME

Every national estuary program should have a unifying theme, a rallying cry -- or, at most, a small number of unifying themes. The Chesapeake Bay Program had submerged aquatic vegetation (SAV), the Long Island Sound Program had anoxia/hypoxia. The themes listed below were proposed by participants in the two Delaware Estuary Program workshops. There may be others. We have not attempted to identify the preferred theme. The Management Committee and others need to do that; to choose a strategic theme.

- o Wetlands are critical to the well-being of the Delaware estuarine system.
- o Rehabilitation of the urban river is a key to conserving and restoring the Delaware system: If the River is healthy, the Bay will be fine.
- o Chronic exposure to low levels of hydrocarbons and organic toxicants are a major influence on this estuarine system and its living resources.
- o Trophic shunts: Where is all the primary productivity going?
- o The role of suspended sediments and light limitation by turbidity in controlling eutrophication.
- o Is the Delaware Estuary hopelessly polluted or an estuary with no major problems. Would the real Delaware Estuary please stand up?

## V. WHERE TO GO FROM HERE

The information needs identified by the workshop participants and the associated research areas all were given a priority by the participants. All are clearly important and worthwhile areas for exploration, but it is clear that not all can be supported through the Delaware Estuary Program. We recommend that the program attempt to forge alliances with other institutions which support research on the estuary to leverage the federal program support. Appropriate institutions might include the Delaware Sea Grant Program, the Delaware River and Bay Authority, and the Delaware River Port Authority. We also recommend that the Scientific and Technical Advisory Committee sharpen the focus of the research areas identified in this report and refine the rankings.

These activities should become the basis for development of Requests for Proposals (RFPs). The RFPs should not over-specify. They should state the broad questions to be answered or the general hypotheses to be tested, but they should leave the formulation of the specific questions and hypotheses and the experimental design to the scientists who respond. As Arno Penzias (1989) has pointed out, the single most important quality that distinguishes outstanding scientists from the rest is in problem selection and formulation. The RFPs should be circulated widely to elicit responses from the best scientists.

Proposals should receive rigorous peer review, both from anonymous reviewers and from a program panel. The reviews should be the basis for proposal selection for funding. This is necessary, but not sufficient. The projects that are funded must not only be good science, they must, in the aggregate, constitute a program responsive to the goals and objectives of the management program. This usually means that some negotiation will be required with individual scientists and public administrators and among them. Mechanisms must be put in place and maintained to ensure a continuing dialogue among scientists and between scientists and managers to ensure that the individual projects make a coherent program responsive to the identified theme. Improving the science and the usefulness of the

science should be the driving forces.

A small, high-level group of distinguished scientists and one or two managers might be useful in carrying out this role. The conventional model in the National Estuary Program for fulfilling this role is the STAC -- the Scientific and Technical Advisory Committee. Our experience has been that these groups are not well configured for this task. Typically, they are too large, their composition is too strongly influenced by socio-political forces and their roles are not well enough defined. We recommend the formation of a small group at the outset; that it include one or two distinguished scientists from outside the region; that they be given considerable freedom in developing and overseeing a scientific program that is responsive to management needs. The Chair of the STAC should be a member of this group, but probably should not chair it.

Annual conferences and workshops should be held at which all of those who receive support from the program for research or educational activities provide detailed status reports on their projects. The Scientific and Technical Advisory Committee (STAC) should be present and should provide on-the-spot feedback to principal investigators.

A uniform format should be specified for data reporting and all investigators supported through the program should be required to sign agreements to provide data in the approved format within 12 months of the project's termination date. There should be no exceptions.

Government agencies, including both state and federal, that provide support, consulting companies and academic scientists should be held to the same standards of performance and accountability in their research and financial obligations.

## VI. FINAL THOUGHTS

Sustained programs of fundamental research are critical to improving our understanding of estuarine processes. This knowledge is essential to long-term, effective management of estuarine systems, but the National Estuary Program was not designed to provide long-term support, or to support fundamental research except to the extent that it is needed to respond to practical problems. One of the best ways to make a compelling case for the value of basic research to management is to demonstrate, by example, how scientific knowledge and improved understanding of natural systems can be utilized in formulating effective management strategies -- management policies and practices. Each National Estuary Program provides an opportunity to make best use of the body of existing scientific data and information for that system and to carefully design scientific studies to be responsive to the specific needs of managers for information. A common deficiency of a number of the national estuary programs has been their failure to identify, at the outset, a research agenda carefully tailored to producing the specific information needed by managers to effectively manage the system. Some attempt to do too much and, as a result, produce little of significance. Identifying an appropriate theme is an important first step.

In this report, some research priorities have been identified. All are important, but they need further culling and refinement.

Existing monitoring programs should be critically reviewed, revised as appropriate and selected elements integrated for the Delaware Estuary system. Useful advice in the design, conduct and oversight of the program can be found in the National Research Council's (1988; 1990 a, b) recent reports: "Managing Troubled Waters: The Role of Marine Environmental Monitoring;" and "Monitoring Southern California's Coastal Waters," and the Chesapeake Bay case study which was prepared as a background paper for "Managing Troubled Waters."

The monitoring program design should be developed through a partnership of scientists and managers. The program design should be subjected to rigorous peer review before it is initiated. The program should be designed to answer specific questions or to test specific hypotheses. On a regular basis, at least once every two years, all data should be used to answer those questions (or to test the hypotheses) and the results should be widely disseminated. Adequate resources should be identified for data management, interpretation and synthesis and for the preparation of information products tailored to the needs of different user groups. The NRC report, *Managing Troubled Waters*, recommended creation of a network of regional centers to carry out such activities.

A number of synthesis efforts are now underway for the Delaware River and estuary. Virginia Lee and Scott Nixon of the University of Rhode Island are preparing for NOAA a historical documentation of how the system, its qualities and uses, have changed. This report is now in draft form. Several other synthesis efforts have been commissioned by the Delaware Estuary Project's STAC.

We recommend that the STAC convene the principal investigators of all of these initiatives as a group to discuss the recommendations of this report and to seek their advice and guidance for appropriate modifications. This could become the basis for an interesting, informative and useful workshop.



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**APPENDIX A**

**A SUMMARY OF DESIRED VALUES AND USES FOR THE  
DELAWARE ESTUARY IN 2020  
AND  
MANAGEMENT STRATEGIES TO ENSURE THEM  
AS SEEN BY WORKSHOP PARTICIPANTS**

## **ECOLOGY AND LIVING RESOURCES: VALUES AND USES FOR 2020**

- o Maintain biodiversity of wildlife and vegetation throughout the system (water/land).
- o Maintain productive wetland habitats; strive for no net loss of function.
- o Enhance freshwater wetlands in the tidal reaches of the river.
- o Ensure that fish caught throughout the system in 2020 meet all FDA and state health criteria (e.g. for PCBs and metals) for consumption without limits or advisories.
- o Enhance and maintain balanced and diversified fish stocks.
- o Establish an appropriate balance between recreational and commercial fisheries and between fish stocks and fish catches. Many fear that if present trends continue by 2020, recreational fishing will put commercial fishing out of business. Others fear that if present trends continue, overfishing will deplete stocks to the point that all fishing will be jeopardized.
- o Enhance and stabilize oyster harvests at one million bushels per year.
- o Develop and deploy hybrid strains to fill voids and supplement stocks (e.g. MSX-resistant oysters) to meet market demands, not to negatively impact natural populations.

**ECOLOGY AND LIVING RESOURCES:  
MANAGEMENT STRATEGIES**

- o Zone the Delaware into three zones based upon their primary functions.
  - Zone I: Trenton to Delaware-Pennsylvania border (industrial, urban and suburban; fresh water).
  - Zone II: Delaware-Pennsylvania border to Chesapeake and Delaware Canal (mixed usage; turbid, low salinity regime).
  - Zone III: Chesapeake and Delaware Canal to Bay mouth (agricultural, residential and recreational; low to high salinity regime; location of majority of biological production).
- o Develop a regional plan to guide development consistent with the primary functions of these three zones.
- o Develop an integrated, regional plan for land use and drainage basin management.
- o Continue and enhance efforts to improve pollution control (point and non-point source controls).
- o Conserve and enhance important habitats.
- o Inventory, map, evaluate and rank habitats in terms of their importance to the estuary and its living resources, including fish, invertebrates, birds and mammals.
- o Develop a comprehensive emergency response system for spills of oil and other hazardous materials.
- o Reestablish wetlands in Zone I.
- o Develop a comprehensive aquaculture plan with goals and objectives for 2020 and strategies to achieve them.
- o Develop appropriate, coordinated management plans for all commercially and recreationally important species of finfish and shellfish.
- o Institute a salt water fishing license with revenues dedicated to marine research, education and habitat enhancement.
- o Educate the public about the complexities of the system, how society has updated the system, and what each of them can do to help.

**PORT ISSUES AND DREDGING:  
VALUES AND USES FOR 2020**

- o Enhance the status of the ports of the Delaware River and Bay as a leading port system and industrial center in harmony with other uses and values of the natural system.
- o Develop a variety of creative/beneficial uses for materials dredged from the port and its approach channels.

**PORT ISSUES AND DREDGING:  
MANAGEMENT STRATEGIES**

- o Develop a comprehensive emergency response system for spills of oil and other hazardous materials.
- o Develop a comprehensive dredging and dredged material management plan that is based upon a thorough analysis of the effects of changes in channel geometry on other uses and values of the system and that maximizes the beneficial uses of dredged materials.
- o Develop a comprehensive plan for continued development of the port that is based upon a rigorous assessment of the full range of plausible options. The analysis should include an evaluation of the short-term and long-term benefits and costs -- economic, environmental and socio-political -- of an oil pipeline in the lower bay or offshore. This analysis must examine all uses and values of the entire system.
- o Develop an appropriate organizational model to enhance the competitiveness of the Bay's ports in the national and world marketplaces.
- o Assign water-dependent uses a priority in waterfront development initiatives, particularly within Zone I.

**RECREATION:  
VALUES AND USES FOR 2020**

- o Enhance people's awareness of the importance of the Bay system and increase access to it for recreation: for swimming, boating, hunting, photography, bird watching, aesthetic enjoyment -- consistent with protecting habitats and living resources.
- o Expand, enhance and enrich the educational, environmental and cultural focus on the Delaware system: nature walks, museums, aquaria, lectures, field trips...
- o Expand opportunities for recreational activities on the river and the estuary for residents of urban areas.
- o Make the entire system fishable and swimmable.
- o Expand and stabilize recreational fisheries; enhance water quality.



**RECREATION:  
MANAGEMENT STRATEGIES**

- o Develop a well-balanced, integrated regional land use management plan for the entire drainage basin; a plan that is based on relationships between land use and water quality.
- o Ensure that local regulatory controls are guided by and consistent with the regional plan.
- o Increase the number of parks (with active and passive recreational opportunities) to keep pace with population and increasing demands for recreational opportunities.
- o Develop and implement an effective public education program concerning the importance of the Delaware Estuary as a natural habitat and as a recreational resource.
- o Expand and stabilize recreational fisheries by improving water quality, by enhancing habitat and, if necessary, by stocking.
- o Establish user recreation programs (e.g. for small boat operators).
- o Expand recreational opportunities in urban areas through enhancement of the aquatic environment and enhanced access.
- o Design and implement boater safety courses for recreational boaters.

**WATER QUALITY:  
VALUES AND USES**

- o Make the entire system fishable and swimmable by 2020.
- o Conserve water quality in the lower Bay; enhance water quality in the upper Bay and in the tidal River.

**WATER QUALITY:  
MANAGEMENT STRATEGIES**

- o Enhance efforts to reduce inputs of contaminants from point and non-point sources.
- o Expand industrial and municipal pre-treatment programs.
- o Assess the relative advantages and disadvantages of an oil pipeline versus lightering.
- o Zone the system into three zones: Zone I, Trenton to Delaware-Pennsylvania border; Zone II, Delaware-Pennsylvania border to Delaware City; Zone III, Delaware City to the mouth of the bay.
- o In waterfront development within Zone I, give preference to water-dependent uses.
- o Within Zone II, develop management strategies to accommodate mixed usage of the aquatic system and contiguous lands.
- o Within Zone III, stabilize the agricultural base with controls on inputs/outputs and enhance recreational opportunities. (The concept of "base" was defined in terms of overall production, not area under cultivation.
- o Preserve existing wetlands; create new ones, particularly in Zone I.

**WETLANDS:  
VALUES AND USES FOR 2020**

- o Maintain productive wetland habitats; strive for no net loss of function.
- o Enhance freshwater wetlands in the tidal reaches of the river.

**WETLANDS:  
MANAGEMENT STRATEGIES**

- o Characterize, assess, enhance and maintain productive wetland habitats. They need to be inventoried, evaluated and ranked in importance to the system and its living resources.
- o Strive for no net loss of Function.
- o Develop and implement effective public education programs to make clear the roles and importance of wetlands.
- o Implement a mapping program of privately-owned ecological preserves.
- o Determine the "carrying capacity" of the lower Bay -- the area with the most extensive wetlands -- for different combinations of uses.
- o Develop a "greenway" along the margins of the Delaware Bay. Its width should vary and should be dependent on natural features and on its specific functions rather than on an arbitrary standard measure. The system needs a marginal "green zone," a buffer zone and a zone for appropriate development.

**HUMAN CARRYING CAPACITIES:  
VALUES AND USES FOR 2020**

- o Ensure that human uses of the system are consistent with carrying capacities that conserve the values identified in the report.

**HUMAN CARRYING CAPACITIES:  
MANAGEMENT STRATEGIES**

- o Prepare a comprehensive documentation of all land uses throughout the system including developed areas, natural areas, water recharge areas, forests, flood plains, agricultural areas, wetlands, and spawning and nursery areas.
- o Assess the availability of water supply, now and the prospects for the future.
- o Prepare a comprehensive plan to provide acceptable wastewater treatment. This will require development of appropriate waste load allocations for the estuary and its tributaries and for groundwaters -- allocations consistent with desired uses and values.
- o Prepare a comprehensive demographic analysis and a plan to ensure appropriate community services and energy sources for a changing population.
- o Prepare a comprehensive land use plan which ensures that population and population density are consistent with desired uses and values of land and nearby waters; open space must be an integral component of the plan.
- o Identify impaired uses (impacts) associated with different land use practices (preservation/development).
- o Develop comprehensive management programs for each specific plan adopted and ensure that they are carried out.
- o Prepare a plan to utilize Transfer of Development Rights in each state to maintain important natural characteristics of counties.
- o Incorporate into plans provisions for monitoring and periodic updating by the implementing agencies.

**FRESHWATER SUPPLY:  
VALUES AND USES FOR 2020**

- o Ensure an allocation of freshwater to the estuary should be adequate to maintain critical habitats and the distribution of salinity. This will require a larger discharge of freshwater in 2020 than in 1990 because of rising sea level. If the rate of sea level rise accelerates because of the greenhouse effect, more freshwater will be needed -- more river discharge -- to maintain the present salinity distribution in the Bay.
- o Ensure an adequate supply of high quality potable water in 2020; demand will be greater in 2020 than in 1990 even if there is no increase in population. The redistribution of population from inner cities to suburbs increases water use for lawns and other domestic activities.



**FRESHWATER SUPPLY:  
MANAGEMENT STRATEGIES**

- o Increase storage capacity.
- o Develop criteria for allocation of freshwater among the various competing uses; criteria should take into account the effects of changes in freshwater input on habitat, salinity distribution, living marine resources, gravitational circulation in the estuary, sedimentation and other important properties and processes of the estuary.
- o Pursue water conservation aggressively to reduce the conflict between competing demands for more water in 2020. Delaware River Basin Commission regulations for low flow toilets in all new construction after 1991 and for retrofitting plumbing in existing buildings is an important component of what needs to be a comprehensive water conservation plan that includes all user groups.
- o Develop an effective public education program to clarify the importance of water conservation to people and the environment.

**TRIBUTARIES AND SUBTRIBUTARIES:  
VALUES AND USES FOR 2020**

- o Clarify the variety of important, but poorly defined, roles that tributaries and subtributaries play in the system's functioning and the uses and users they serve. These need to be clarified and priorities set for the estuary of 2020.

**TRIBUTARIES AND SUBTRIBUTARIES:  
MANAGEMENT STRATEGIES**

- o Develop and implement management plans for each of the tributaries and subtributaries to ensure that use patterns are consistent with their important natural functions and with uses desired by society.
- o Ensure that plans are consistent with zoning of the estuary.
- o Employ conflict resolution techniques in reducing and resolving conflicts.

**POPULATION AND DEMOGRAPHICS:  
VALUES AND USES FOR 2020**

- o Guide the growth and distribution of population throughout the drainage basin to ensure healthy ecosystems -- terrestrial and aquatic -- and a diversity of high quality natural terrestrial and aquatic environments for people to live, work and recreate in.

**POPULATION AND DEMOGRAPHICS:  
MANAGEMENT STRATEGIES**

- o Develop management models to relate changes in population and demographics to environmental quality and characteristics.
- o Create, expand, and enhance programs to purchase or transfer development rights to ensure adequate open space for protection of the environment and its living resources and for human enjoyment.
- o Employ these strategies in designing and implementing appropriate zoning plans to ensure the mixture of uses and values of the system desired by society and appropriate to a healthy ecosystem.
- o Develop comprehensive land use plans for the entire system.



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