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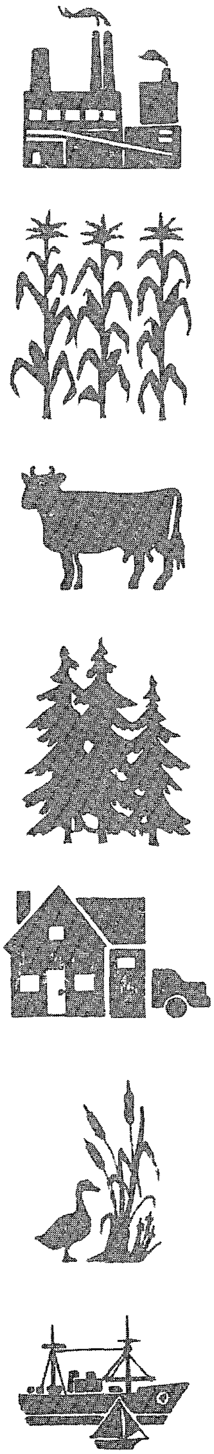
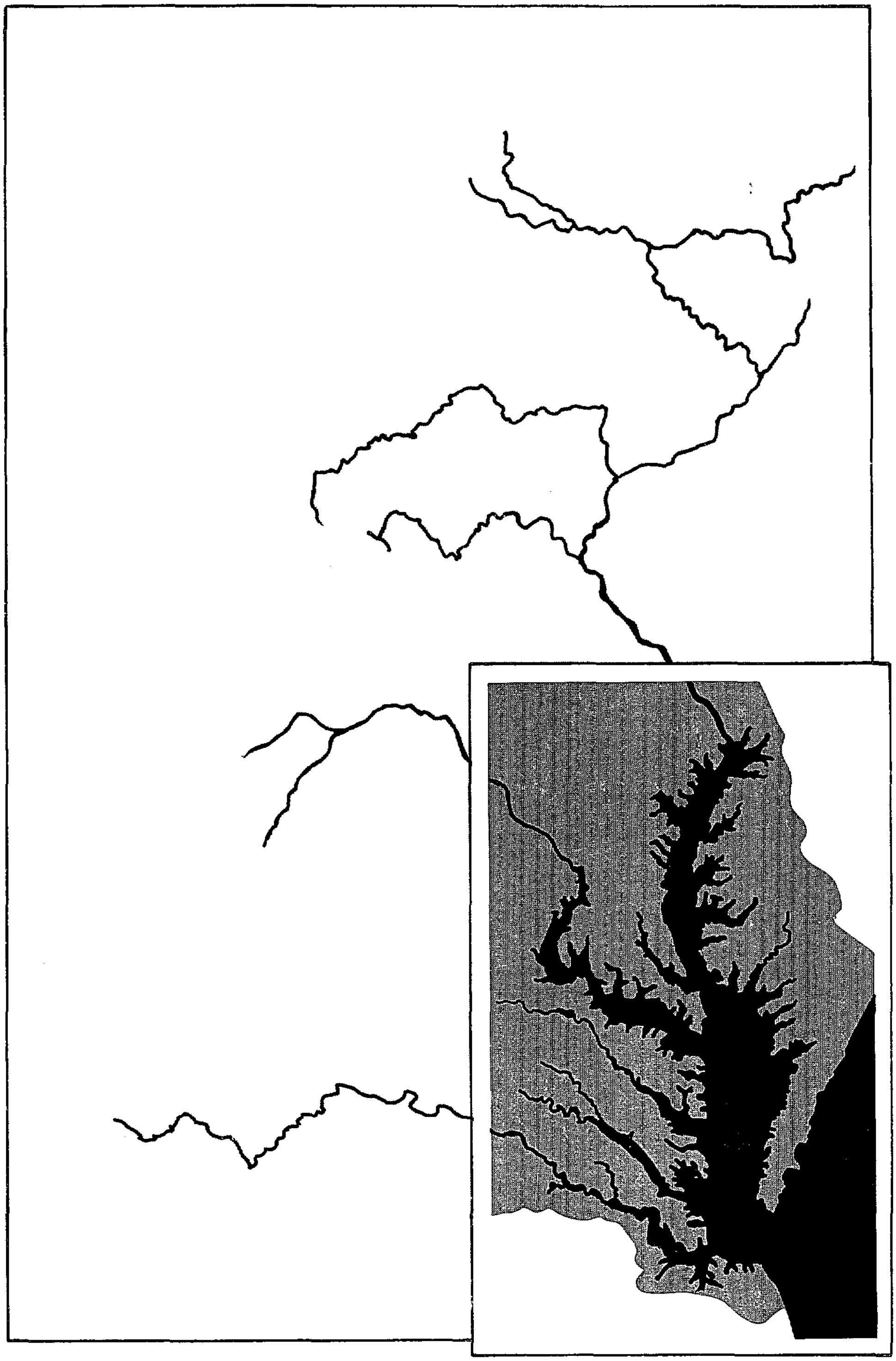
CHESAPEAKE BAY: A FRAMEWORK FOR ACTION





U.S. Environmental Protection Agency

CHESAPEAKE BAY: A FRAMEWORK FOR ACTION

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FOREWORD

The Chesapeake Bay, the nation's largest and most productive estuarine system is experiencing significant stress from pollution. In 1976, Congress directed the Environmental Protection Agency (EPA) to undertake a comprehensive study of the Bay's resources and water quality, and to identify appropriate management strategies to protect this national resource. To address this mandate, the EPA's Chesapeake Bay Program (CBP) funded over fifty research projects. In addition to individual technical reports, four summary reports have been developed:

Chesapeake Bay: Introduction to An Ecosystem
– A primer on the ecology of the Bay

Chesapeake Bay Program Technical Studies: A Synthesis
– A synthesis of the CBP scientific studies on nutrients, toxics, and submerged aquatic vegetation

Chesapeake Bay: A Profile of Environmental Change
– A characterization of the health of the Bay and its tributaries

Chesapeake Bay: A Framework for Action
– A management report that calls for action to mitigate pollution in the Bay

In addition a summary publication *Chesapeake Bay Program: Findings and Recommendations* is available.

A Framework for Action represents the culmination of the seven-year effort that began in 1976. It describes the state of the Bay, the sources of pollution, control alternatives for reducing pollution, and recommends a range of actions to improve the Bay.

This study marks the first time that a basin-wide assessment of the Bay, its tributaries, and the surrounding land has been undertaken. Our knowledge of the workings of the Bay and the interrelationship of land and water is now keener because of this effort. However, the advances in our technical understanding are perhaps less important than the development of the regional management ethic which the Chesapeake Bay Program has fostered. This ethic was encouraged by the Chesapeake Bay Program Management Committee which guided the program's efforts over the years. The committee is comprised of representatives from the EPA, the states of Virginia, Maryland, Pennsylvania, and the District of Columbia. In addition, a diverse group of Bay-users have been involved in developing alternative strategies to improve the Bay. As a result, the states and the EPA, with the support of the public, are now ready to forge new approaches to managing the Bay. It is our hope that this document will provide the framework for achieving the goal of restoring and maintaining the Bay's ecological integrity.

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Over the years, many researchers have been involved in this massive effort; it would be impossible to recognize them all. However, Tudor Davies, the former Director of the Program, and Thomas DeMoss, the former Deputy Director are gratefully acknowledged for their leadership during the critical developmental phase of this project. A special thanks is also in order for Gregory McGinty whose vision guided the initial phase of the Management Study. Thanks is also extended to Jack Hartigan, Elizabeth Southerland, and James Smullen for their efforts in developing a predictive Basinwide water quality model.

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TECHNICAL SYMBOLS

Ag	silver
BAT	Best Available Technology
BMP	Best Management Practice
BOD_5	5-day biological oxygen demand
BPT	Best Practical Technology
Cd	cadmium
Cr	chromium
Cu	copper
DO	dissolved oxygen
Fe	iron
ft^3	cubic foot
GC/MS	gas chromatography/mass spectography
IFD	Industiral Facilities Discharger File
kg	kilogram
km	kilometer
km^2	square kilometer
m	meter
m^3	cubic meter
MGD	millions of gallons per day
ug L^{-1}	microgram per liter
mg L^{-1}	milligrams per liter
ml L^{-1}	milliliters per liter
mi^2	square mile
N	nitrogen
NH_3	ammonia
Ni	nickel
NO_2	nitrite
NO_3	nitrate
NPDES	National Pollutant Discharge Elimination System
O & M	operation and maintenance
P	phosphorus
Pb	lead
PNAS	polynuclear aromatics
POTW	publicly owned treatment plant
ppb	parts per billion
ppm	parts per million
SAV	submerged aquatic vegetation
SIC	Standard Industrial Classification
Sn	Tin
STP	sewage treatment plant
TMDL	total maximum daily load
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids
UPCB	Upper Chesapeake Bay P Limitation
WPL	waste pickle liquor
Zn	zinc

EXECUTIVE SUMMARY

INTRODUCTION

The Chesapeake Bay Program (CBP) Management report, *Chesapeake Bay: A Framework for Action* describes the state of the Bay, the sources of pollution, alternative control options, and recommends specific actions. To make this assessment, a comprehensive data base was compiled and predictive models were developed. The CBP computerized data base contains information on trends in living resources, water and sediment quality, pollutant sources and loadings, and costs for alternative control strategies. The CBP predictive models simulate the transport and fate of nutrients from point and nonpoint sources in the 64,000 square mile Chesapeake Bay watershed. These tools were used to assess the health of the Bay and evaluate alternative strategies to improve its conditions. This information was utilized to develop specific recommendations which are discussed in the text and summarized below.

The Chesapeake Bay Program findings clearly indicate that the Bay is an ecosystem in decline. It is also evident that actions thoughout the Bay's watershed can affect the water quality of the rivers flowing into the Bay. Degradation of the Bay's water and sediment quality can, in turn, affect the living resources. Thus, effective management of the Chesapeake Bay must be based on an understanding and an ability to control both point and nonpoint sources of pollution throughout the Chesapeake Bay basin. To achieve this objective, it is essential that the states and Federal government work closely together to develop specific management plans that address the basin-wide problems identified by the Program. Our common goal is to restore and maintain the Bay's ecological integrity.

MANAGEMENT RECOMMENDATIONS

GOAL:

To restore and maintain the Bay's ecological integrity

1. *The Chesapeake Bay Program Management Committee should be maintained and expanded to provide a coordinating mechanism for the implementation of the CBP findings and recommendations.*

The Committee will report periodically but at least bi-annually to the EPA Regional Administrator and state secretaries or their equivalent. In addition, the committee will submit an annual report to the EPA Federal Administrator and Governors outlining new initiatives, implementation plans, and improvements in the environmental quality of the Bay.

2. *The States and EPA, through the Chesapeake Bay Program Management Committee, should utilize the existing water quality management process to develop a comprehensive basin-wide plan by July 1, 1984, to reduce the flow of pollutants into the Bay.*

This plan would consist of five-year components which would be updated every two years. In addition, specific annual operational and implementation plans would be developed which would specify the level of effort for the upcoming year.

STATE OF THE BAY

Chesapeake Bay is changing, in ways which are generally considered negative. CBP has documented declines in living resources such as submerged rooted grasses, striped bass and shad, oysters and clams. These declines are paralleled by changes in water quality which include increases in nutrient concentrations, chlorophyll *a*, turbidity, and toxic chemicals, and decreases in dissolved oxygen. Some of these trends appear to be long-term ones, but in many instances they have accelerated over the past decade. These trends are described in Chapter 2 and discussed in *Chesapeake Bay: A Profile of Environmental Change*. They are summarized below:

- Submerged aquatic vegetation (SAV) has declined throughout the Bay. The loss of submerged aquatic vegetation appears to be most severe in the northern Bay and western shore tributaries.
- Oyster spat set has declined significantly in the past 10 years, particularly in the upper Bay, western tributaries, and some Eastern Shore areas such as the Chester River. Trends in oyster harvest show a similar pattern.
- Landings of freshwater-spawning fish, such as shad, alewife, and striped bass, have decreased in recent years. Spawning success of these and other semi-anadromous or anadromous species has also been fair to poor in most areas sampled. Harvests of marine-spawning fish, such as menhaden, have generally remained stable, or increased.
- Levels of nutrients (primarily nitrogen and phosphorus) are increasing in many areas of the Bay, leading to declining water quality. Nutrient enrichment is most severe in the northern and middle Bay, and upper reaches of tributaries and large algal blooms have been observed. Only parts of the Potomac and James River, and some smaller areas currently exhibit improving water quality with regard to nutrients.
- The amount of Bay water showing low (or no) dissolved oxygen in the summer is estimated to have increased 15-fold in the last 30 years. Currently, much of the water deeper than 39.8 ft (12.4 m) is anoxic from early mid-May through September in an area reaching from the Bay Bridge to the Rappahannock River.
- Elevated levels of heavy metals and toxic organic compounds are found in Bay water and sediments. Highest concetrations occur near urban or industrialized area, and in the upper Bay. Some of these toxicants are being bioconcentrated by plankton, shellfish, and finfish.

The observed relationships between the water quality and resource trends, and laboratory research has enabled us to begin to identify cause and effect. For example, Bay-wide, the areas experiencing significant losses of SAV have high nutrient water column concentrations. The high levels of nutrients enhance phytoplankton growth and epiphytic fouling of plants, thus reducing the light reaching SAV to below critical levels. However, it is also probable that high levels of turbidity and herbicides contribute to the SAV problem in localized areas. In another analysis, the reduced diversity and abundance of benthic organisms in urbanized areas was related to toxic contamination of sediments. Low dissolved oxygen (DO) in the summer-time is also a major factor limiting the benthic population, particularly in the upper and mid-Bay. The low DO is attributed to increased algal production and decay triggered by nutrient enrichment. Lastly, nutrient enrichment and increased levels of toxicants occur in the major spawning and nursery areas for anadromous fish, as well as in areas experiencing reduced oyster spat. This type of information has been utilized to develop a preliminary Environmental Quality Classification Scheme (EQCS) that relates water quality criteria to resource use attainability (Appendix A).

The characterization of the Bay, and the attempt to link water quality trends to living resource trends, makes science useful to managers and citizens. This retrospective approach is imperfect though, because large gaps in the data base and necessary assumptions limit our ability to make strong scientific causal inferences. We have only correlations, not proof. We also do not know with certainty to what extent levels of pollution must be reduced in order to achieve a quality of water that can support the resource objective. Mathematical models, which will someday enable us to arrive at these answers, have not yet been perfected for the complex Chesapeake estuary. Based on these significant gaps in our understanding, some would argue that we cannot afford to act. It seems more likly that we cannot afford not to act. Nonetheless, whatever actions are taken, we must bear in mind that our ability to assess the effectiveness of control programs and redirect our efforts will depend on the adequacy of our monitoring and research efforts.

MONITORING AND RESEARCH RECOMMENDATIONS

OBJECTIVE:

TO ACQUIRE INFORMATION TO REFINE THE CBP ENVIRONMENTAL QUALITY CLASSIFICATION SCHEME (APPENDIX A) AND TO DEVELOP STATE WATER QUALITY STANDARDS BASED ON RESOURCE USE ATTAINABILITY.

3. *The states and the Federal government, through the Management Committee, should implement a coordinated Bay-wide monitoring and research program by July 1, 1984.*

This program should include the following components:

- A baseline (descriptive and analytical) long-term monitoring program, as described in Appendix F.
- A coordinated, and sustained, interpretive program of monitoring and research to improve our understanding of relationships between water and sediment quality and living resources, as described in Appendix F.
- A research effort to identify important resource habitats, and guide their preservation and restoration.

NUTRIENTS

Nutrients enter the Bay from point sources, such as sewage treatment plants, and from nonpoint sources, such as agricultural and urban runoff. In general, the nitrogen entering Bay waters is contributed primarily by nonpoint sources, which are dominated by cropland runoff loadings. Point sources on the other hand, and especially sewage treatment plants, are the major source of phosphorus to Chesapeake Bay. It is important to note that in dry years, point source nutrient discharges tend to be more dominant than in wet years. In contrast, nonpoint sources, which enter waterways primarily in stormwater runoff, contribute a greater share of total nutrient loadings during wet years. Also, different river basins tend to be dominated by different sources, and therefore require different control strategies. For example, nutrient loadings in the Susquehanna River are primarily associated with nonpoint sources, while nutrient loadings to the James are primarily attributed to point sources. The major findings regarding nutrient sources, loadings, and control programs are discussed in Chapter 3 and are summarized below:

- The Susquehanna, Potomac, and James Rivers are the major sources of nutrients to the Bay. They contribute, respectively, 40, 24, and 14 percent of the nitrogen and 21, 21, and 28 percent of the phosphorus in an average year.
- Runoff from cropland and other nonpoint sources are the major sources of nitrogen to the nutrient enriched areas in the Bay. Nonpoint sources contribute 67 percent, whereas point sources contribute only 39 percent, of the total nitrogen load to the Bay in an average year.
- Point sources, such as sewage treatment plants, are the dominant source of phosphorus to the nutrient enriched areas of the Bay. Point sources contribute 61 percent, whereas nonpoint sources contribute only 39 percent of the total phosphorus load to the Bay in an average year.
- Agricultural runoff control strategies, such as conservation tillage, best management practices, and animal manure waste management, can effectively reduce nutrient loadings from areas dominated by agricultural nonpoint sources (e.g. the Susquehanna River Basin).
- Urban runoff control efforts have been shown to be effective in reducing nutrient loadings to small tributaries located in the Baltimore, Washington, D.C., and Hampton Roads areas.
- Point source control strategies, such as restrictions on nutrient discharges from municipal sewage treatment plants, or limitations on phosphate in detergents, can

significantly reduce nutrient loadings to those areas dominated by point sources (e.g. the James and Patuxent River basins).
- Point and nonpoint source controls in combination achieve consistent reductions in pollutant loadings during varying rainfall conditions in all basins.

The Federal government and the states have a variety of point and nonpoint source control programs to reduce loadings to the Bay. However, CBP research has shown that many areas of the Bay are over-enriched with nutrients and that the Bay acts as a sink, essentially trapping and recycling nutrients through the system. We can only conclude that additional actions designed to reduce the nutrient loads to the Bay will ultimately be beneficial. In response to these findings, the states are already taking bold new initiatives, as well as providing additional funding for proven old ideas. For example, Maryland is attempting to provide state dollars to pay for phosphorus and nitrogen removal at selected sewage treatment plants which are not eligible for Federal funding. Virginia has already established an innovative new incentive program for farmers, paying them from the state coffers for removing from production buffer strips along waterways. Pennsylvania is initiating a pilot manure management program that may decrease nutrient loadings to the lower Susquehanna. Still, there is much more that needs to be done if we are to achieve our objective.

BAY-WIDE NUTRIENT RECOMMENDATIONS

OBJECTIVE:

TO REDUCE POINT AND NONPOINT SOURCE NUTRIENT LOADINGS TO ATTAIN NUTRIENT AND DISSOLVED OXYGEN CONCENTRATIONS NECESSARY TO SUPPORT THE LIVING RESOURCES OF THE BAY.

General Recommendations

1. *The states* and the EPA, through the Management Committee, should utilize the existing water quality management process to develop a basin-wide plan that includes implementation schedules, to control nutrients from point and nonpoint sources by July 1, 1984.*

2. *The States and the EPA, through the Management Committee, should continue the development of a Bay-wide water quality model to refine the ability to assess potential water quality benefits of simulated nutrient control alternatives. This model should be continuously updated with new information on point source discharges, land use activities, water quality, etc.*

Point Source Recommendations

3. *The states and the EPA should consider CBP findings when updating or issuing NPDES permits for all point sources discharging directly to Chesapeake Bay and its tributaries. Furthermore, the States should enforce NPDES permit limitations.*

4. *Technical data from CBP findings should be considered when evaluating funding proposals for POTWs under the EPA's Advanced Treatment Policy.*

5. *The States of Maryland, Virginia, and the District of Columbia should consider by July 1, 1984, as one of several control alternatives, a policy to limit phosphate in detergents to 0.5 percent by weight, in light of the immediate phosphorus reductions achieved.*

6. *The following administrative procedures should be reviewed for action by January 1, 1985, by the States, counties, and/or municipalities:*
   - To increase POTW efficiency, improve operator training programs, and provide or encourage incentives for better job performance, such as increased salaries, promotions, bonuses, job recognition, etc.
   - The states should consider CBP findings when ranking construction grant projects.
   - Accelerate the development and ad-

*The States refers to the District of Columbia, Maryland, Pennsylvania, and Virginia.

ministration of state and local pretreatment programs.

- Continue to evaluate the application of innovative and alternative nutrient removal approaches.
- Improve sampling and inspection of point source discharges.
- Develop plans to ensure long-term operation and maintenance of small, privately-owned sewage treatment facilities.
- Institute educational campaigns to conserve water to reduce the need for POTW expansion as population in the Chesapeake Bay basin increases.

Nonpoint Source Recommendations

7. *The states and the EPA, through the Management Committee, should develop a detailed nonpoint source control implementation program by July 1, 1984 as part of the proposed basin-wide water quality management plan.*

Initial efforts should concentrate on establishing strategies to accelerate the application of best management practices in priority subbasins to reduce existing nonpoint source nutrient loadings. Long-term strategies should seek to maintain or further reduce nutrient loads from other subbasins to help restore Chesapeake Bay resources.

The implementation program should not be limited to traditional approaches toward soil and water conservation; an intensified commitment of resources for educational, technical, and financial assistance is warranted and may require innovative administration of available resources. Long-term funding must be assured at the outset of the implementation program, and a detailed plan to track accomplishments, including water quality improvement, should be developed by the states through the Management Committee. The framework for this program should include the following stages:

Stage 1 –

A program that emphasizes increased education, technical assistance, and cost-sharing, as well as other financial incentives, should be in place by July 1, 1985 in priority sub-basins (i.e., those determined through nonpoint source modeling to be significant contributors of nutrients to identified problem areas of the Bay). Full implementation of the abatement program should occur by July 1, 1988.

Stage 2 –

The Stage 1 program should be expanded to intermediate priority sub-basins based on additional basin-wide nonpoint source modeling and Bay-wide water quality modeling assessments that should determine both the need for additional nonpoint source nutrient reductions and the additional sub-basins to be targetted for nonpoint source control.

Stage 3 –

Provide the necessary educational, technical, and financial assistance to maintain or improve the level of soil and water resource protection throughout the Chesapeake Bay basin. Soil conservation districts should establish annual conservation goals and report annually on accomplishments and technical, financial, educational, and research needs.

Concurrently with stages 1 through 3, the states and the EPA, through the Management Committee, should initiate research to evaluate the effectiveness of BMPs in reducing the loss of soluble nutrients from farmland, to improve soil-testing procedures to refine recommended fertilizer application rates (especially with respect to nitrogen), and to explore a range of financial incentives, disincentives, or other measures that would accelerate the BMP-adoption process. Regulatory alternatives should be evaluated, and where necessary, implemented if the above approaches do not achieve the needed nutrient reductions.

8. *The USDA and the EPA, in consultation with the Management Committee, should strengthen and coordinate their efforts to reduce agricultural nonpoint source pollution to improve water quality in Chesapeake Bay.*

Specifically, an agreement that establishes a cooperative commitment to work toward the goal of improved water quality in Chesapeake Bay and its tributaries should be developed. The agreement should outline ways that programs could be targetted to reduce loadings of a) nutrients (from soil, fertilizer, and animal wastes), b) sediment, c) agricultural chemicals, and d) bacteria from animal wastes. Also, the agreement should encourage the targetting of EPA and USDA technical assistance and computer modeling personnel to Chesapeake Bay priority sub-basins.

9. *Federal agencies, states, and counties should develop incentive policies by July 1, 1984, that encourage farmers to implement BMPs.*

Policies that could be considered include: incentives to maintain sensitive or marginal farmland out of production, such as the USDA Payment-in-Kind Program or other similar state or local efforts; cross-compliance; changes in the Internal Revenue Code, or state and local tax structures that will encourage landowner investment in BMPs or discourage the lack of adequate BMPs; the establishment of Federal, state, or local agricultural conservation trust funds for additional cost-share, education, or technical resources; user fees; dedicated taxes; or expanded implementation funding.

10. *The states, counties, and municipalities located in sub-basins adjacent to tidal-fresh and estuarine segments of Chesapeake Bay and its tributaries should implement fully and enforce existing urban stormwater runoff control programs.*

Although nonpoint source loadings of nutrients from urban land were not found to contribute significantly to overall nutrient loads, unnecessary loadings of nutrients, sediment, heavy metals, and other pollutants from urbanized or developing watersheds should be avoided because of their potential impact on living resources in isolated or sensitive reaches of the Bay. In addition, stormwater management programs should place equal emphasis on runoff quality quantity control techniques; they should also either establish owner-developer responsibility for long-term maintenance of urban stormwater BMPs or else include innovative finance mechanisms to pay for long-term BMP maintenance.

11. *The States of Maryland and Virginia and local governments should consider strengthening wetland protection laws to include non-tidal wetlands because of their value as nutrient buffers and living resource habitat.*

Research has shown that wetlands vegetation removes nutrients from the water column and thus provides a natural treatment process for pollution control. Wetlands also provide habitat and breeding grounds for commercially and recreationally important fish, shellfish, furbearers and waterfowl.

TOXIC COMPOUNDS

Toxic compounds enter the Bay from point sources, such as industrial facilities and sewage treatment plants, and from nonpoint sources such as urban runoff, dredged material disposal, and atmospheric deposition. The three major tributaries to the Chesapeake Bay, the Susquehanna, Potomac, and James Rivers, are the major sources of metals and organic compounds to the Bay. Industrial facilities and sewage treatment plants discharging directly to the Bay are signficant sources of cadmium, copper and organic compounds. Urban runoff is an important source of lead, and atmospheric deposition is an important source of zinc to the Bay. The toxic problem is most severe in industrialized areas such as Baltimore and Norfolk, where the water and sediments have high metal concentrations and many organic compounds. The major findings regarding toxic sources and controls for toxic compounds are discussed in Chapter 4, and are summarized below:

- The James, Potomac, and Susquehanna Rivers are the major sources of metals to the Bay. Collectively, they account for 69 percent of the cadmium, 72 percent of the chromium, 69 percent of the copper, 80 percent of the iron, 51 percent of the lead, and 54 percent of the zinc discharged to the Bay system.
- Over 300 organic compounds were detected in the water and sediments of the Bay; up to 480 organic compounds were detected in Baltimore Harbor. Most of the compounds detected were toxic and many were priority pollutants.
- An analysis of effluent from 20 industries

and 8 publicly owned treatment works revealed that over 75 percent of the facilities had toxic substances in the effluent. The possible causes of toxicity were metals, chlorine, and chlorinated organic compounds.

- Point source control programs resulted in significant reductions in metal loadings between 1970 and 1980 to areas such as Baltimore Harbor. However, these programs only control the 129 EPA priority pollutants.
- Nonpoint source control efforts, such as urban runoff controls, integrated pest management, and the regulation of dredge spoil disposal, have probably resulted in reduced loadings of toxic compounds to the Bay.
- Toxic pollution control tools, and information developed by the CBP, such as the toxicity index, the toxicity testing protocol, and the effluent and sediment fingerprinting procedure, will help managers address the toxic substance problem.

The Federal government and states have made significant advances in the control of toxic substances. However, we still find alarmingly high levels of toxic compounds in certain 'hot spot' areas of the Bay. It is also disconcerting that our present monitoring efforts could not detect an illegally discharged or dumped bioaccumulative compound which exceeded chronic toxicity levels. This would suggest that a Kepone-type incident as occurred in the James River in 1975 could easily occur again. Such a possibility is frightening in light of the fact that toxic materials tend to easily adsorb to sediment and remain trapped in the Bay. They are often recycled throughout the system, causing repeated damage, until they are eventually buried by the accumulation of clean sediment. The above findings suggest that current permitting, monitoring, and enforcement programs do not sufficiently control toxic loadings to the Bay.

BAY-WIDE TOXICANT RECOMMENDATIONS

OBJECTIVE:

CONTROL AND MONITOR POINT AND NONPOINT SOURCES OF TOXIC MATERIALS TO MITIGATE THE POTENTIAL OR DEMONSTRATED IMPACT OF TOXICANTS ON THE LIVING RESOURCES OF THE BAY.

General Recommendations

1. *The states and the EPA, through the Management Committee, should utilize the existing water quality management process to develop a basin-wide plan, that includes implementation schedules, to control toxicants from point and nonpoint sources by July 1, 1984.*

Point Source Recommendations

2. *The states, through the NPDES permit program, should use biological and chemical analyses of industrial and municipal effluents to identify and control toxic discharges to the Bay and its tributaries.*

Biomonitoring and chemical analyses (GC/MS "fingerprint") of effluents can be used to identify toxic discharges and to assess potential impacts on receiving waters. Initial focus should be on all major discharges, facilities known or thought to be releasing priority pollutants, and POTW's receiving industrial wastes. In developing this protocol, the States should follow EPA policy and recommendations (Appendix D). Priority areas for implementation should be the Patapsco, Elizabeth, and James Rivers, to be expanded to other areas as appropriate. All effluent biological and chemical data will be stored in EPA's Permit Compliance System (PCS), as well as the CBP data base. Monitoring of effluents should be coordinated with the Bay-wide monitoring plan outlined in Appendix F; this includes analysis of toxicant levels in sediments, water column, and in tissues of finfish and shellfish.

3. *The states and the EPA, through the Management Committee, should utilize Chesapeake Bay Program findings in developing or revising water quality criteria and standards for toxicants.*

Initial priority should be given to pollutants identified as highly toxic and prevalent in the Bay, specifically chlorine, cadmium, copper, zinc, nickel, chromium, lead, and in tributaries, atrazine and linuron. Numerical criteria should be developed when needed and incorporated into state water quality standards as soon as feasible. Site-specific criteria that are developed, should be based on biological and chemical characteristics of individual receiving waters according to EPA guidelines.

4. *The states should base NPDES permits on the EPA effluent guidelines or revised state water quality standards, whichever are more stringent. Furthermore, the states should enforce all toxicant limitations in NPDES permits.*

The EPA should maintain its current schedule for promulgating BAT effluent guidelines. To facilitate writing of permits, the EPA should continue to transfer knowledge and expertise developed during the effluent guideline process to the States. The States should also consider increasing the number of training programs for permit writers.

5. *Pretreatment control programs should be strengthened where needed to reduce the discharge of hazardous and toxic materials.*

The pretreatment programs in various basins have contributed to reductions of toxicants in some municipal discharges, but the CBP has found that, as a group, treatment plants continue to be major contributors of heavy metals, organic compounds, and other toxicants including chlorine. Current EPA regulations require pretreatment programs to be developed by July 1, 1983. Municipal dischargers who have not submitted their program should do so as soon as possible. The EPA and the States should enforce these programs.

6. *Chlorine control strategies should be implemented (or continued, where now in place) in areas of critical resource importance. Strategies should focus on reduction or elimination of chlorination, use of alternative biocides, and reduction of impact of effluents.*

Major areas of emphasis would include fresh or brackish fish spawning and nursery areas, and shellfish spawning areas. Maryland and Virginia have already begun to reduce chlorine residuals, evaluate site-specific effects of chlorine, and consider environmental effects in siting and permitting of dischargers. Specific programs and strategies for chlorine are described in Appendix D.

Nonpoint Source Recommendations

7. *The EPA, the U.S. Army Corps of Engineers, and the States should utilize CBP program findings and other new information in developing permit conditions for dredge-and-fill and 404 permits.*

Information developed (or assembled) by the Chesapeake Bay Program includes: a measure of the relative enrichment of sediments by six metals, concentrations of organic materials in surface sediments, shoaling and erosion patterns, distribution of sediment types, location of submerged aquatic vegetation beds, shellfish beds, fish spawning and nursery areas, as well as relationships between habitat quality and living resources.

8. *A Bay-wide effort should be made to ensure proper handling and application techniques of pesticides and herbicides, particularly in light of the potential increase in use of these materials in low-till farming practices.*

Innovative strategies, such as integrated pest management (IPM) and reduction and timing of application have proven to be successful in the Bay area. The States should encourage the use of these reduction strategies, support runoff and erosion control programs, and monitor the fate and effect of those substances on the Bay's aquatic environment.

9. *Research, monitoring programs, and control strategies to reduce urban runoff should be continued and strengthened by the localities which are most directly affected.*

The states and urban areas should develop and implement plans which identify urban management strategies to protect water quality in those areas where urban runoff controls provide the most effective results.

10. *The states and the EPA should evaluate the magnitude and effects of other sources of toxicants, including atmospheric deposition, acid precipitation, contaminated groundwater, acid mine drainage, hazardous waste disposal and storage sites, accidental spills, and antifouling paints.*

As information becomes available, it should be factored into control and permit processes, etc. For example, models indicate that 30 to 40 percent of atmospheric emissions generated within the Bay area are deposited there. CBP has estimated potentially significant inputs of metals from acid mine drainage and anti-fouling paints, particularly in tributaries. Many of these toxicant sources are currently being investigated by federal and state agencies.

BAY MANAGEMENT

To effectively manage the Bay, we must recognize both its variability and its unity. The Bay's water quality needs vary from region to region as do the controls necessary to support specific regional resource use objectives. The industrialized Patapsco and Elizabeth Rivers have a very different water quality problem than the Choptank or Rappahannock Rivers. Also, the desired and actual use of these areas varies significantly, industrial versus agriculture, and fishing. It is apparent that we must also target our control strategies by geographic area. Chapter 5, *Basin Profiles* describes the different areas of the Bay and recommends actions to address their specific regional needs. We must always keep in mind that the Bay is a complex interactive ecosystem and that actions in any part of the watershed may result in water quality degradation and impacts on aquatic resources downstream. For this reason, it is essential that a Bay-wide management mechanism with appropriate representation coordinate the respective activities of the Federal and state plannning and regulatory agencies. This concept is discussed in Chapter 6, which concludes that: *The Management Committee should be the coordinating mechanism to ensure that actions are taken to reduce the flow of pollutants into the Bay, and to restore and maintain the Bay's ecological integrity.*

The Management Committee's specific responsibilities should include:

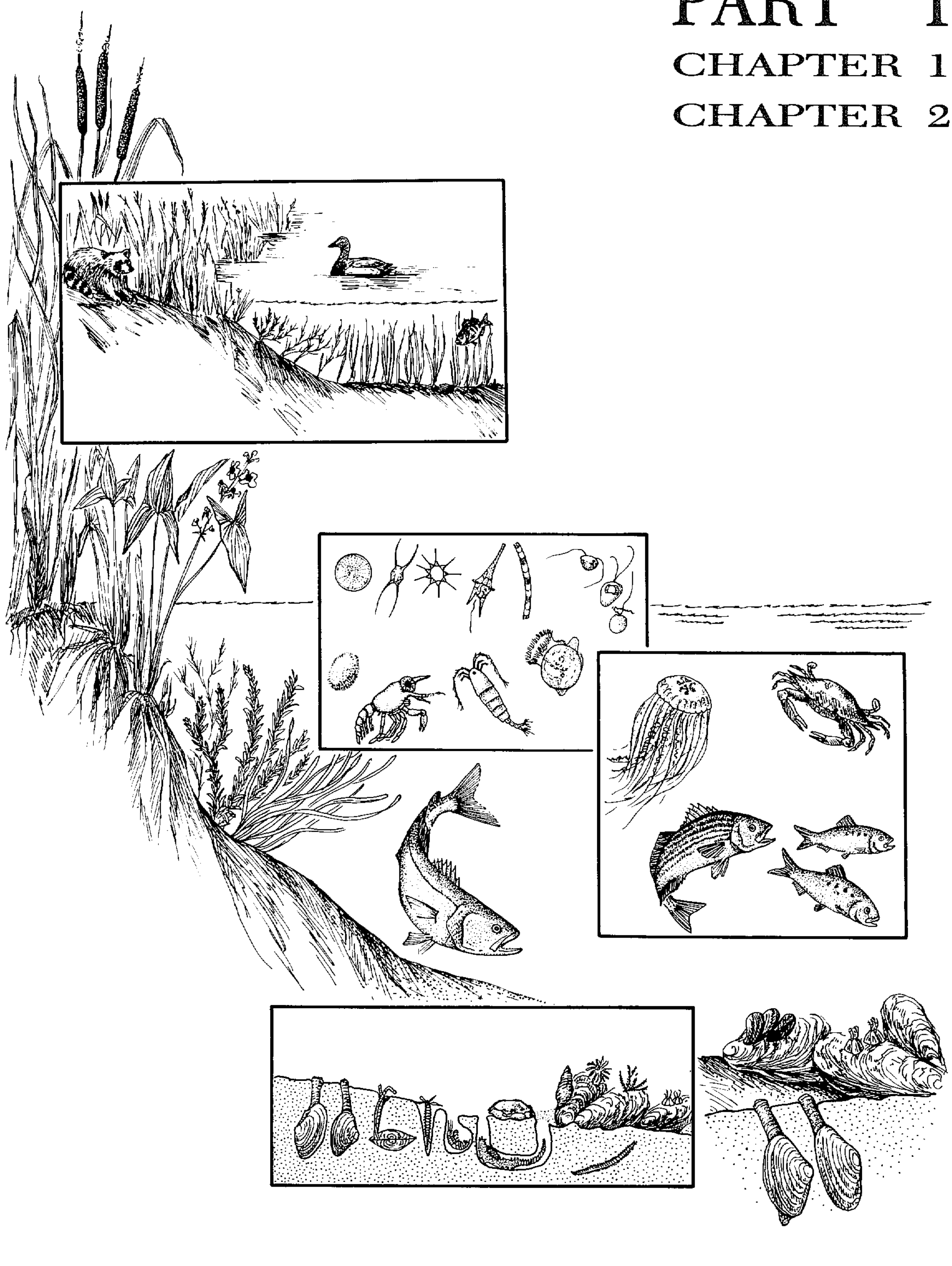
- Coordinating the implementation of the Chesapeake Bay Program recommendations;
- Developing a comprehensive basin-wide planning process in conjunction with ongoing planning efforts;
- Investigating new regional approaches to water quality management including creative financing mechanisms;
- Resolving regional conflicts regarding water quality issues; and
- Reviewing ongoing Bay research efforts and recommmending additional research needs.

Hopefully, the needs of the future can be met and the quality of the Bay preserved. It is apparent that we are talking about some governmental change, long-term commitments, and money. There will be no quick-fix for the Chesapeake's problems. We will need to continue to study and to monitor, but while we do that, we will also need to focus concerted remedial action on some of the most severe problems in the system. Above all, we will need to continue the dialogue among the states and among the users of the Bay. The new spirit of cooperation and awareness generated by the Chesapeake Bay Program has brought us to the point of believing that we can, after all, manage the Bay for the benefit of all.

PART I

CHAPTER 1

CHAPTER 2



CHAPTER 1
AN INTRODUCTION TO CHESAPEAKE BAY

Harry W. Wells, Jr.
Stephen J. Katsanos
Frances H. Flanigan

Estuaries are coastal bodies of water which contain sea water diluted by freshwater from riverine sources. Their unique physical, chemical, and biological characteristics create a favorable environment for the growth of plants and animals. The Chesapeake Bay is one of the largest, most productive estuarine systems in the world. Its harvests are legendary: fisheries records maintained since the early 1880's show that the Chesapeake has yielded millions of pounds of seafood annually, satisfying the domestic and foreign market demand for oysters, crabs, and other commercial aquatic species. It has served for centuries as a commercial shipping center with two major port complexes connected by modern and efficient interstate highway, air, and rail systems to important inland points. The Bay is also a recreational center, offering boating, sportfishing, and wildlife experiences to shoreline residents and millions of visitors each year. It is truly a national treasure.

The Chesapeake Bay main-stem is situated within two middle Atlantic states: Maryland and Virginia (Figure 1). It is 195 miles (314 km) long, 3.4 to 35 miles (5.5 to 56 km) wide, and has 1,750 miles (2,817 km) of navigable shoreline (Wolman 1968). It is relatively shallow, having a mean depth of 28 feet (8.5 m). It also has a deep, natural channel running the length of the Bay which was carved thousands of years ago by the Susquehanna River.

The main stem of Chesapeake Bay is only a small portion of the 64,000 square mile (165,760 km^2) Chesapeake drainage basin (Figure 2). Over 150 rivers, creeks, and branches flowing through portions of six states and the District of Columbia contribute freshwater to the estuary. Among the rivers, 50 are considered major. Six of these 50, however, contribute almost 90 percent of the freshwater contained within the Bay main stem. The Susquehanna is by far the largest river in the basin, discharging approximately 50 percent of the freshwater that reaches the estuary. It begins in the Finger Lakes region of New York State, etches its way through central Pennsylvania, and discharges freshwater to the head of Chesapeake Bay at a mean annual rate of 40,000 cubic feet (1132.7 cubic meters) per second. It has the highest freshwater discharge rate of any river on the east coast of the United States. Its flow is exceeded only by the St. Lawrence in all of eastern North America. The Susquehanna's total length measures about 440 miles (708 km), and its basin occupies 27,500 square miles (71,225 km^2), more than one third of the entire Chesapeake basin. The other primary tributaries are the Potomac, the Rappahannock, the James, the York, and the Patuxent Rivers. Together, these six rivers shape the circulation and salinity regimes which govern the Chesapeake estuary. How land is managed within each of these basins largely determines the volume and chemical characteristics of freshwater discharged to the Bay.

GEOGRAPHY

The modern Chesapeake is a relatively young estuary, the product of climatic changes that began 20,000 years ago. At that time, the Atlantic coastline was about 70 miles (113 km) east of Ocean City, Maryland; sea level was 327 feet (98 m) lower than at present; and eastern North America was covered, down to central Pennsylvania, by a dense continental glacier. A warm-

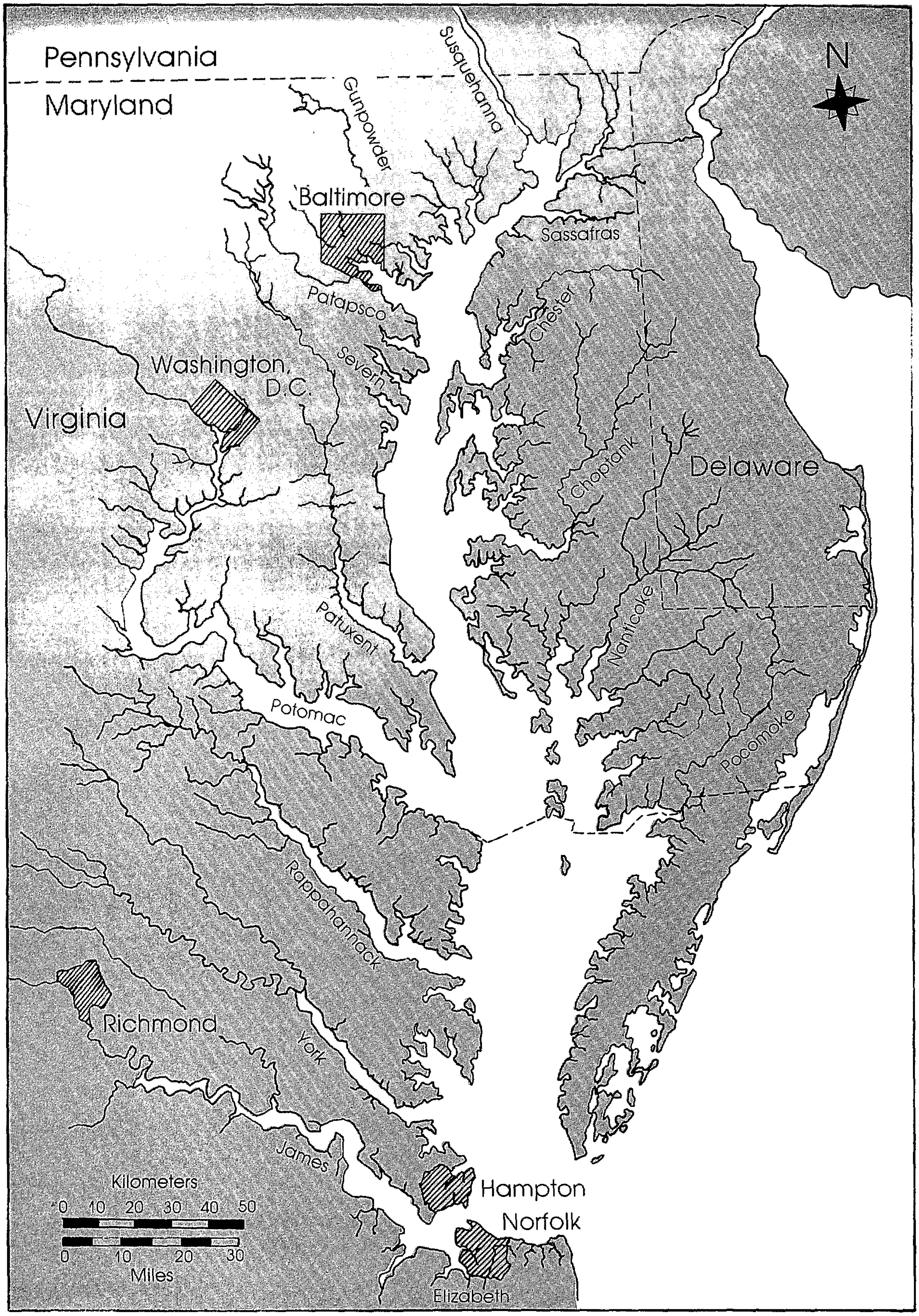


FIGURE 1. The Chesapeake Bay.

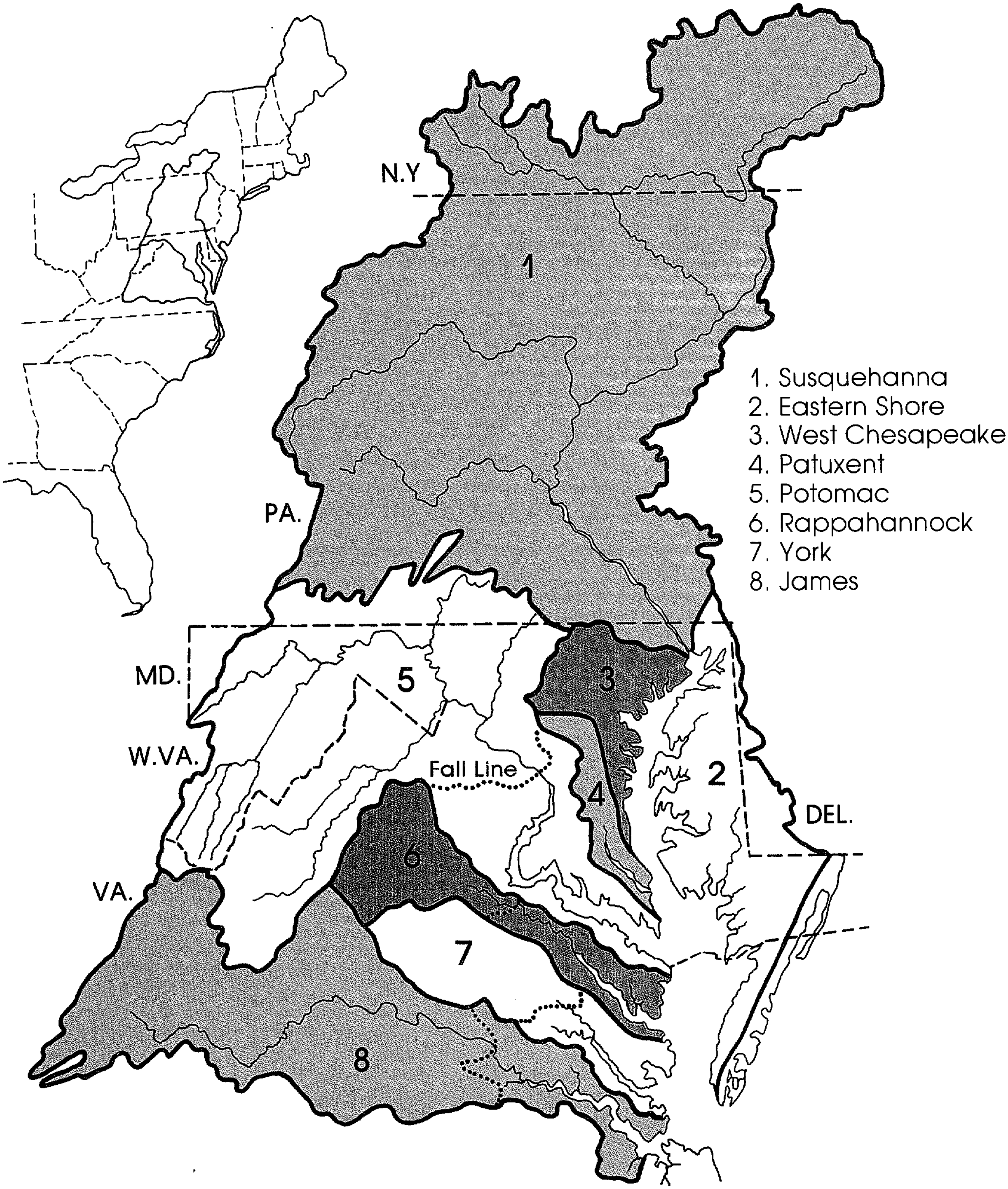


FIGURE 2. The Chesapeake Bay drainage basin.

ing trend started and, as temperatures rose, the volume of melt water seasonally discharged from the North American ice sheet increased. As sea level rose, the inundation of the continental shelf began. Eventually, the rising sea reached and flooded what was then the Susquehanna River Valley forming the Bay as we know it. The sea level continues to rise today in response to continued glacial melting, thus, slowly changing the shape of the Bay. Figure 3 shows a cross-section of the Bay with its deep channel, shallow shoals, and surrounding geological formations.

The Chesapeake Bay region boasts a moderate climate and a central location between the heavily industrialized New England states and the high-growth Southern Atlantic states. Virtually every type of land usage and economic activity is found within the basin. Agriculture dominates in many portions of the 14,300 square mile (37,037 km^2) coastal plain. Forestry, coal mining and other uses occupy approximately 59 percent of the land area, including major portions of the 50,600 square mile (131,054 km^2) Piedmont.

Approximately 12.7 million people now live within the Maryland, Pennsylvania, and Virginia tri-state portion of the Chesapeake drainage basin. Major urban centers include the Norfolk-Hampton Roads area, and Richmond in Virginia; Washington, D.C.; Baltimore, Maryland; and Harrisburg, and York, Pennsylvania. Most of the population is concentrated in the coastal region of the basin (i.e. below the fall line). This area offers many commercial and recreational opportunities, and is also the most environmentally sensitive. The lure of Chesapeake Bay is vividly demonstrated in the tidewater portions of Virginia where 60 percent of the entire state's population lives on one-third of Virginia's land area.

COMMERCE

For over 300 years the Bay has been used to support a number of regional use-objectives and economic needs. One of the earliest colonial uses of the Bay was waste assimilation; today thousands of municipalities, and commercial and industrial facilities use the Bay and its tributaries as sources of process water and outlets for treated wastes. The Bay also is a major link in the Intracoastal Waterway, and its value as a commercial shipping center increases every day.

The Chesapeake's shoreline, including tidewater tributaries, measures 4,600 miles (7,406 km); almost 1,750 miles (2,818 km) of the tidewater region are navigable. This vast navigable area is relatively shallow, but the Bay's deep, natural channel has helped make Baltimore and Hampton Roads two of this country's five major North Atlantic port complexes.

Hampton Roads and Baltimore are, without doubt, the two major export points for coal mined

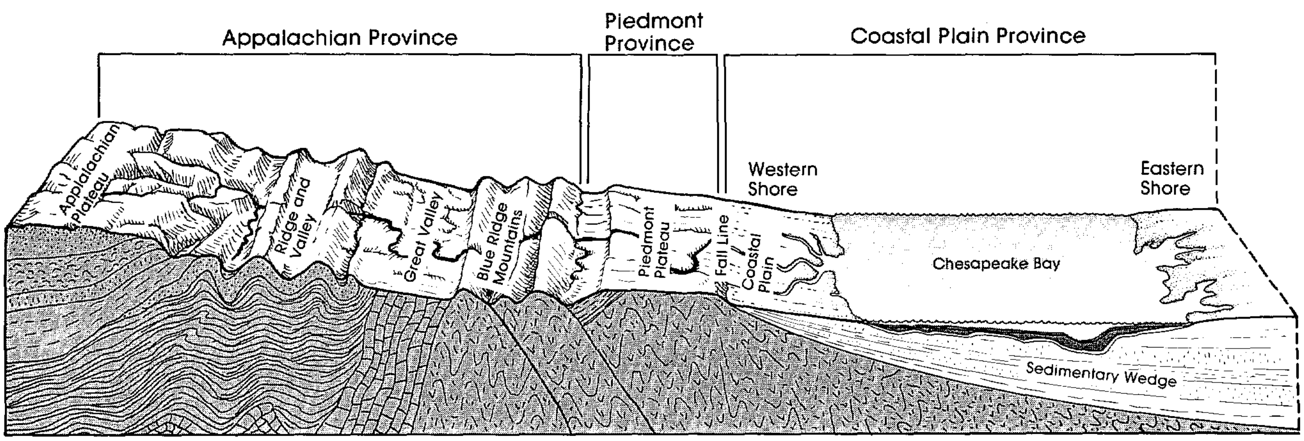


FIGURE 3. A cross section of the Bay showing the deep channel, shallow shoals, and geological formations.

in the United States, accounting for about 50 and 14 percent of total export tonnage, respectively. The Hampton Roads complex, which includes Portsmouth, Norfolk, Hampton, and Newport News, dominates the mouth of the Bay. Together with the northern Bay's Port of Baltimore, the two shipping facilities moved 42 million tons of coal during 1979 (U.S. Army Corps of Engineers 1979). In 1980, coal exports grew to 61 million tons, a 45 percent increase over 1979 levels. Industry projections indicate that coal exported through Chesapeake Bay ports could reach 280 million tons by the year 2000, and total cargo tonnage handled by Hampton Roads and Baltimore could double during the next 20 years. Land-based distribution systems serving both ports are available, including direct rail transportation from the ports to the rich Appalachian coal seams located in the Piedmont portions of the Chesapeake basin.

Other major industrial activities found within the basin are steelmaking and shipbuilding, leather tanning, plastics and resin manufacturing, and chemical production. Soybeans, vegetables, and tobacco are major agricultural commodities grown in the region. Poultry, seafood, and vegetable processing are important industries on the Chesapeake's Eastern Shore. Other animal husbandry and processing activities can be found throughout the basin.

FISHERIES

The Bay's ability to support abundant and diverse populations of finfish and shellfish made seafood harvesting and processing two of the earliest commercial activities in the region. The seafood industry is more than 374 years old, and it continues to be an important element in the economies of both Maryland and Virginia. It is primarily an industry comprised of small businesses, many of which are family enterprises with roots as old as the coastal communities they support. Chesapeake Bay provides thousands of commercial watermen with jobs harvesting fish, while on-shore processing and distribution generates a number of secondary income opportunities. In many cases commercial fishing is the primary source of household income, while processing, distribution, and related marine activities represent the revenue base for coastal communities.

Oysters, blue crabs, soft shelled clams, and menhaden are the Bay's 'staple' crops. The Chesapeake oyster, which first attracted world attention in the mid-1800's, has since occupied a market position exceeded only by Japan. During the early years when new canning techniques first enabled processors to ship oysters to Europe, annual production reached 15,000,000 bushels (U.S. Department of Commerce and the U.S. Department of the Interior 1880-1980). Unchecked harvests during the legendary 'oyster wars,' continued harvesting pressure, and other factors have reduced the Bay's oyster stock, but the harvest has averaged 27 million pounds (12.5 kg) of meats annually for the last 50 years. By some estimates Chesapeake Bay oysters represent 42.6 percent of total domestic production, exceeding all other areas in the country. Blue crab production totals about 55 million pounds (24.8 kg) annually, making the Chesapeake one of the largest producers in the world. The Bay accounts for more than one-half of the total U.S. soft shell clam catch, surpassing all of New England's production. Striped bass, bluefish, white perch, shad, herring, and spot are other important commercial species landed in the Bay. The total dockside value of commercial fish species landed in Maryland and Virginia primarily by resident watermen was 106 million dollars in 1980. More than one-half of the total landings were made in Chesapeake Bay, while the balance was caught in the Atlantic Ocean offshore of Maryland and Virginia (U.S. Department of Commerce and U.S. Department of the Interior 1880-1980).

RECREATION

In addition to commercial fishing, other forms of recreation such as sportfishing and boating, generate jobs and a significant portion of the revenues which sustain local and state economies in Maryland and Virginia. Millions of visitors come to the Bay every year, lured by the Chesapeake's countless recreational opportunities. Statistics compiled by Maryland indicated that more than 122,000 sail and power pleasure craft were registered primarily for use on Chesapeake

Bay during 1979 (Maryland Department of Natural Resources 1980). Sportfishermen took an estimated 28 million pounds (12.6 kg) of gamefish from Chesapeake waters during that same year. The recreational interest in the Bay is clearly demonstrated by the number of activity days recorded in 1979 by Maryland and Virginia, 2,592,072 and 1,529,322, respectively. The Bay's sportfishing value alone is estimated at 261.33 to 290.14 million dollars annually. Secondary spending related to sportfishing is estimated to increase the Bay's sportfishing income value to 770.28 million dollars annually, or one-third of the Chesapeake's water-based contribution to the regional economy (JRB Associates 1982).

Boating activity, both sail and power, can be seen throughout the Bay during most of the year. Annapolis, home of the Naval Academy, is commonly called the "sailboat capital" of the United States. Oxford, Solomons, Crisfield, Deltaville, and countless other safe harbors dot the Chesapeake coastline. The Chesapeake, because of its recreational appeal, has directly sustained these small ports as well as the large ones. Boating and fishing alone, however, do not represent the only recreational uses of the Bay.

The estuary, with over 7,000 miles (11,270 km) of shoreline, lush wetlands, and numerous protected creeks, is home to countless animals and plants and a major stop along the Atlantic Migratory Bird Flyway. Over one-half million Canada geese, ducks, and other migratory waterfowl can be found over-wintering along the Chesapeake, providing numerous sport opportunities. Whistling swans in numbers approaching 40,000 can be counted during the winter. The endangered bald eagle nests in the region, and its threatened cousin, the osprey, is more common around the Chesapeake than anywhere else in the United States. The Chesapeake, without doubt, today supports a mixture of wildlife and commercial activities unmatched by any other estuary. It appears, however, that the Chesapeake's ability to maintain its diverse ecological productivity and other uses is slipping.

HISTORICAL TRENDS

The Bay is no longer the clean, pristine estuary John Smith knew. Changes in land usage along the main stem and Bay tributaries have led to increased sediment, nutrient, metal, and organic chemical loadings to the estuary. Due to its unique circulation, substances discharged to the Bay by its tributaries are not freely exchanged with the ocean. They are essentially trapped within the system where they may be assimilated and utilized by Bay organisms. As these 'pollutants' accumulate in Bay waters or sediments, they can alter the function or quantity of the ecosystem.

Assessing the impact of land usage and related environmental changes on living resources is difficult, primarily because accurate records depicting Bay conditions reflect only a small portion of the Chesapeake's history. The period of scientific research in the Bay is brief, and many aspects of the Bay's environment were radically altered by man by the time research was initiated. One must recognize that the Chesapeake of today is a reflection of time, constantly changing in response to nature, and reacting, often unpredictably, in response to human activities. Use-related conflicts and water quality changes have occurred in the past, but the water quality alterations caused primarily by nutrients and resource diversity shifts during the past 15 years are unprecedented. Figure 4 summarizes a number of salient historical features that reflect the changes in the Bay. These features remind us that many Bay changes caused by human activity are not of recent origin, but began at the time of European settlement and continue today. Another important aspect of the Bay's historical ecology is that this continuous human activity has been operating against a background of natural climatic cycles and an occasional extreme event such as a hurricane. The Bay ecosystem is dynamic, and our view of its current "quality" and assimilative capacity can benefit from examining the past as we attempt to manage its future.

In Figure 4, the time horizon begins at 1600, near the time of the first permanent settlement in Virginia at Jamestown. Several historical events mark the calendar, such as the industrial revolution and major wars. Major land-use activities and living resources are listed on the vertical axis and chronicled over the 380 years of record. Major land "improvements," primarily clearing of land for farming, were well along by the mid-1700's.

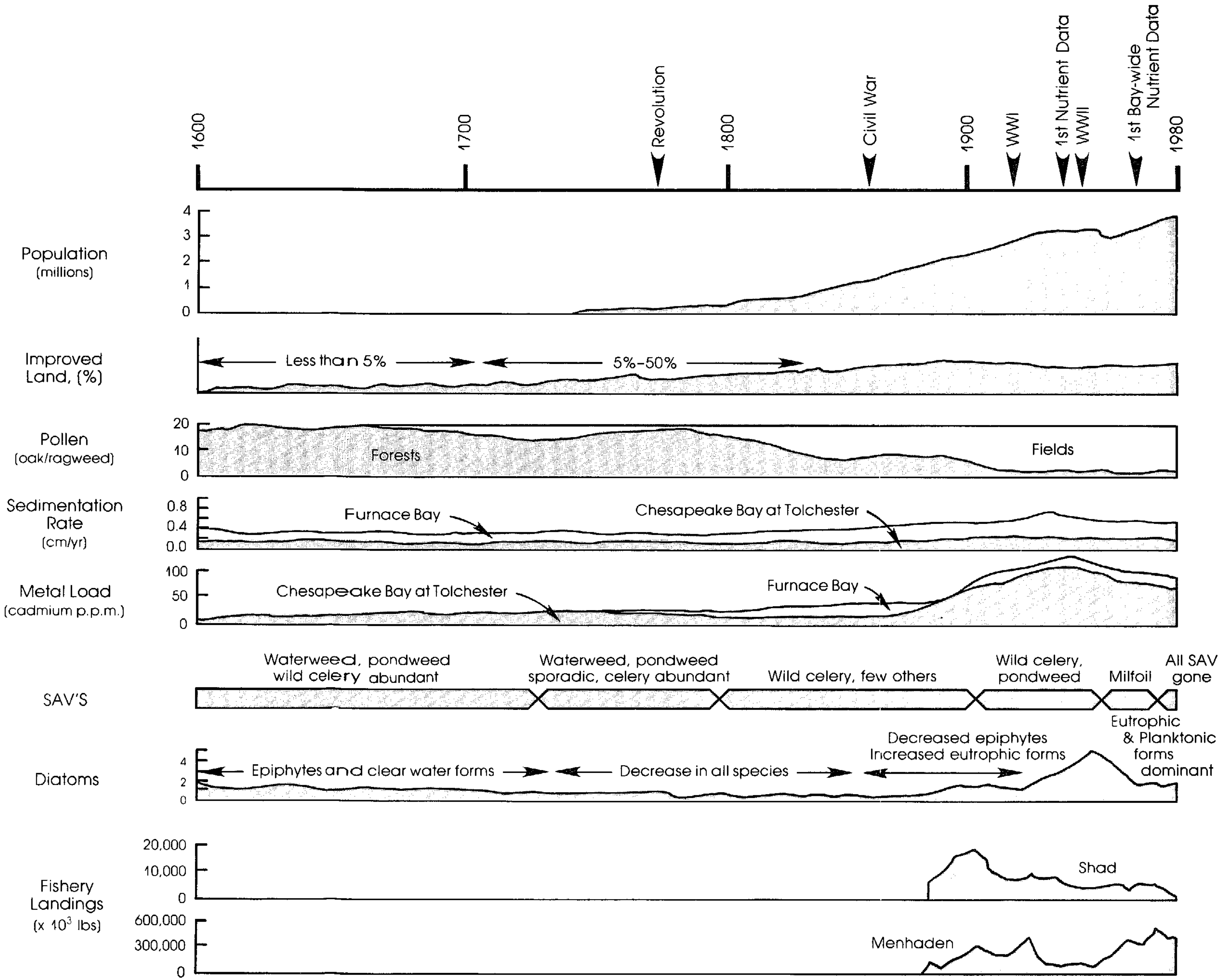


FIGURE 4. TIME HISTORY OF NORTHERN CHESAPEAKE BAY, 1600 TO 1980. An important aspect of understanding how Chesapeake Bay will respond to pollution is to examine the Bay's past. In the northern Bay, human activity, beginning at the top of the chart with population growth has been changing water quality since the time line began (see Appendix A for further discussion).

The forested area shows a consequent decrease followed by a return of some cleared land to forest condition by the 1780's. Much of this land was devoted to the production of tobacco. After about 1800 there is a distinct and continuous trend of the conversion of forests into fields. Also, about the time of the Civil War, discharge of potentially harmful trace metals to the Bay began to increase considerably marking the early stages of the Industrial Revolution. In addition, sedimentation rates began to increase rapidly due to accelerated erosion.

Bottom sediment cores from Furnace Bay, located on the northern shore of Susquehanna Flats, provide insights into the history of submerged aquatic vegetation (SAV) and diatoms, microscopic algae that leave behind a skeleton formed from silica (Brush and Davis 1982). These single-celled algae help in making inferences about nutrient conditions at the time the diatoms were deposited. Apparently, at about 1720, the rooted plant species shifted dominance: the formerly dominant waterweed and pondweed became sporadic, with wild celery becoming abundant. Changes were noted in the epiphytic algae that grow on the leaves and stems of SAV. During this period of initial land clearing, many clearwater diatoms became less abundant and a few species disappeared as the Bay's clear, shallow waters first became more turbid. This was the first signal that nutrient enrichment was occurring. The recent dramatic decline of SAV, however, is a phenomenon whose magnitude in the Bay has no apparent parallel in the past four centuries (Brush and Davis 1982).

Paralleling the more recent changes in the Bay's character, shifts in many of the Bay's fisheries are seen. Harvests of many species have undergone fluctuations since the first landing records were published. Marine spawners, such as menhaden, began to dominate the Bay's finfish communities during the last several decades while freshwater spawners, such as shad, have declined. As a result, the quantity and diversity of finfish found in the estuary is not as great now as in the past.

This brief summary leaves an indelible impression. The Bay ecosystem has been interacting with natural events such as droughts or hurricanes, as well as cycles of climatic change. The Bay is also showing changes clearly related to human activity which began to impact the Bay by the mid-1700's. The most significant changes began in the mid-1800's and reached high levels around WWII. The past 40 years have been a time of new events for the Bay—many possibly not coded into the genetic memory of the Bay species, including humans. Discharges of chlorinated hydrocarbons, heavy metals, and other toxicants are all relatively new problems confronting the Bay and challenging the capabilities of scientists and Bay managers. Nutrients and sediment, discharged in ever increasing amounts since colonial days, have become major problems as urbanization and centralized wastewater treatment elevated the rate at which these conventional pollutants reach the Bay.

POPULATION TRENDS AND LAND USE

Population estimates between 1950 and 1980 and projections to 2000 are shown in Figure 5. Basin-wide, the population grew by 4.2 million between 1950 and 1980 and is expected to grow an additional 1.9 million, to a total of 14.6 million by 2000. Although the largest increases in population (1.4 million) will occur in the three largest basins, the Susquehanna, Potomac, and James Rivers, the highest rates of increase between 1980 and 2000 are expected in the York (43 percent), Rappahannock (40 percent), and Patuxent (27 percent) River basins. More people living in the drainage basin could place additional stress on the Chesapeake because of increasing freshwater withdrawal and larger amounts of wastes (sewage, urban runoff, construction activity, intensified agricultural activities, additional industrial activity, etc.) which the Bay will have to assimilate unless necessary actions are taken.

Land-use changes in the Chesapeake Bay basin between 1950 and 1980 are illustrated in Figure 6 (Census of Agriculture and Timber Survey 1982). Cropland and pasture land have decreased significantly (24 and 39 percent, respectively) throughout the entire watershed while forest land has increased slightly (3.5 percent). The percentage of land in urban and residential usage has almost doubled (182 percent increase) since 1950. As shown in Figure 6, the "other" land-use category represents county lands not identified as

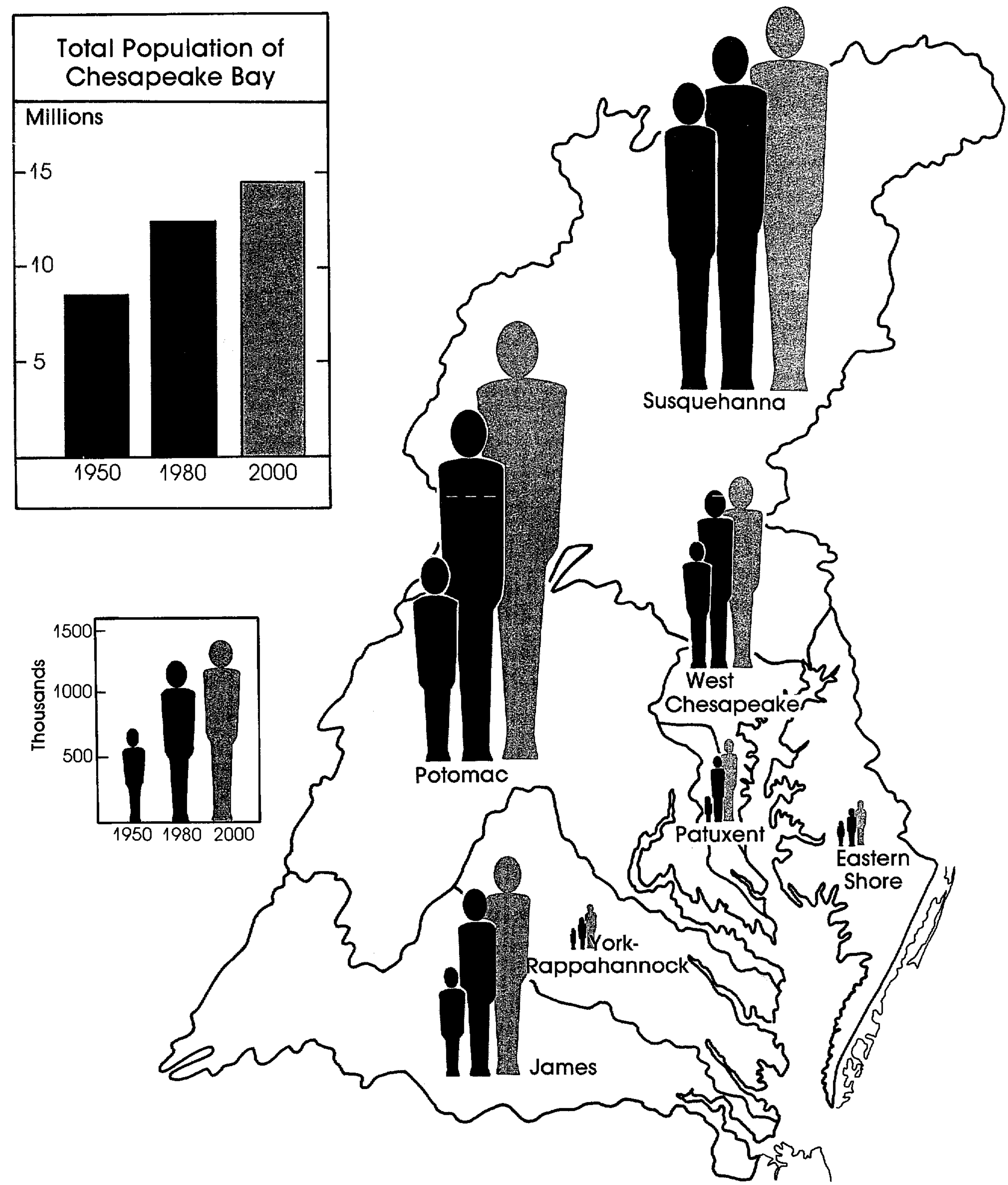


FIGURE 5. Comparisons of Chesapeake Bay populations in 1950 and 1980 to the projected population for the year 2000.

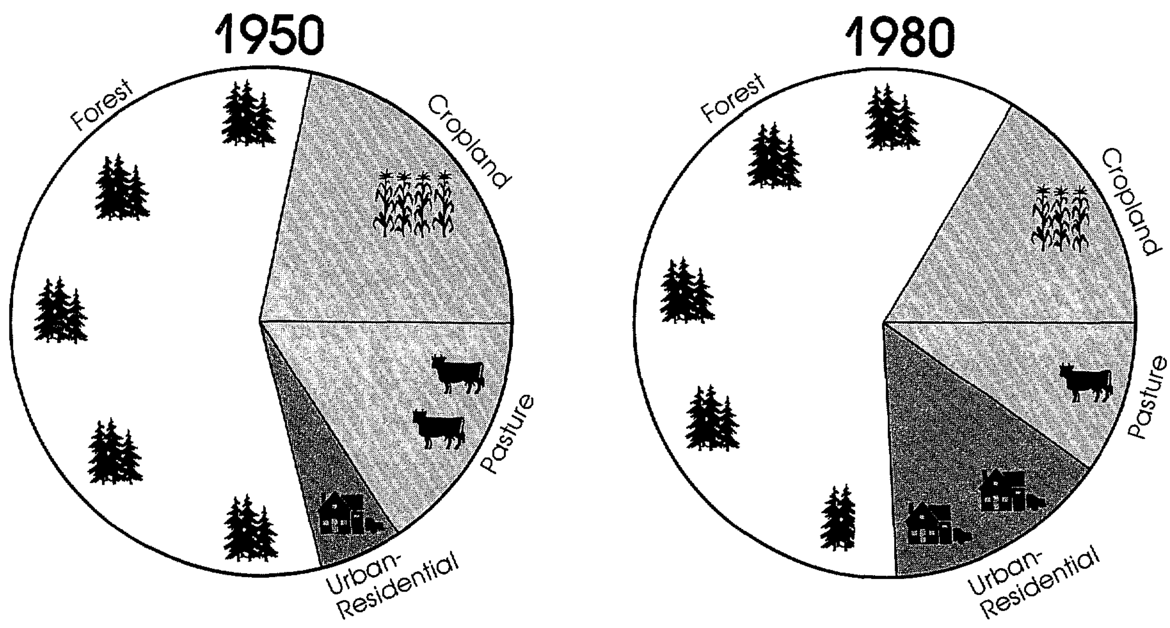


FIGURE 6. Land-use changes in the Chesapeake Bay drainage basin, 1950 to 1980.

either cropland, pasture land, or forest land and may include institutional lands, wetlands, and idle lands, but most closely reflects the percentage of urban and residential land uses. These physical changes in the uses of land, coupled with changing perceptions of the Bay, have had a significant impact on the system and the ways humans have tried to manage it.

THE CHESAPEAKE BAY PROGRAM

The connection between human activities and the resources of the Bay was recognized in the nineteenth century. Representatives of the oyster industry voiced concern over the decline of the fishery in the twentieth century. Both Maryland and Virginia established laboratories whose sole purpose was to study the Bay and its tributaries. A number of conferences were held (1933, 1968, 1977) and citizens groups became active pollution control advocates. Whereas in the nineteenth century concern for the Bay was voiced primarily by the oyster industry, today the chorus includes boaters, sportsmen, fishermen, and a large phalanx of concerned citizens and their elected representatives. State governments have responded with an increasingly complex and sophisticated range of pollution control and management agencies. In addition, the Federal government recognized the need for the national protection of water resources and, in the 1970's, passed a series of laws which fundamentally changed the framework for managing and protecting water resources. Government programs are described in detail later in this report.

The specific impetus for the EPA's Chesapeake Bay Program (CBP) came from a tour of the Bay conducted by Senator Charles Mathias (R-MD) in 1973. That tour, which focussed on the problems alluded to above, led to conversations with Russell Train, then the EPA Administrator. In fiscal year 1976, Congress directed the EPA to conduct a five-year, 25-million- dollar study of Chesapeake Bay. Senate Report 94–326, which accompanied the authorizing Act (P.L. 116), required the EPA to access water quality problems in the Bay, to establish a data collection and analysis mechanism, to coordinate all of the various activities involved in Bay research, and to make recommendations on ways to improve existing Chesapeake Bay management mechanisms.

In choosing problems upon which to focus research, the EPA looked to the scientific community, the Bay area governments, and the public. A list of ten candidate issues was drawn up. From this list, three topics were chosen as targets for the 25 million dollar research program. Nutrient enrichment, toxic substances, and the disappearance of submerged grasses were major concerns upon which little previous research money had been spent. Shortly after the priority objectives were established, the Chesapeake Bay Program's managers developed and implemented a unique approach to managing a water quality research program. To the greatest extent possible they involved all components of the Bay community in the decision process. This included scientists, state officials, citizens, recreational interests, watermen, business, and industry.

In the scientific area, over 17 million dollars were spent by the CBP to support over forty individual scientific research projects, enabling a broad spectrum of scientists and institutions to participate in analyzing the Bay. These projects are summarized in the report *Chesapeake Bay Program Technical Studies: A Synthesis*. In addition to coordinating and staffing principal research efforts, the CBP also developed a computerized data management system to compile and evaluate the data collected by individual CBP projects and by other research efforts. All data entered into the system have been quality assured and a procedure has been established to allow the Bay research community access to the system. The information assembled in the CBP data base is considered to be the most extensive body of scientific knowledge on any single estuary in the world. More important, the data base provides a common set of knowledge about the Bay's ecological problems — a prerequisite necessary to carry out individually and collectively the most urgent task of establishing common goals for action to improve the Bay.

The data base was used to characterize the state of the Bay by evaluating water/sediment quality and living resource variables in each of 45 segments of the Bay. The segments were based on physical and chemical properties and can be used to compare the relative health or condition of the Bay. Such a comparison gives an indication of the relationship between water quality and biological response. These relationships are discussed in the EPA report *Chesapeake Bay: A Profile of Environmental Change*. To facilitate citizen input into all aspects of program management, the EPA established a public participation program as an integral part of the CBP. It is the main mechanism by which information flows between Bay citizens and Bay Program managers. The public participitation program is managed by the Citizens Program for the Chesapeake Bay, Inc. (CPCB). This program was founded in 1971, and is an independent, non-profit, Bay-wide alliance of organizations whose purpose is to provide an avenue for discussion of issues affecting the Chesapeake. The EPA grants enabled the CPCB to transmit research findings to the public so that informed choices could be made on Bay resource management issues. To assure the continuance of the cooperative effort represented by the Chesapeake Bay Program, the EPA encouraged state (Maryland, Virginia, and Pennsylvania) participation in all aspects of the Program. This enabled the EPA to receive assistance and support from state agencies in the areas of program planning, technical support, data compilation and processing, scientific planning, and technical program development and implementation. The lead agencies in Maryland are the Departments of Natural Resources and Health and Mental Hygene. The counterpart in Virginia is the Department of Commerce and in Pennsylvania the Department of Environmental Resources and the Susquehanna River Basin Commission. These agencies along with the District of Columbia served as liaison between the Chesapeake Bay Program and other state/federal agencies.

Decisions concerning Program policy and management were made by the Chesapeake Bay Program Management Committee chaired by the EPA Region III. The Committee has representatives from both water quality and resource agencies from Pennsylvania, Virginia, and Maryland. In addition, citizens, the Distric of Columbia, and the Susquehanna River Basin Commission are members of the Management Committee. The Committee's success in providing guidance and coordinated leadership to the Chesapeake Bay Program effort made it the appropriate organization to coordinate the implementation of the CBP findings. Thus:

> *"It is recommended that the Chesapeake Bay Program Management Committee be maintained and expanded to coordinate the implementation of the CBP findings and recommendations."*

The Management Committee will therefore, take the specific responsibility of coordinating a response to many of the recommendations in this report. Specific recommendations for monitoring (Chapter 2), nutrient controls (Chapter 3), toxic controls (Chapter 4) and basin actions (Chapter 5) are summarized in the text that follows. These recommendations have been develped in consultation with the Management Committee and will be considered by EPA in the context of agency policy, priorities, and planning processes.

CHAPTER 2
STATE OF THE BAY

Gail B. Mackiernan
David A. Flemer
Willa Nehlsen
Virginia K. Tippie

INTRODUCTION

This chapter is in part a summary of the CBP characterization report, *Chesapeake Bay: A Profile of Environmental Change* (Flemer et al. 1983), which describes trends in water and sediment quality, and in the living resources of Chesapeake Bay. The water quality parameters evaluated include nutrients, dissolved oxygen (DO), organic chemical compounds, and heavy metals. The living resources that were assessed include phytoplankton, submerged aquatic vegetation, benthic organisms (including shellfish), and finfish. Trends in water and sediment quality, and in living resources, including the interrelationships among these factors, were used to characterize the current state of the Bay. The CBP's characterization of Chesapeake Bay is based on a comparison of specific segments of the Bay with regard to selected nutrient and toxicant variables, and to the diversity and abundance of the living components. This characterization has been developed further in this document as a preliminary Environmental Quality Classification Scheme (EQCS). Each segment's relative status was established according to the following CBP principal scientific findings:

- Levels of nutrients (primarily nitrogen and phosphorus) are increasing in many areas of the Bay, leading to declining water quality. Nutrient enrichment is most severe in the northern and middle Bay, and upper reaches of tributaries. Only parts of the Potomac and James Rivers, and some smaller areas, currently exhibit improving water quality with regard to nutrients. Concentrations of chlorophyll *a* are also increasing in most regions where sufficient data are available for assessment.
- The amount of Bay water showing low (or no) DO in the summer is estimated to have increased 15-fold in the last 30 years. Currently, much of the water deeper than 40.0 ft (12.4 m) is anoxic from early mid-May through September in an area reaching from the Annapolis Bay Bridge to the Rappahannock River.
- Elevated levels of heavy metals and toxic organic compounds are found in Bay water and sediments. Highest concentrations occur near urban or industrialized areas, and in the upper Bay. Some of these toxicants are being bioconcentrated by plankton, shellfish, and finfish.
- Oyster spat set has declined significantly in the past 10 years, particularly in the upper Bay, western tributaries, and some Eastern Shore areas such as the Chester River. Trends in oyster harvest show a similar pattern.
- Landings of freshwater-spawning fish, such as shad, alewife, and striped bass, have decreased in recent years. Spawning success of these and other semi anadromous or anadromous species has also been fair to poor in most areas sampled. Harvests of marine-spawning fish, such as menhaden, have generally remained stable or increased.
- The recent loss of submerged aquatic vegetation appears to be most closely linked to increasing nutrient enrichment: enhanced phytoplankton growth and epiphytic fouling of plants has reduced the

light reaching SAV below critical levels. Increased turbidity from sediment loads may also be contributing to light limitation in some areas. Toxicants such as herbicides seem to be a problem primarily in local areas close to sources.

- Reduced diversity and abundance of benthic organisms can be related to toxic contamination of sediments in heavily impacted areas. Low DO in the summer is another major factor limiting benthic populations, including shellfish, in the upper and mid-Bay. Low DO can also be expected to reduce available habitat for certain finfish.
- Declining water quality — nutrient enrichment and increased levels of toxicants — is occurring in major spawning and nursery areas for anadromous fish, as well as in areas experiencing reduced oyster spat set.
- Classifying Bay regions based on water and sediment quality status indicates that the upper and mid-Bay main stem, tidal-fresh and transition reaches of major tributaries, and many smaller tributaries contain moderate to high levels of nutrients. The pattern of toxic substances is generally similar, although high contamination is also found near urban and industrialized areas in the lower Bay.

WATER AND SEDIMENT QUALITY

The quality of the Bay's water and sediments reflects both the natural physical and chemical characteristics, and the impact of human activities. Over 150 tributaries drain the 64,000 square mile (165,760 km^2) watershed. Along with fresh water, the rivers bring other materials into the Bay: nutrients, sediments, and toxic substances. Although the Bay has the ability to assimilate much of this material, most remains within the estuary (Bieri et al. 1982a). As discussed in Chapter 1, human activities have greatly contributed to the input of nutrients, sediment, and a variety of synthetic chemicals, heavy metals, and other potential toxicants into Chesapeake Bay.

The delivery of nutrients to the Bay has increased, reflected by increases in runoff containing suspended sediment and fertilizers, and sewage effluents. The amount of toxic materials — heavy metals and organic chemicals — has similarly increased as industrialization has progressed. Many of these changes occurred before the first scientific surveys of the Bay. For that reason, it is sometimes difficult to show strong recent trends, as the bulk of the change had already taken place before any data were collected. Recognizing this limitation, the trends identitifed by the CBP become even more alarming.

Nutrient Enrichment

Nutrients, such as nitrogen and phosphorus, are essential for plant growth, and thus for primary productivity in the estuary. However, in excess, these nutrients can cause problems, including blooms of undesirable algae, reduction in DO, and decreased water clarity. Based on data collected between 1950 and 1980, the CBP has determined that most areas of Chesapeake Bay are experiencing increased nutrient concentrations. Currently, the northern Bay and upper portions of the tributaries have relatively high nutrient concentrations; the mid-Bay, lower portions of the tributaries, and eastern embayments have moderate concentrations of nutrients; and the lower Bay (where sufficient data exist) appears not to be enriched (Figure 7).

When data from 1950 to 1980 are analyzed, they indicate that, in most areas, water quality is degrading; that is, nutrient levels are increasing. Total nitrogen concentrations are declining in the Patapsco, lower Potomac, and upper James Rivers; total phosphorus concentrations are declining in the upper Potomac and throughout the James. Elsewhere, trends are increasing (or stable) for most forms of nutrients, particularly in the upper and mid-Bay main stem and larger tributaries. The improvement in the Potomac is probably due primarily to phosphorus control efforts at the Blue Plains Sewage Treatment Plant and facilities in Virginia. Control efforts appear to be making a difference, but it is apparent from the effects discussed below that additional Bay-wide nutrient controls are needed.

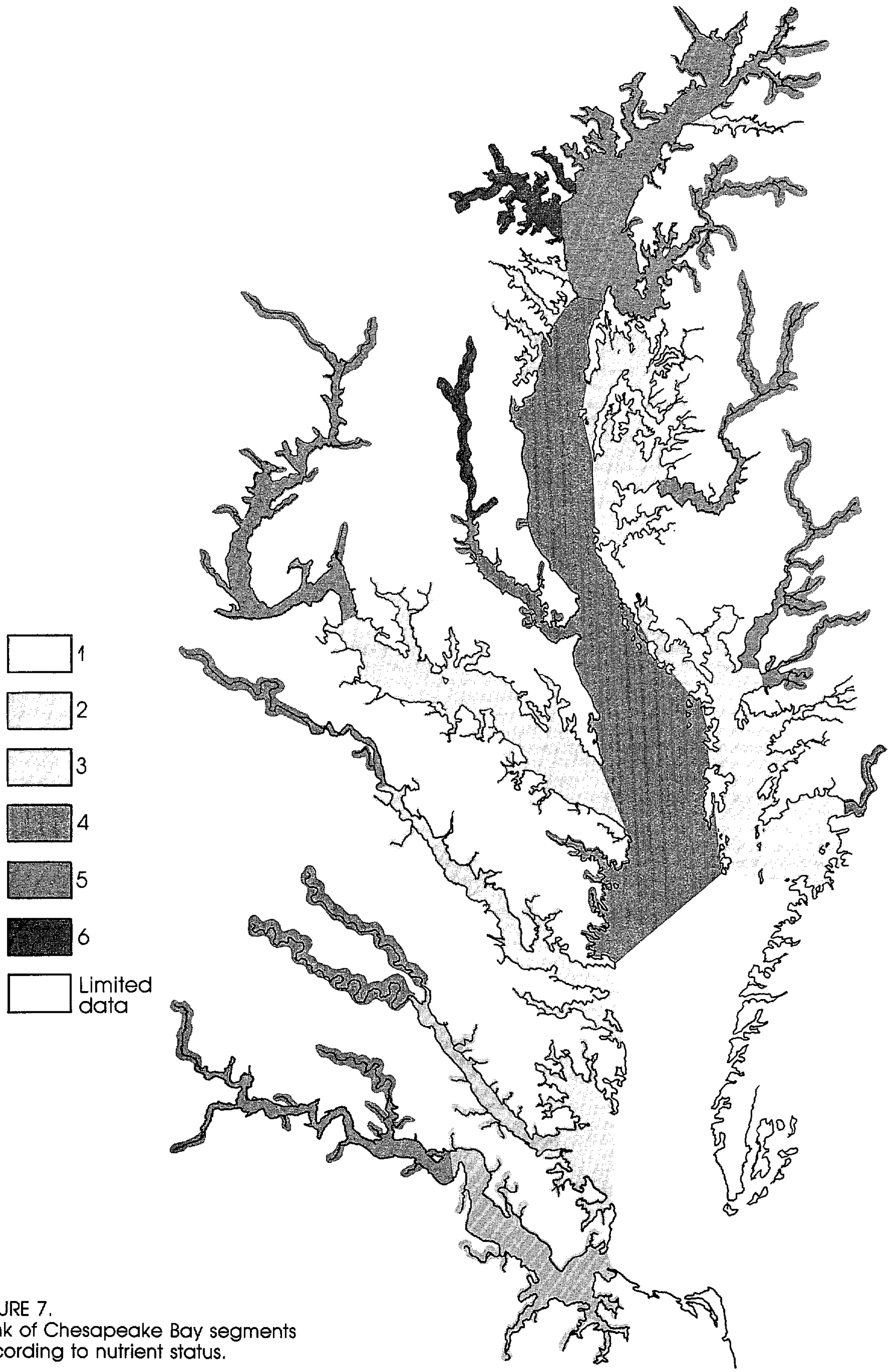


FIGURE 7.
Rank of Chesapeake Bay segments according to nutrient status.

Dissolved Oxygen Trends

To assess the management implications for resources of these nutrient trends, it is valuable to examine a related parameter, dissolved oxygen. As nutrient levels increase, phytoplankton (algal) growth is encouraged and more organic matter is produced. Decay of this organic matter consumes oxygen. If more oxygen is used than is supplied by reaeration or photosynthesis, as often occurs in deep water, the water becomes anoxic and devoid of most forms of life except anaerobic bacteria. This process occurs naturally in some Bay areas during the summer; however, high nutrient loads can increase its severity.

Both the chlorophyll *a*, an indicator of algal biomass, and the DO trends suggest that the duration and extent of anoxia have been accelerated in the Bay in recent years. There were no anoxic waters and only limited areas of low DO in the main stem of the Bay during July of 1950 (Figure 8). In July 1980, however, a very large area of the main stem of the Bay was experiencing anoxic conditions. It is estimated that the volume of water with DO concentrations equal to or less than 0.7 mg L^{-1} was 15 times greater in 1980 than in 1950. The duration of oxygen depletion has also increased. It was sporadic during the mid-1950's; occurred from mid-June to mid-August during the 1960's; and, in 1980, began during the first week in May and continued into September. This increase in the spatial and temporal extent of low DO levels reduces the area of the Bay that can support normal finfish and shellfish populations.

Organic Compounds in the Water and Sediments

Organic compounds can occur naturally; the ones of major concern are synthetically produced. The distribution of organic compounds, such as hydrocarbons, pesticides, and herbicides, in the bottom sediments and the water column of the main Bay (Figure 9), and an analysis of limited tributary data, suggest that organic compounds concentrate near sources, at river mouths, and in maximum turbidity areas. The highest concentrations of organic chemicals in the sediments were found in the Patapsco and Elizabeth Rivers, exceeding 100 parts per million (ppm) at several locations. In the main Bay, highest concentrations of organic substances occur in the northern half. Most observed sediment concentrations range from 0 to 10 ppm; however, in the upper Bay, some stations had levels of total organics over 50 ppm.

These general trends suggest that many of the problem organic compounds in the Bay tend to adsorb to suspended sediments, and then accumulate in areas dominated by fine-grained sediments. Benthic organisms located in such areas tend to accumulate the organic compounds in their tissues. Studies of Kepone, a toxic organic substance which was discharged into the James River during the 1970's, have further substantiated these conclusions. A major mechanism for accumulation of this persistant pesticide appears to be bioconcentration by plankton; this fact has implications for transfer of this and similar toxicants through the food web. Some toxic organic compounds (such as the herbicides atrazine and linuron) appear to undergo fairly rapid chemical and physical degradation once they enter the estuary. Therefore, they probably do not pose as serious a problem Bay-wide, although local impacts could be significant (Kemp et al. 1983).

Metal Contamination

Metals are chemical elements which occur naturally in the environment; however, in excess, they can become toxic to organisms. Many areas of the Bay show metal concentrations that are significantly higher than natural background levels. Figure 10 shows the degree of metal contamination in the bottom sediments of the Bay. The Contamination Index (C_I) was developed by comparing present concentrations of cadmium (Cd), copper (Cu), chromium (Cr), nickel (Ni), lead (Pb), and zinc (Zn) in the Bay's surface sediments to predicted natural levels from the weathering of rock in the Bay watershed and measured pre-colonial levels from sediment cores. If the present concentration of a given metal exceeded these natural Chesapeake Bay background levels, it was considered to be anthropogenically enriched.

The most contaminated sediments are located

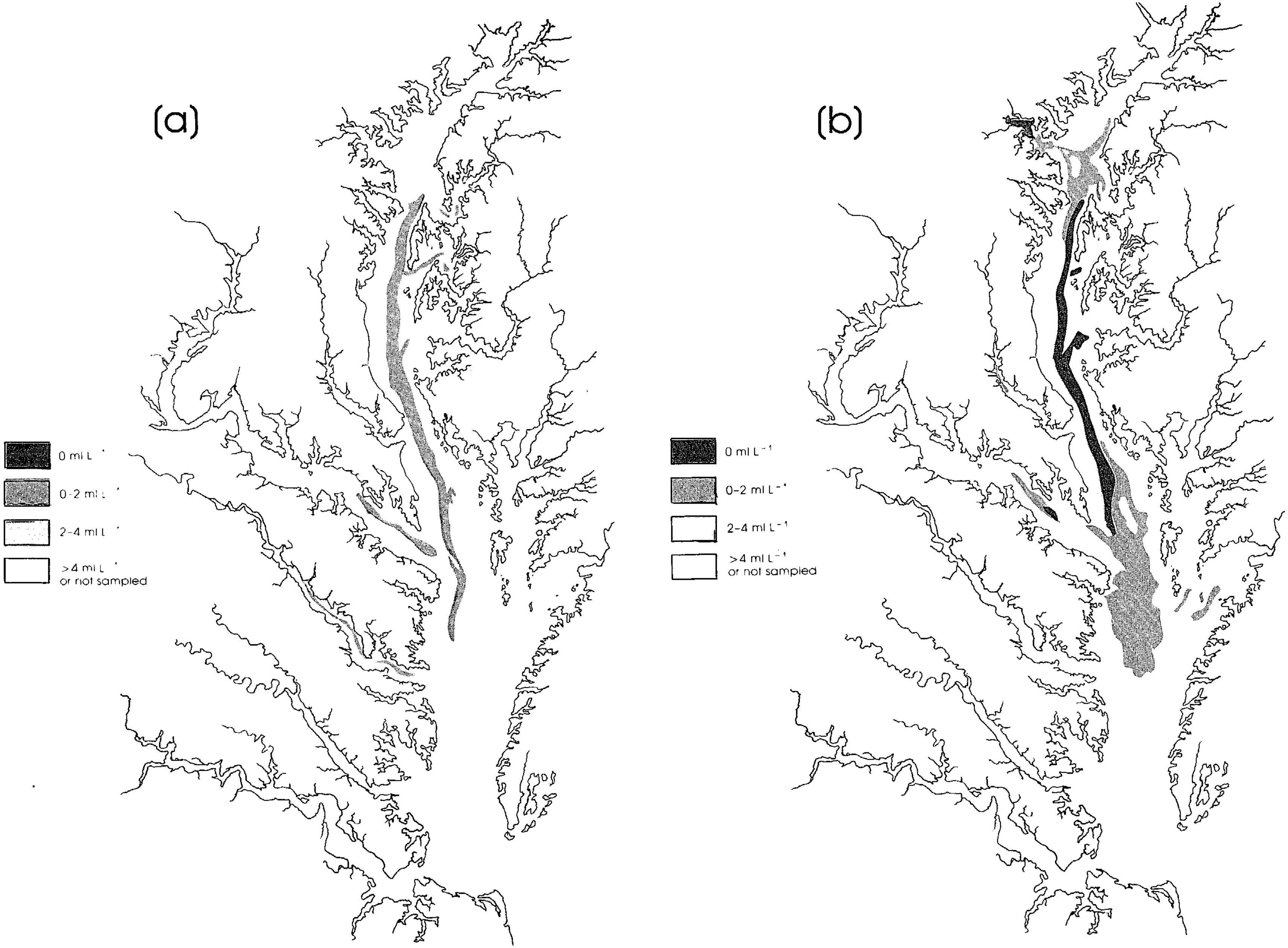


FIGURE 8. Comparison of dissolved oxygen levels in Chesapeake Bay in (a) 1950 and (b) 1980.

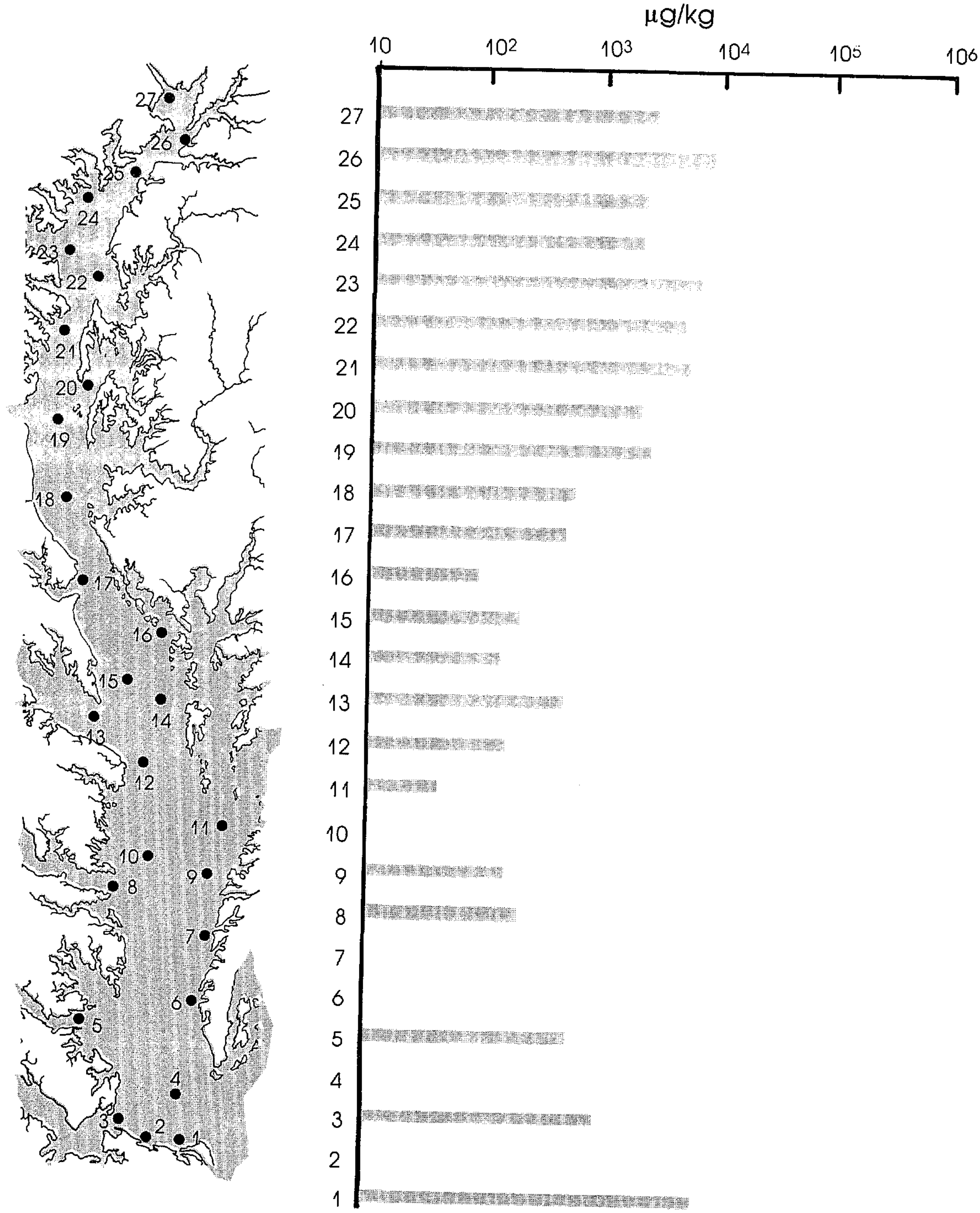


FIGURE 9. Station locations and bar graphs representing concentration sums of all recognizable peaks for organic compounds after normalizing for silt and clay content. (From Bieri et al. 1982).

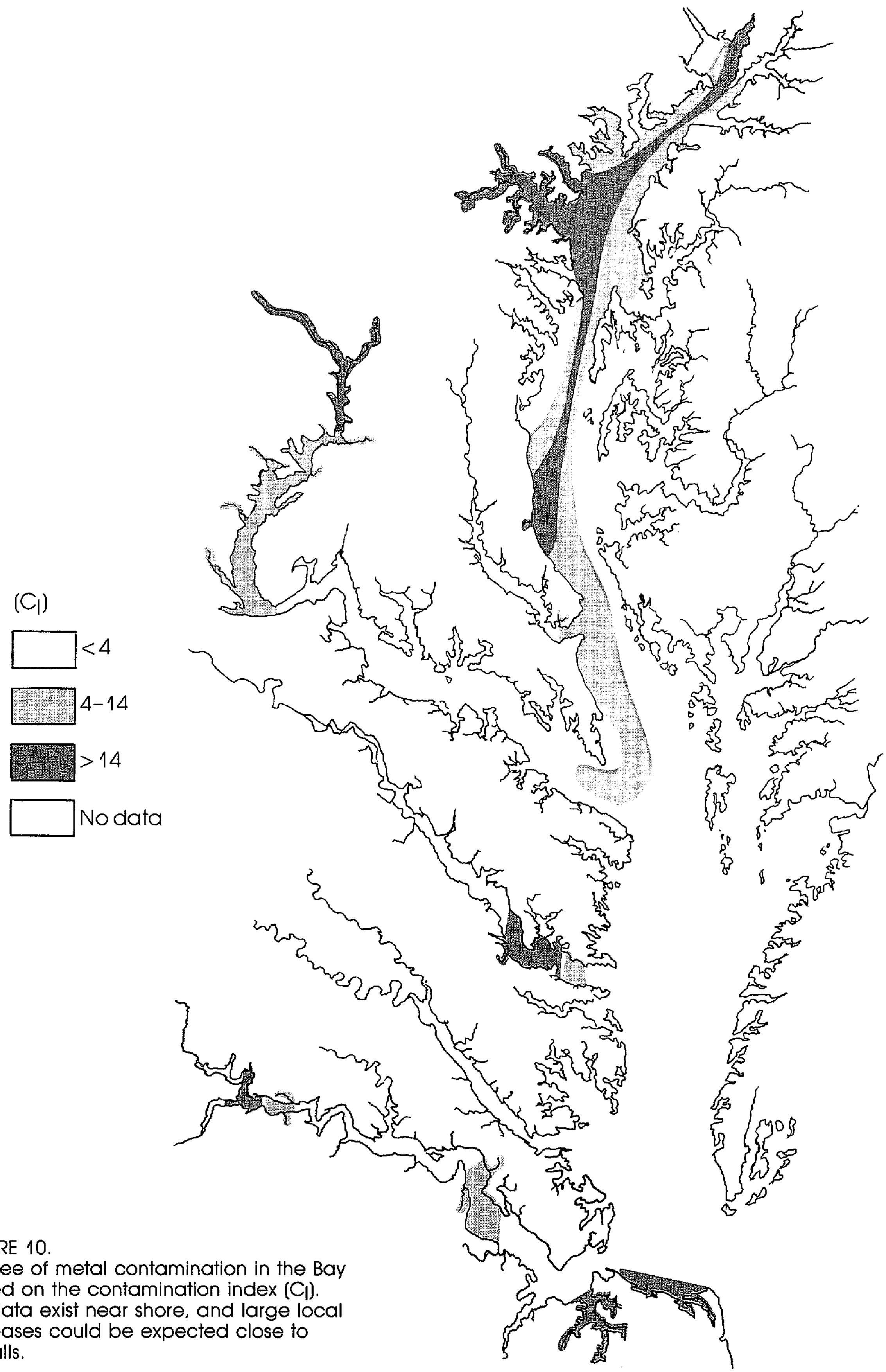


FIGURE 10.
Degree of metal contamination in the Bay based on the contamination index (C_I). No data exist near shore, and large local increases could be expected close to outfalls.

in the Patapsco and Elizabeth Rivers, both heavily industrialized tributaries. Metal concentrations up to 100 times greater than natural background levels were found in these areas. High levels of metal contamination ($C_I > 14$) were also found in the upper Potomac, upper James, small sections of the Rappahannock and York Rivers, and the upper mid-Bay. Moderate contamination occurs in the Susquehanna Flats and off the mouth of the Potomac River. These trends suggest that higher concentrations are found near industrial sources and in areas where fine sediments accumulate, such as in the deep shipping channel of the upper Bay. In general, there is little movement of metals out of the most contaminated areas, except when physically transported, as might occur through movement or disposal of contaminated dredge material.

Significant levels of particulate and dissolved metals occur in the water column. Concentrations of particulate Cd, Cr, Cu, Ni, and Zn are greatest in the upper Bay and near the turbidity maximum; actual values vary greatly with the tidal cycle and the amount of suspended sediment. High dissolved values, some exceeding EPA water quality criteria, have been observed, particularly for Cd, Cu, Ni, and Zn. These are most frequent in areas near industrial sources, and near upper reaches of the main Bay and western shore tributaries.

To better assess the potential biological impact of these observed high metal concentrations a Toxicity Index was developed. The index utilizes water column toxicity information in conjunction with the contamination index. It essentially weights the contamination factors for the six metals by their relative toxicities from EPA bioassay information. The analysis is described in detail in Appendix A.

LIVING RESOURCES

Major changes in Bay resources can be identified, including shifts in the relative abundance of species or the types of biological communities found in various areas. The CBP focussed on individual living resource groups (e.g., submerged aquatic vegetation, finfish), describing the documented trends, and comparing present conditions with the potential status.

Phytoplankton in Two Well-Documented Areas

The upper Bay (above the Annapolis Bay Bridge) and upper Potomac River (tidal-fresh reach) have shown increased dominance by a single species of phytoplankton and increased biomass. Such changes are considered to be indicative of eutrophication and, in fact, have paralleled changes in nutrient enrichment in these areas. These two areas are those for which the best data are available; similar changes may be occurring elsewhere, or could be expected to occur if nutrient enrichment continues.

The Potomac River's tidal-fresh reach was characterized in the 1960's and 1970's by massive blue-green algal blooms, indicators of excess nutrients. Increased phosphorus control in the watershed in recent years appears to have been beneficial. In 1979, algal populations were diverse, with bluegreens composing only 25 percent of the total. Total cell counts for 1979 and 1980 were also considerably lower than in the past.

Trends in nutrient enrichment of the upper Bay tributaries have closely paralleled those of the upper Potomac during the 1960's. Massive algal blooms have been frequently reported in the upper main Bay (above the Annapolis Bay Bridge) in recent years, with elevated chlorophyll levels caused by increasing numbers of blue-green algae. By comparison, observers of this area from 1965 to 1966 reported only an occasional occurrence of blue-green algae. It is estimated that cell numbers in this area have increased approximately 250-fold in the last 30 years.

Decline of Submerged Aquatic Vegetation

Since the late 1960's, a dramatic, Bay-wide decline has occurred in the distribution and abundance of submerged aquatic vegetation. Loss has moved progressively down-estuary. Submerged aquatic vegetation now occupies a significantly more restricted habitat than at any time during the past, according to CBP studies (Brush and Davis 1982, Orth et al. 1983). The role of SAV in the ecosystem has been reduced; its ability to recover from this current status is uncertain. Changes in the distribution and abundance of Bay waterfowl, which feed on SAV, have paralleled these vegetation changes.

Annual surveys of SAV conducted by the Maryland Department of Natural Resources and the U.S. Fish and Wildlife Service Migratory Bird and Habitat Research Laboratory have shown that the number of vegetated stations in Maryland dropped from 28.5 percent in 1971 to 4.5 percent in 1982. Species diversity also declined significantly. Comparison of the habitat filled in 1978 with the expected habitat (Figure 11) shows that the areas of greatest loss (upper Bay, western shore tributaries, and upper Eastern Shore tributaries) correspond with areas of greatest nutrient enrichment.

Changes in Benthic Invertebrates

Benthic animals are considered good indicators of pollution because most are relatively immobile and cannot readily escape unfavorable conditions. Changes in benthic biomass, community structure, and diversity can indicate a variety of stressful conditions. Where sufficient data exist, comparisons were made of current conditions, particularly in the main Bay and in certain tributaries. Trends in diversity seem to be related to physical aspects of the environment (i.e., salinity and sediment type). Highest diversity occurs in the lower Bay. In some polluted tributaries, especially the Patapsco and Elizabeth Rivers, significant declines in species diversity and enhancement of pollution-tolerant annelids, relative to molluscs or crustacea, are observed. These changes are characteristic of stressed communities.

Trends in Commercial Shellfish

The density of annual oyster spat set is a measure of the success of oyster reproduction and recruitment, and is a reasonable predictor of oyster harvest. Comparison of the average oyster spat set for the past ten years with the previous ten to thirty years shows significant declines in the upper main Chesapeake Bay and the Chester, James, Nanticoke, Patuxent, Pocomoke, Potomac, Rappahannock, and Wicomico Rivers, Eastern Bay, Fishing Bay, and Pocomoke Sound. In general, 1980 was a good year for spat fall, particularly in Eastern Shore tributaries; this fact is related to high salinities during the spawning period. Spat set in the upper Chesapeake and its western tributaries was generally light even in this good year. The trend toward light spat set in upstream reaches has been documented in detail for the Potomac River; while spat set in the lower Potomac has continued to vary in response to salinity, set in the middle and upper Potomac has been suppressed since the late 1960's.

The harvest of oysters for Chesapeake Bay has declined since 1880, but has remained relatively stable since 1960 to 1965 (Figure 12). This is in part due to management practices, such as shell and seed planting. The harvest for the western shore has decreased significantly during the period from 1962 to 1980; the harvest for the Eastern Shore increased significantly. This is consistent with the Eastern Shore's consistently better spat set. For the Chesapeake Bay as a whole, declines in oyster harvest have been somewhat offset by an increased harvest of blue crabs. As a result, the Bay-wide landings of shellfish have not changed greatly from 1962 to 1970 and 1970 to 1980. However, overall shellfish harvest for the western shore has decreased significantly during this period.

Shifts in Finfish Harvest

The CBP examined trends in harvest and other indicators (young-of- the-year surveys) for the major commercial species historically landed in Chesapeake Bay. These include freshwater spawners such as striped bass, white perch, yellow perch, catfish, shad, and alewife; marine spawners such as menhaden, croaker, spot, bluefish, and weakfish; and three estuarine forage fish: Bay anchovy, mummichog, and Atlantic silverside.

The Maryland juvenile index provides consistent data since 1958 for the upper Bay, Nanticoke, Choptank, and Potomac Rivers. Juvenile indices of most anadromous and freshwater species show declines in recent years, with the exception of the Potomac River where white perch and yellow perch have increased. Information for Virginia waters is not directly comparable, because of dif-

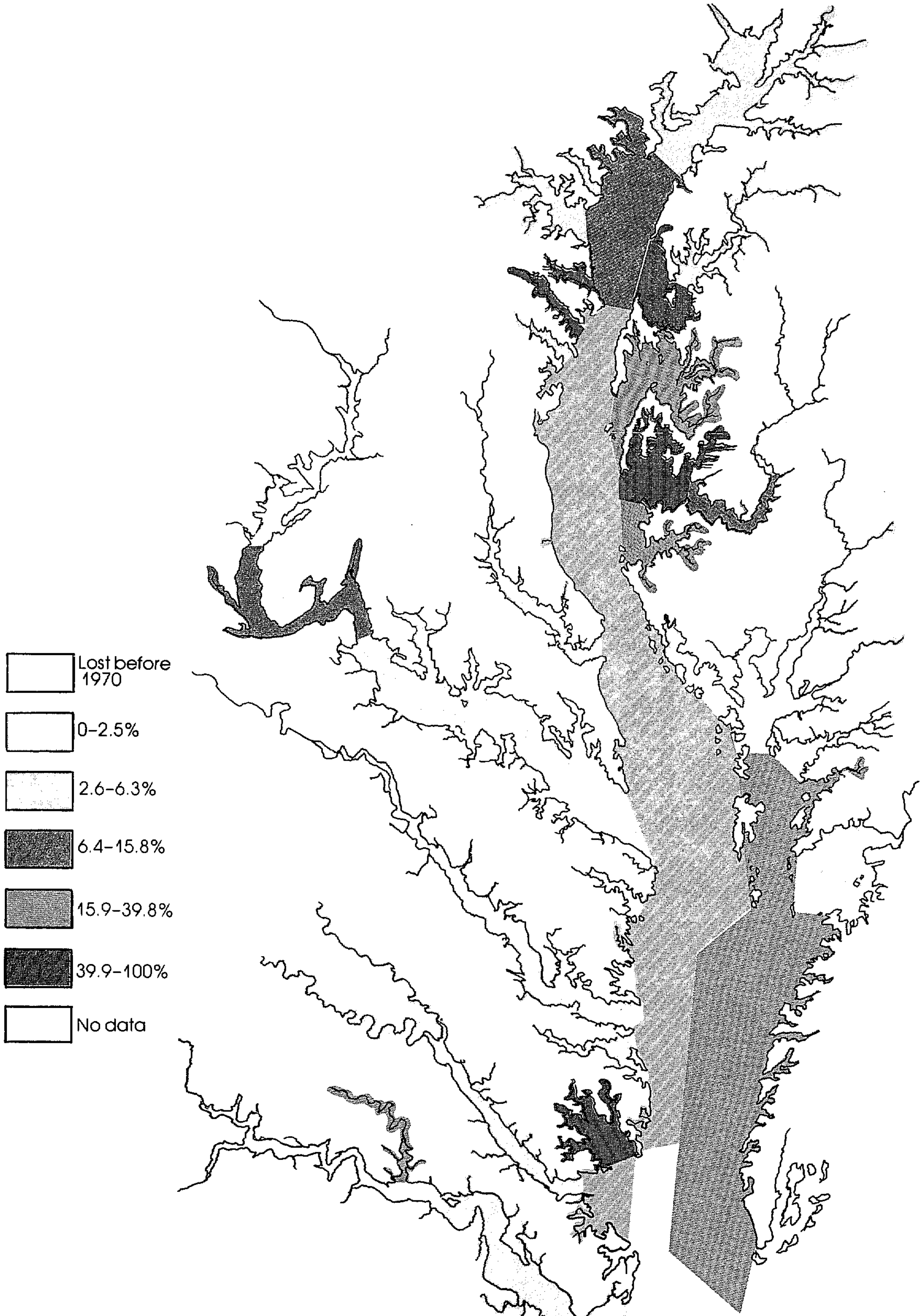


FIGURE 11.
Percent of expected submerged aquatic vegetation habitat occupied in 1978 for aggregated sampling areas.

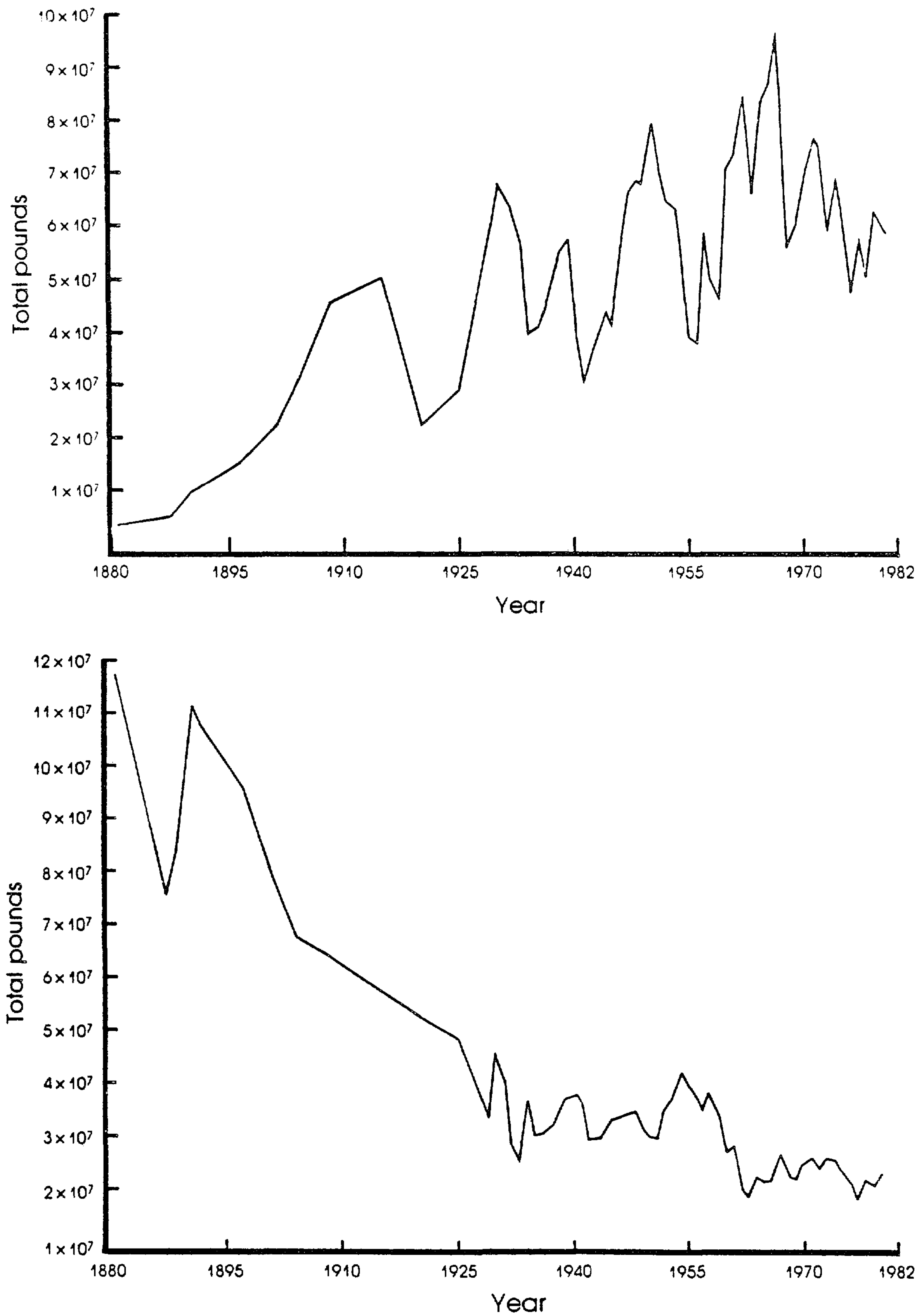


FIGURE 12. Historical landings of blue crabs, above, and historical pounds of shucked oyster meat, below, for Chesapeake Bay, 1880 to 1981.

ferences in methodology and target species (sciaenids). However, trends in marine-spawning fish were similar in both data sets. Marine spawners show general overall increases in all basins, although some species show declines in the most recent surveys. In Maryland, mummichog shows an increasing pattern similar to that of marine spawners, while the Bay anchovy and Atlantic silverside show declines. However, the anchovy has been increasing in Virginia tributaries surveyed during the same period. This may reflect differences in water quality or habitat (particularly the availability of SAV which is used as shelter by this species) between the two states.

Harvests of anadromous and freshwater species have declined in Chesapeake Bay (Figure 13). The downward trend in American shad has been continuous since 1900, while declines in river herring and striped bass landings have been more recent. Landings of alewife, shad, and yellow perch are now at unprecedented low levels. Harvests of marine spawners, on the other hand, have increased in most areas. Menhaden landings have risen steadily since 1955; the increase in bluefish landings has been more recent. The increased yield of marine spawners and decreased yield of freshwater spawners represent a major shift in the proportion of the finfishery accounted for by each group: during 1881 to 1890, marine spawners accounted for about 75 percent of the fishery; during 1971 to 1980, they accounted for 96 percent. Similarly, an assessment of individual basins for the two periods from 1962 to 1970 and from 1971 to 1980, shows significant declines in freshwater spawners while landings of marine spawners in most basins increased significantly.

The large relative increase in marine spawners and actual decline in freshwater spawners illustrate a gradual reduction in the diversity of Chesapeake Bay fisheries. Diversity is not used here in the sense of number of species alone, but in the sense of number of species and the relative evenness of the contribution of these species toward the total harvest. Such a loss of diversity can be viewed as potentially undesirable because harvests are more vulnerable to year-to-year fluctuations in population size of major commercial and recreational species. There is less resiliency (both economical and ecological) in single-species fisheries. The economic impacts of the failure of the California sardine, the Peruvian anchoveta, or the Delaware Bay menhaden fisheries are prime examples. Because freshwater-spawning fish and estuarine-spawning shellfish spend all or most of their sensitive life stages in the Bay, their well-being may be considered as an indication of the health of the estuary. Thus, the simultaneous declines in most of these species is reason for concern.

RELATIONSHIPS BETWEEN WATER AND SEDIMENT QUALITY, AND LIVING RESOURCES

Organisms respond directly to changes in their habitat, food supply, competitors, or predators. Major factors which affect the Bay's living resources include natural variables such as freshwater inflow, temperature, or other organisms, as well as human-induced stress such as nutrient and toxicant enrichment. Distinguishing between effects triggered by anthropogenic, as opposed to natural, causes is often difficult due to the natural variability of organism distribution and abundance. Although the CBP was unable to pinpoint exact causes for specific resource changes, the similarity in patterns and the overlap in the distribution of water or sediment quality and living resource trends in the Bay should be considered as more than a striking coincidence.

Submerged Aquatic Vegetation

The CBP supported a major research effort to identify the causes of the recent SAV decline. Investigators focussed on two main hypotheses: 1) the use of toxic agricultural materials, particularly herbicides, has increased in recent years. Runoff of these substances from agricultural areas may be reducing or eliminating SAV and 2) the reduction in the light available to the plants because of an increase in water column turbidity or increased growth of epiphytes (or both) may be causing the decline. Nutrient enrichment was considered a major factor affecting both turbidity and epiphyte growth. Research sponsored by the CBP

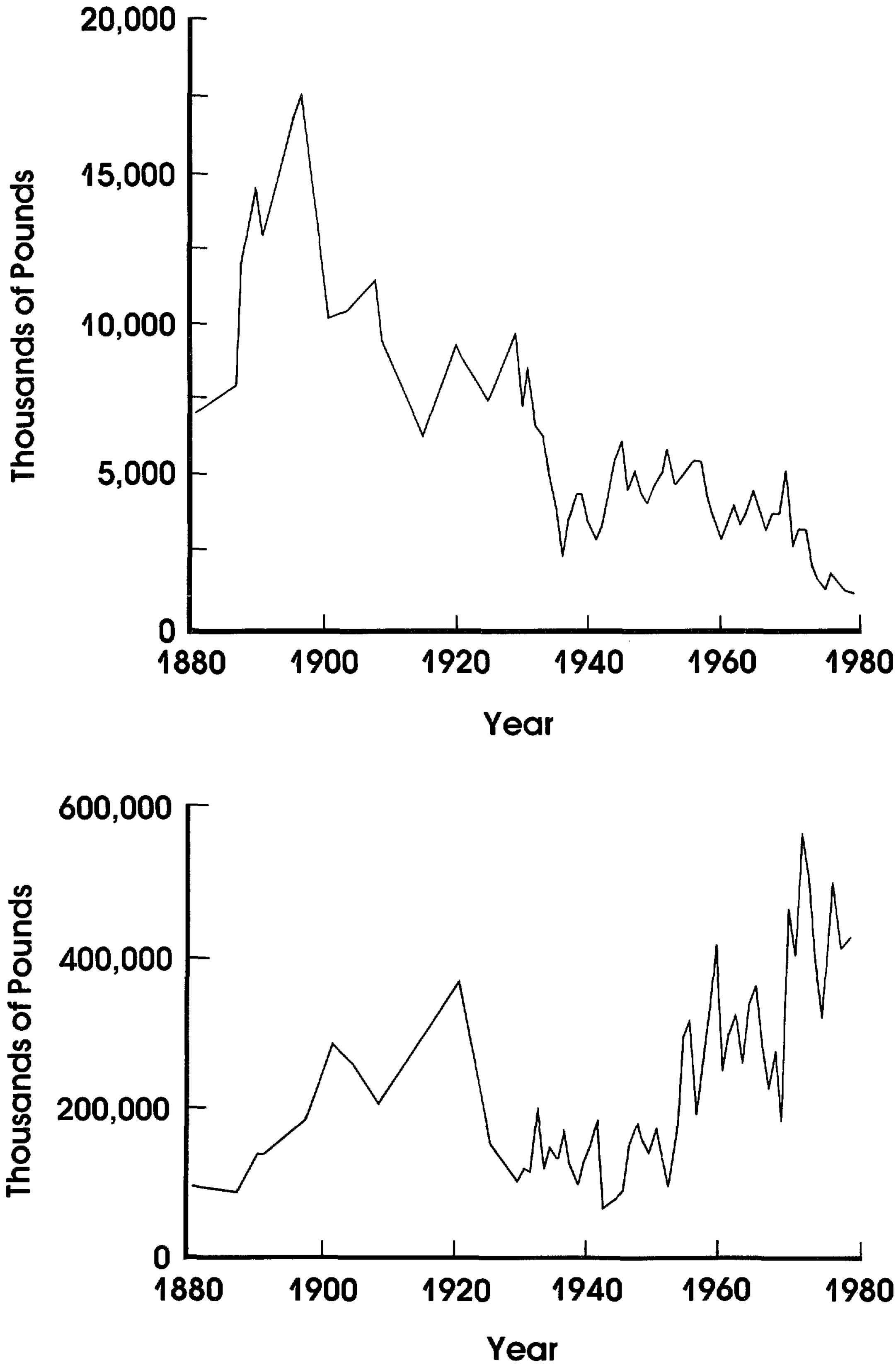


FIGURE 13. Landings of shad, above, and landings of menhaden, below, 1880 to 1981.

implicated light limitation as the most important factor regulating the Bay-wide SAV loss. Herbicides could be important locally, or close to sources (although areas affected may represent significant habitat).

The CBP's research conclusions are supported by field observations. Comparison of a map of current SAV status to Bay nutrient conditions reveals that vegetation now occurs primarily in areas that are not enriched or only moderately enriched. Statistical analysis (rank correlation) shows a significant correlation between declines in SAV and increased nutrient concentrations in many areas. The major nutrient which appears to correlate with SAV abundance is nitrogen (Figure 14). A negative response to maximum chlorophyll *a* values, an analog of both nutrient loading and turbidity, was also found. These analyses support experimental results linking the recent loss of Bay vegetation to increases in nutrient loadings and ultimately to light stress caused by increasing phytoplankton biomass and epiphytic growth.

Benthic Organisms

Major anthropogenic factors which could adversely affect benthic organisms in Chesapeake Bay are toxic materials, either in bed sediments or in the overlying water column, and nutrients. Toxicants can produce either acute (elimination of susceptible species) or sublethal (accumulation in body tissues) effects. Nutrient enrichment can alter the Bay's benthic community structure by stimulating phytoplankton production. Excessive production of organic material has been linked to the increased duration and extent of low DO in Chesapeake Bay, decreasing available benthic habitat.

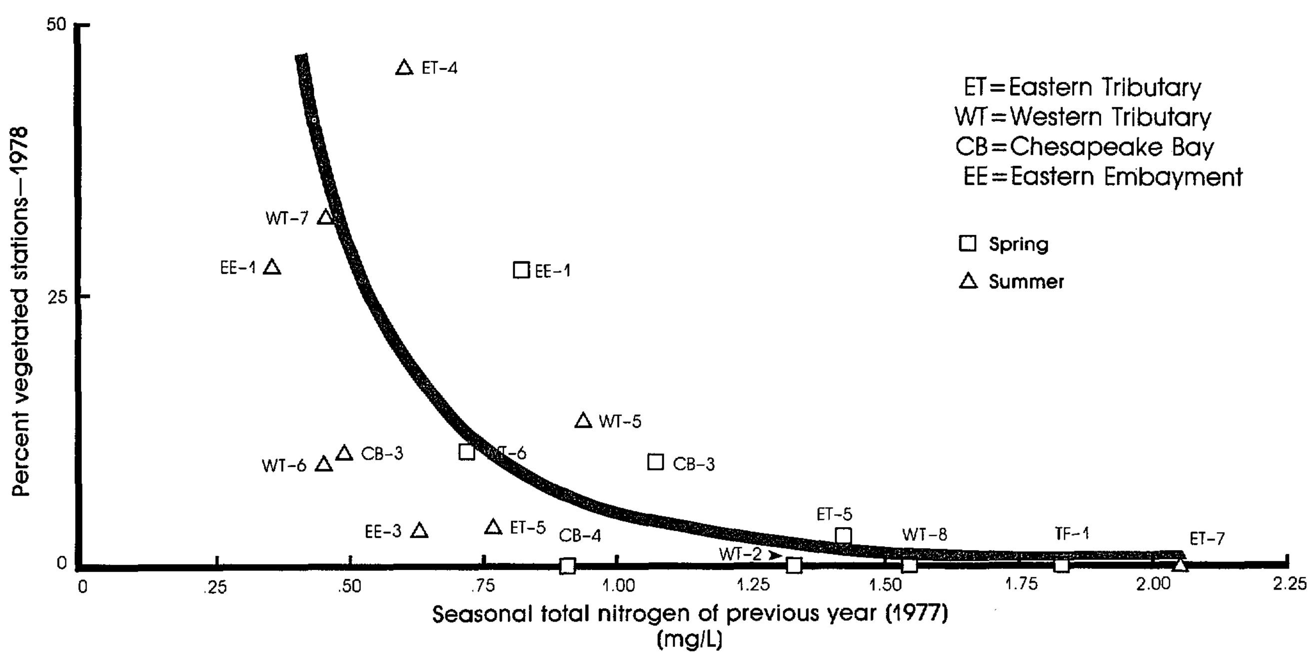


FIGURE 14. Percent vegetation compared to seasonal total nitrogen of the previous year.

Episodes of low DO have been cited as the major factor limiting benthic distribution in deeper waters of the upper- and mid-main Bay (e.g., Mountford et al. 1977). The documented increase in the extent of anoxic water in the mid-Bay can be related to the complete loss of benthic habitat or replacement with ephemeral assemblages. This may have secondary impacts on bottom-feeding predators such as crabs or fish, which can be stressed by food limitation and reduction of habitat. Recent changes in the mid-Bay blue crab fishery, especially the necessity to set pots in shallower water, may be a direct result of these anoxic episodes. Changes in benthic diversity, abundance, and community structure could also be related to toxic contamination of sediments in areas recognized as "impacted" (e.g., the Patapsco and the Elizabeth Rivers) (Figure 15). These areas are characterized by low benthic diversity and abundance, and dominance by pollution-tolerant annelids, in comparison to nonpolluted reference areas (e.g., Rhode River). Elsewhere, other factors, primarily physical or biological, are apparently controlling benthic distributions. However, bioaccumulation of certain metals in the tissues of shellfish could be correlated with enrichment of those metals in the bed sediments, even in the main Bay.

Oysters

Oysters (and other shellfish) are benthic organisms but, because of their commercial importance, oysters are treated separately here. Factors affecting benthic communities in general (i.e., low DO water, toxicants in the sediments or water column) will impact oysters as well. In addition, oysters are potentially vulnerable to shifts in phytoplankton species brought about by nutrient enrichment. Phytoplankton species usable as food can be replaced by undesirable or inedible forms. Comparison of EPA water quality criteria to measured and estimated concentrations of toxicants in the water column revealed a number of violations in the areas of oyster habitat; these were chiefly for heavy metals. Although the duration or extent of high toxicant concentrations is unknown, the observations may be significant. Some populations, stressed by a variety of factors, may be more vulnerable than others to diseases such as MSX or "Dermo." The impact of these protozoan parasites has increased in recent years because of higher salinities resulting from drought conditions. In addition, oyster habitat may be adversely impacted by the increased rate of sedimentation in Chesapeake Bay. Beds may be buried, or spat set impeded, by the deposition of sediment. Loss of once productive oyster bars in the upper Bay is probably due in part to sedimentation over the past 100 years.

Fishery Landings and the Juvenile Index

Although total fishery landings have increased since 1920, the distribution of landings among species has changed significantly. Anadromous and other freshwater-spawning fish such as shad and striped bass have declined greatly; marine spawners have remained stable or increased. The finfish juvenile index, a measure of recruitment success, reflects these changes as well.

Several causes of this change in distribution have been suggested: 1) nutrient enrichment may lead to food web shifts as suggested by changes in phytoplankton species, primarily affecting early life stages; 2) the levels of toxicants, particularly heavy metals, pesticides, and chlorine, in major spawning areas are elevated and, in fact, have exceeded EPA criteria in some spawning or nursery areas used by anadromous fish; 3) habitat is being lost because of an increased area of low DO water; 4) adverse climatic conditions (freshwater inflow, temperature, etc.) have reduced the spawning success of anadromous species; 5) overfishing is affecting stock sizes; 6) construction of dams represents physical obstructions that impede the spawning success of shad and other anadromous species; and 7) modifications of upstream spawning and nursery habitat, such as wetlands destruction and stream channelization, further stresses the fisheries stock. It is possible that all of these factors are working in unison.

AN ENVIRONMENTAL QUALITY CLASSIFICATION SCHEME FOR CHESAPEAKE BAY

A framework for classifying the quality of Bay

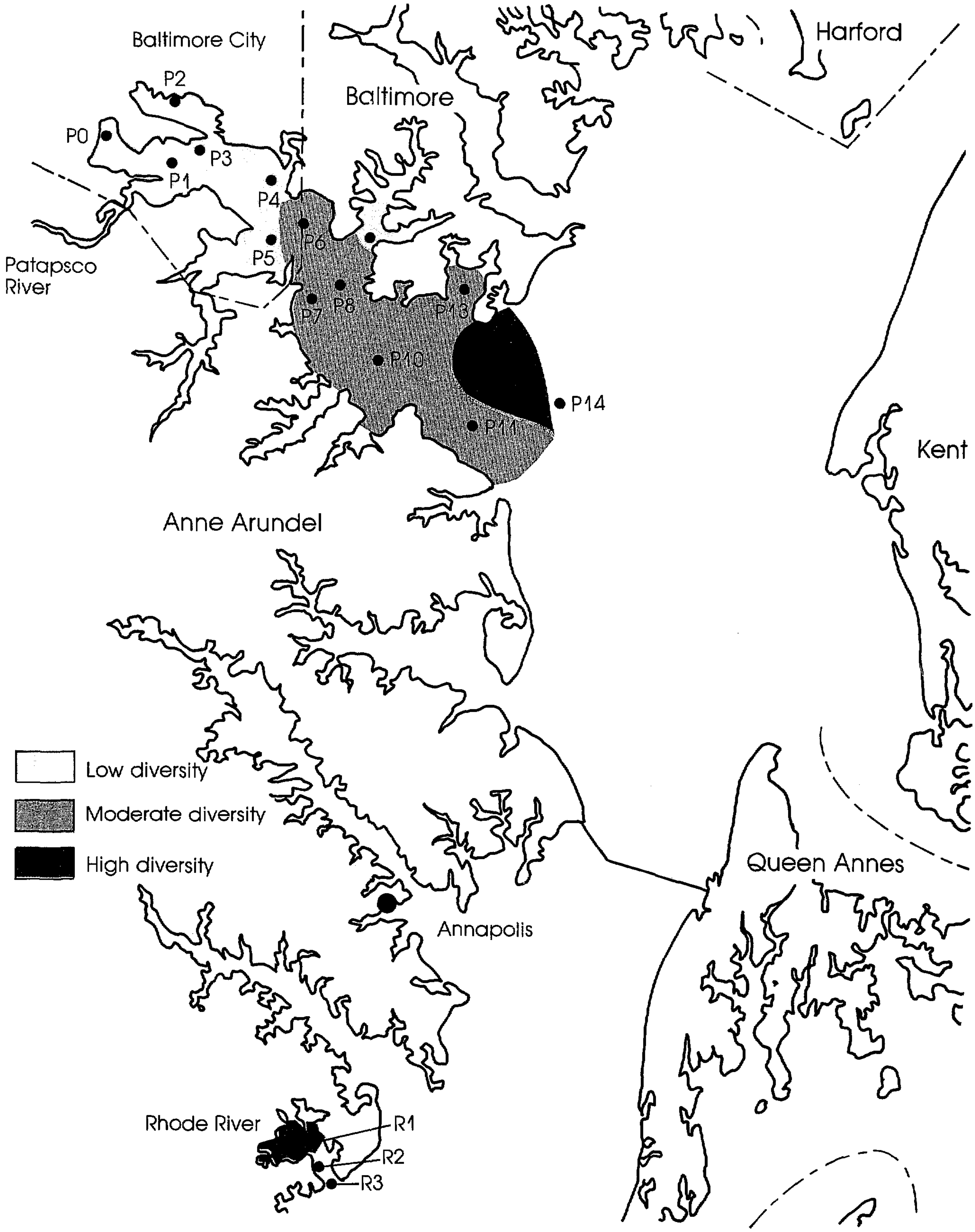


FIGURE 15. Comparison of benthic community diversity in the Patapsco and Rhode Rivers, Maryland.

waters has been developed based on the observed relationships discussed above between water quality and living resources (Appendix A). Theoretically, if these relationships were well understood, such an environmental quality classification would allow managers to tailor water quality controls to the desired resource use of the waters. However, the ability to relate pollutant loads to water column concentrations is still imperfect. For this reason, the present classification system will undoubtedly be refined in the future as scientific understanding increases.

It must also be emphasized that the attainment of a certain water quality criterion alone does not necessarily ensure that environmental or resource objectives will be met. While inferior water quality will not support desired resources, other environmental factors may prevent resource recovery even if the water quality is improved. For this reason, this framework is probably most reliably applied to situations in which the objective is to maintain existing resources, rather than to improve degraded areas. Also, data are sparse on the length of time required for a system to recover once resources have been lost.

With these caveats, the present classification system was developed based on nutrient and toxicant concentrations, and related to resources as described in this chapter and in the Chesapeake Bay Program's characterization report (Flemer et al. 1983). Nutrient criteria were based on concentrations of total nitrogen (TN) and total phosphorus (TP), N:P ratios, and on the contribution of nutrient enrichment to low DO in Chesapeake Bay. Toxicant criteria were based on the enrichment of trace metals in bottom sediments (the Contamination Index) and their relative toxicities (the Toxicity Index). The resource use related to each criterion level was based on relationships developed in the characterization report: nutrients to submerged aquatic vegetation; nutrients to DO and, thus, to fisheries; and sediment contamination to benthic communities.

Assessment of N:P ratios and TN or TP concentrations indicates that regions where resource quality is currently moderate to good have lower concentrations of ambient nutrients and N:P ratios between 10:1 and 20:1. Regions characterized by little or no SAV (phytoplankton-dominated systems) or massive algal blooms had high nutrient concentrations and significant variations in the N:P ratios (Figure 16). Moving a system from one class to another could involve either a reduction of the limiting nutrient (N or P) or a reduction of the non-limiting nutrient to a level such that it becomes limiting. For example, removal of P from a system characterized by massive algal blooms could force it to become the a more desirable phytoplankton-dominated system with a higher N:P ratio. This, in fact, occurred in the Potomac after removal of phosphorus at the Blue Plains Sewage Treatment Plant. Because of recycling during the growing season, it is estimated that only a relatively small reduction in nutrient loads could result in significant reductions in phytoplankton production.

Metal enrichment and the toxicity of bottom sediments in general follow a pattern similar to that of nutrient enrichment. Sediments of the upper- and mid-Bay and western shore tributaries have the greatest enrichment of toxic metals, particularly Cd and Cu. Areas with the highest Toxicity Index ($T_I > 10$) were found to have reduced benthic diversity as well as altered community structure in favor of pollution-tolerant forms, whereas areas with a low Toxicity Index ($T_I < 1$) had high diversity.

Comparing levels of nutrients, DO, and sediment toxicity to the observed resources enables the requirements needed to sustain different resources to be defined. Table 1 provides the best estimate at this time of the relationship between these requirements or criteria and environmental quality objectives. The criteria presented are only preliminary "target levels," to be refined as additional data are obtained on living resources and water quality relationships. The CBP anticipates that both accuracy and precision can be improved dramatically in the near future.

Figure 17 classifies the different areas of the Bay using the Environmental Quality Classification Scheme. Each area is classified based on the mean of the TN, TP, and T_I classes (or ranks). The map indicates that the upper Bay and upper reaches of several major the tributaries are Class C or D (poor or fair-to-poor transition); the mid-Bay, middle and some lower reaches of tributaries are Class B (fair); while the lower Bay, eastern embayments, and lower reaches of major western

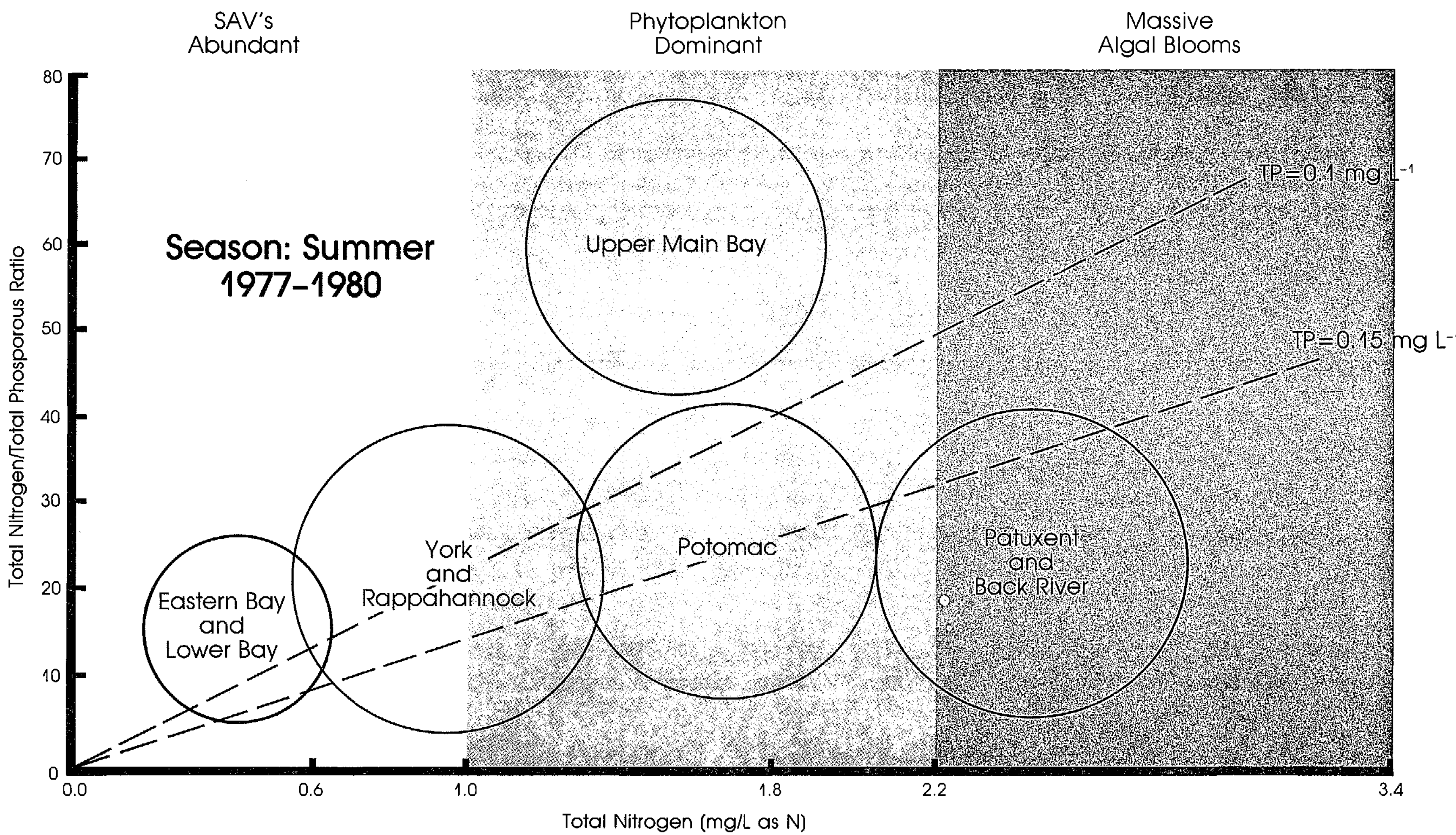


FIGURE 16. N/P Ratios for the tidal-fresh segments of Chesapeake Bay and tributaries.

TABLE 1.
A FRAMEWORK FOR THE CHESAPEAKE BAY ENVIRONMENTAL QUALITY CLASSIFICATION SCHEME

Class	Quality	Objectives	Quality	T_I	T_N	T_P
A	Healthy	supports maximum diversity of benthic resources, SAV, and fisheries	Very low enrichment	1	<0.6	<0.08
B	Fair	moderate resource diversity reduction of SAV, chlorophyll occasionally high	moderate enrichment	1–10	0.6–1.0	0.08–0.14
C*	Fair to Poor	a significant reduction in resource diversity, loss of SAV, chlorophyll often high, occasional red tide or blue-green algal blooms	high enrichment	11–20	1.1–1.8	0.15–0.20
D	Poor	limited pollution-tolerant resources, massive red tides or blue-green algal blooms	significant enrichment	>20	>1.8	>0.20

Note: T_I indicates Toxicity Index;
T_N indicates Total Nitrogen in mg L^{-1};
T_P indicates Total Phosphorus in mg L^{-1}.

*Class C represents a transitional state on a continuum between classes B and D.

shore tributaries are Class A (good).

In general, the resource quality of these areas fall into similar classes. Lack of SAV in some areas where present conditions are Class A may in part reflect the impact of past conditions as well as problems of recolonization. However, the agreement shown with the initial effort indicates that further refinement and development of the EQCS would be useful for Bay managers. It further suggests that, to improve the quality of resources in the Bay, water and sediment pollution must be reduced. Achieving this goal will require the concerted effort of both government and the private sector.

SUMMARY

To further develop the Environmental Quality Classification Scheme, as well as to determine the effectiveness of any control programs, a comprehensive monitoring program is necessary. Such a framework is presented in this report (Appendix F). Monitoring should not only be directed to ambient water quality, but should gather data in such a manner that relationships can be made between environmental parameters and Bay resources. This will serve to strengthen the classification system, and to give managers better direction in instituting control programs.

The linking of monitoring and research through systems-level field experiments or through a series of microcosm studies of ecosystem response to perturbations can give additional insight into resource and water quality relationships. Support of a program such as the MERL mesocosms (Marine Ecosystem Research Laboratory at Narragansett, RI) could be useful and informative for

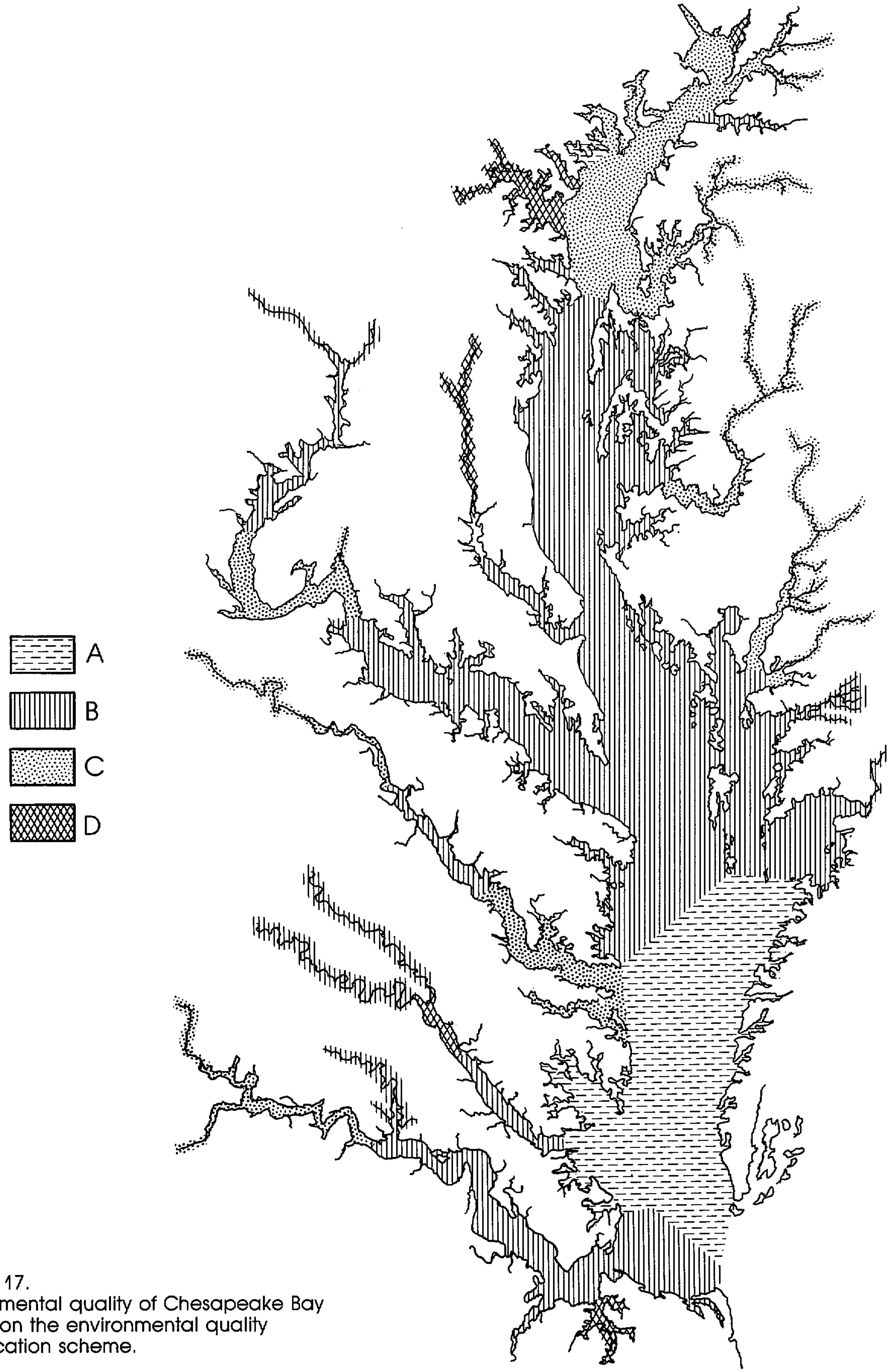


FIGURE 17.
Environmental quality of Chesapeake Bay based on the environmental quality classification scheme.

scientists and managers alike. In addition, such monitoring and research information improves the understanding of Bay processes, and will provide important inputs to future water quality modeling efforts.

Water quality monitoring and research efforts can give information on factors affecting Chesapeake Bay for which very incomplete information is now available. These factors include: the magnitude of inputs, as well as the source and effects, of atmospheric deposition of nutrients and toxicants from dryfall as well as from precipitation; the impact of toxic metals from anti-fouling paints and acid mine drainage; runoff from industrial sites and other facilities; the flux of nutrients and toxicants from bottom sediments; and the magnitude of inputs of pesticides from agricultural sources.

Resource monitoring and research programs can help us identify, preserve, and restore critical resource habitats. The importance of habitat preservation for many resource species, particularly freshwater-spawning fish, is well documented (Flemer et al. 1983). Unfortunately, we do not always recognize the indirect impacts of human activity on aquatic habitats nor do we fully understand how best to restore critical habitats.

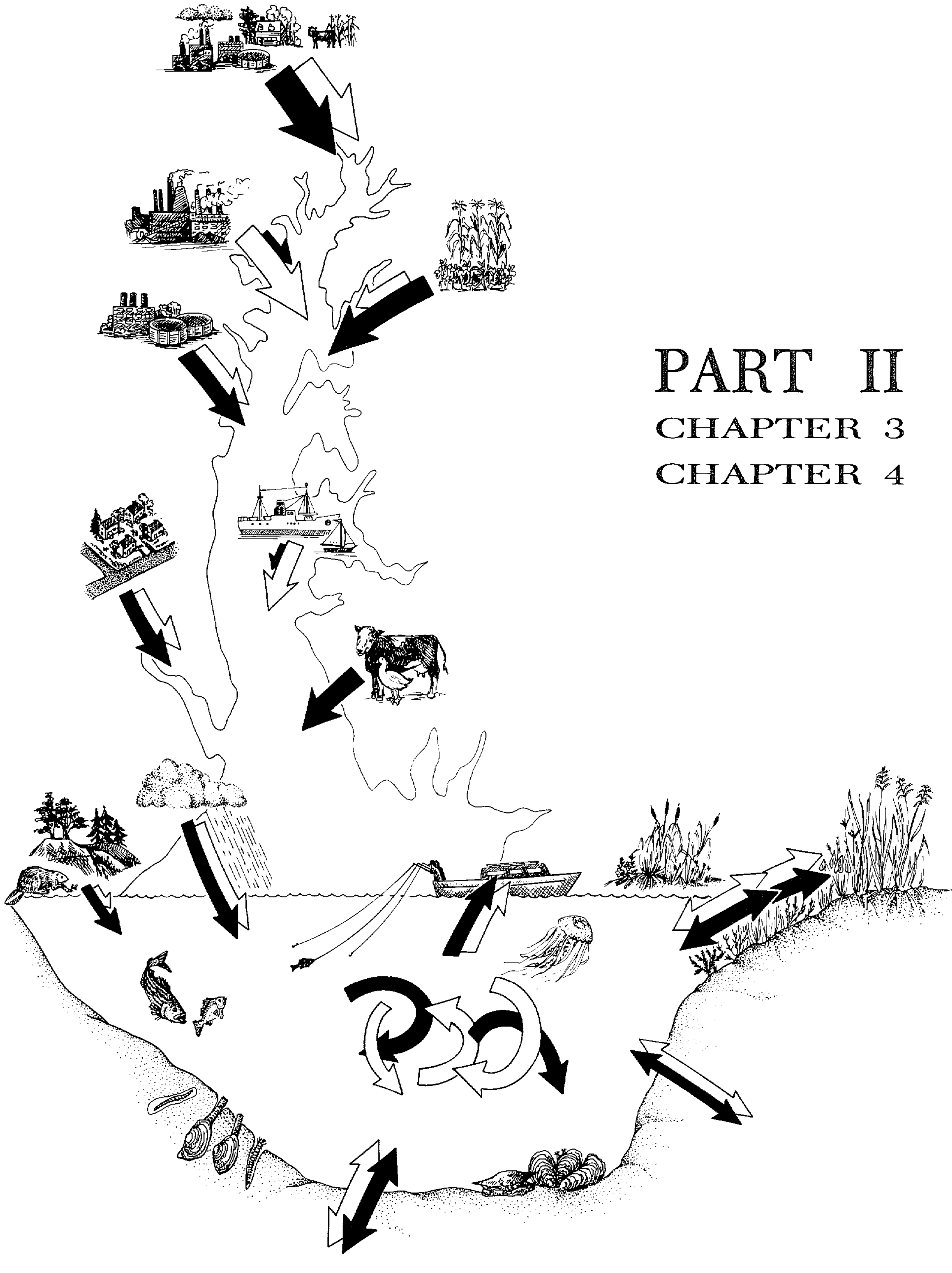
MONITORING AND RESEARCH RECOMMENDATION

The states and the Federal government, through the Management Committee, should implement a coordinated Bay-wide monitoring and research program by July 1, 1984.

This program should include the following components:

- A baseline (descriptive and analytical) monitoring program, as described in Appendix F.
- A coordinated, interpretive monitoring and research program to improve our understanding of relationships between water and sediment quality, and living resources, as described in Appendix F.
- A monitoring and research effort to identify, preserve, and restore important resource habitats.

Information from this monitoring and research effort should be utilized to refine the CBP Environmental Quality Classification Scheme (Appendix A) and to develop state water quality standards based on resource-use attainability.



PART II

CHAPTER 3
CHAPTER 4

CHAPTER 3
NUTRIENTS

Mary E. Gillelan
Joseph Macknis

INTRODUCTION: THE PROBLEM

Nutrients such as nitrogen and phosphorus enter the Bay from a variety of sources including runoff from forests, farmland and urban areas as well as discharges from sewage treatment plants and industries. Research conducted by the Chesapeake Bay Program has shown that very little of the nutrients entering the Bay are transported out to the Atlantic Ocean. Nutrients are essential to the productivity of the Bay but, as documented in Chapter 2, the Bay and its tributaries contain higher concentrations of phosphorus and nitrogen than were evident thirty years ago. The increased nutrient availability in the Bay has stimulated excess phytoplankton growth that has contributed to the worsening problem of low dissolved oxygen levels (DO) in the Bay. Simultaneously, populations of living resources of the Bay, such as freshwater-spawning fish, oysters, and submerged aquatic vegetation, have been decreasing. These trends suggest that reductions in the loading of nutrients to the Bay would limit the total amount of nutrients available and, thus, improve the state of the Bay over the long term.

This chapter indicates what the primary sources of nutrients are; discusses how much phosphorus and nitrogen each source contributes to the Bay and to major river basins; summarizes what controls are currently in place to reduce nutrient loadings and their effectiveness to date; and describes the range of controls or other measures that could be instituted and their relative cost and effectiveness. This information on nutrient sources, loadings, and alternative measures provides the raw material needed to formulate objectives and strategies for the improvement of Chesapeake Bay. Recommendations are proposed for Bay-wide policies and for more specific action within tributary systems.

SOURCES AND LOADINGS: AN OVERVIEW

The sources and loadings of nutrients[1] to Chesapeake Bay are influenced by population growth and land-use changes (described in Chapter 1 and detailed in Appendix B). Population growth contributes to the major point source of nutrients to the Bay, sewage treatment plants, also referred to as publicly-owned treatment works (POTWs); the other major type of point source in the basin is industrial wastewater. Changing land-use activities such as intensified agricultural activities or urbanization can result in higher nutrient loads from diffuse or nonpoint sources. Before initiating efforts to reduce nutrient loads to the Bay, it is necessary to determine the relative contributions of point and nonpoint sources now and in the future in each major drainage area, or basin, of Chesapeake Bay. Figure 18 shows the location of the major and minor basins described throughout this chapter.

Nutrient control strategies should be based upon a knowledge of the relative contributions of point and nonpoint sources of nutrients. Comparisons of these contributions have to be made not only Bay-wide, but also at the river basin level to link specific sources of nutrients to problem areas in the Bay. In addition, it is important to know how much of the loading originates above the fall line and how much enters tidal waters

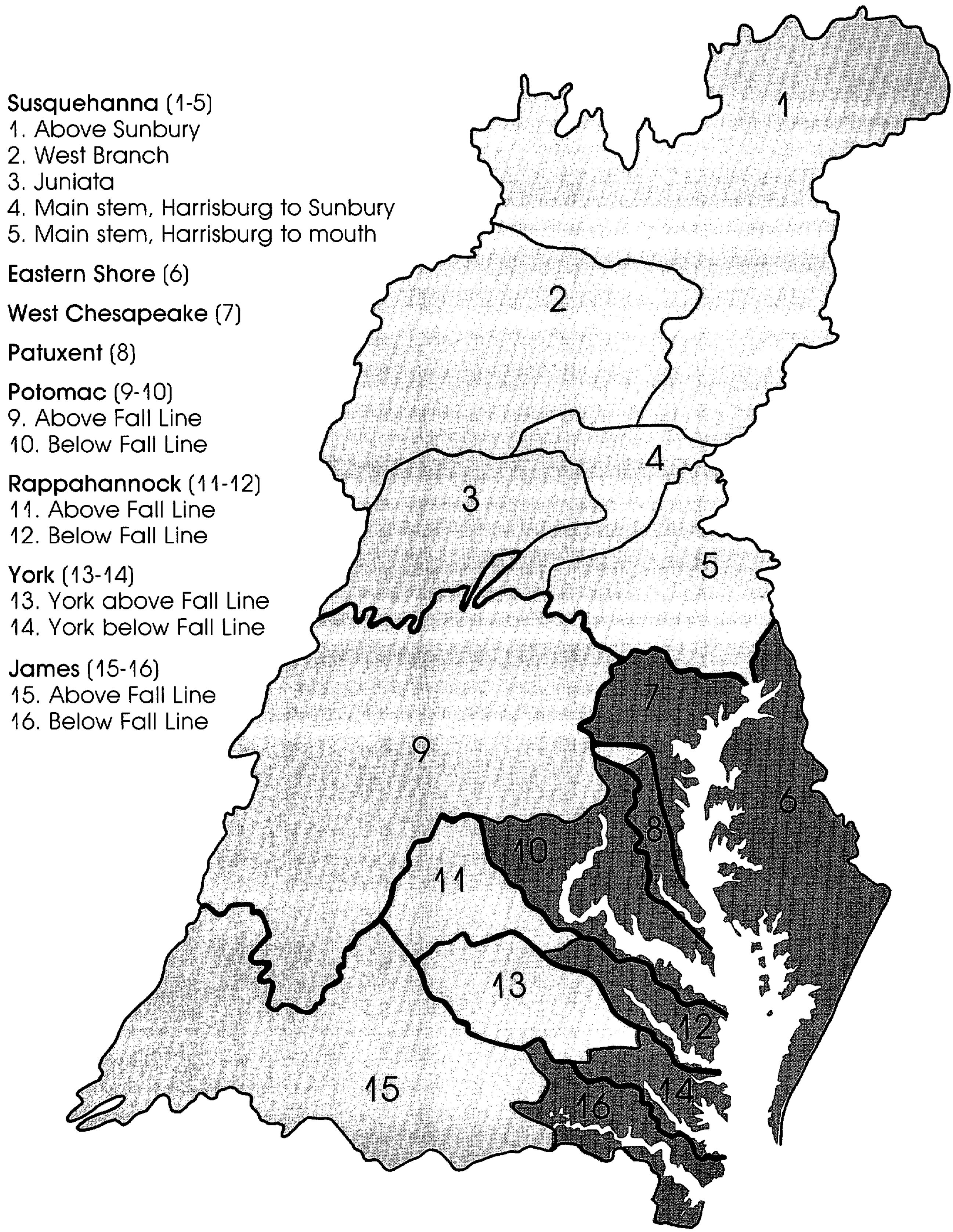


FIGURE 18. Major and minor river basins of the Chesapeake Bay.

directly. Computer modeling, described in more detail below, was used to determine how much of the point and nonpoint loadings discharged to freshwater rivers between March 1 and October 31 (the most critical period for water quality in Chesapeake Bay) are delivered to tidal waters. In this way, the effectiveness of upland point and nonpoint controls on Bay water quality can be evaluated against controls implemented in the land area adjacent to tidal waters.

Bay-wide Point and Nonpoint Sources of Nutrients

Most of the phosphorus loadings to Chesapeake Bay come from point sources which are concentrated close to tidal waters, and most of the nitrogen enters the Bay from nonpoint sources located throughout the Chesapeake Bay basin. Figure 19 indicates that the total nutrient load to the Bay varies in magnitude according to rainfall conditions. This figure also shows that the relative amounts of point and nonpoint source loadings to the Bay similarly change with rainfall conditions. Bay-wide, nonpoint sources contribute between 31 and 64 percent of the phoshorus load (39 percent — average rainfall conditions) and between 62 and 81 percent of the nitrogen load (67 percent — average); point sources contribute between 36 and 69 percent of the phosphorus load (61 percent — average) and 19 to 38 percent of the nitrogen load (33 percent — average), depending upon the annual rainfall conditions.

Basin Nutrient Loadings

Figure 20 illustrates the present loadings of phosphorus and nitrogen from each major basin draining to Chesapeake Bay in an average year of rainfall (March 1 to October 31). Collectively, the James (28 percent), Potomac (21 percent), and Susquehanna (21 percent) River basins contribute 70 percent of the total phosphorus load to the Bay (6,900 tons). The total nitrogen load of 73,000 tons is primarily associated with the Susquehanna, (40 percent), Potomac (24 percent), and the James (14 percent) Rivers. The West Chesapeake basin is also significant, contributing 17 percent of the phosphorus and 11 percent of the nitrogen loads. The Eastern Shore and other basins (Patuxent, Rappahannock, and York River basins) contribute the remaining loads. To determine the impact of each basin's loadings on Bay water quality, the loadings must be evaluated by Bay segment (rather than comparisons with total Bay-wide loadings) in order to link water quality to resource problem areas and their specific contributing sources.

Figure 21 evaluates the nutrient loads originating from each of the 16 sub-basins shown in Figure 18 to determine whether point or nonpoint sources are the major source of nutrients from individual sub-basins. Tables 5 and 6 contain the actual nutrient loads. It is important to recognize that Figure 20 differs from Figure 21 which illustrates point versus nonpoint contributions from entire river basins. For example, while the major sources of nitrogen from the entire Potomac River basin are nonpoint sources, the point source nitrogen load from the tidal Potomac River basin (below the fall line) by itself exceeds the nonpoint source load generated in this sub-basin.

The fact that point sources are concentrated in sub-basins adjacent to Chesapeake Bay is striking in Figure 21. The predominant sources of nitrogen and phosphorus from the West Chesapeake, tidal Potomac, and tidal James River basins are point sources. In the Patuxent River basin, point sources dominate the phosphorus load and are significant contributors of nitrogen. Point sources of phosphorus are also significant from the tidal portion of the York River basin. Nonpoint sources of phosphorus are dominant in the Eastern Shore, Susquehanna, and the upper portions of the Potomac, Rappahannock, York, and James River basins. Nonpoint sources of nitrogen are dominant in all areas except the West Chesapeake and tidal portions of the Potomac and James River basins.

Estimates of future (year 2000) nutrient loadings (summarized below and fully described in Chapter 5) indicate significant increases in phosphorus (43 percent) and nitrogen (7 percent). These will put even more stress on the living resources of the Bay than current loadings are already causing. Measures to curb the loadings of

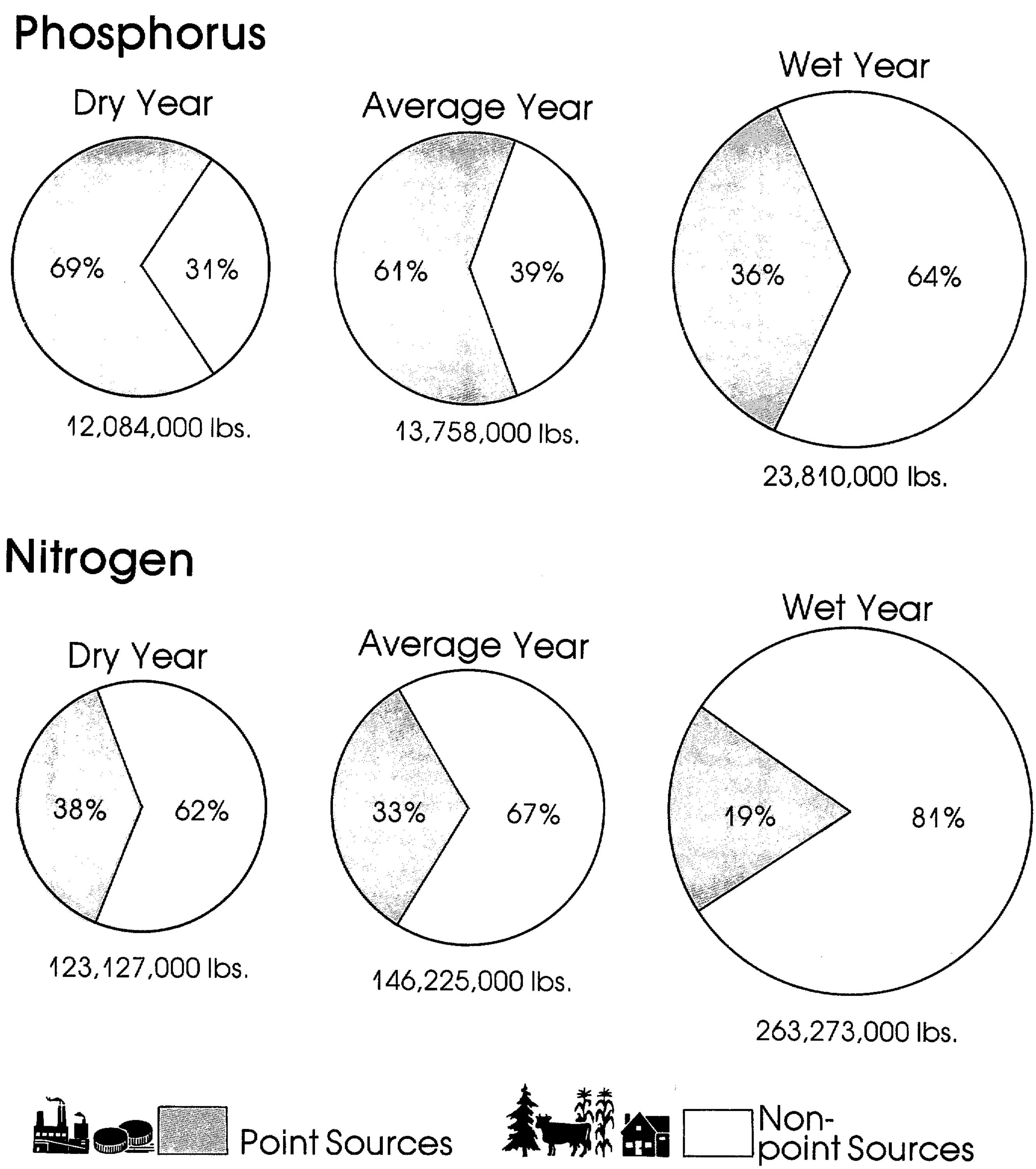


FIGURE 19. Bay-wide nutrient loadings, (March to October) under dry, average, and wet conditions.

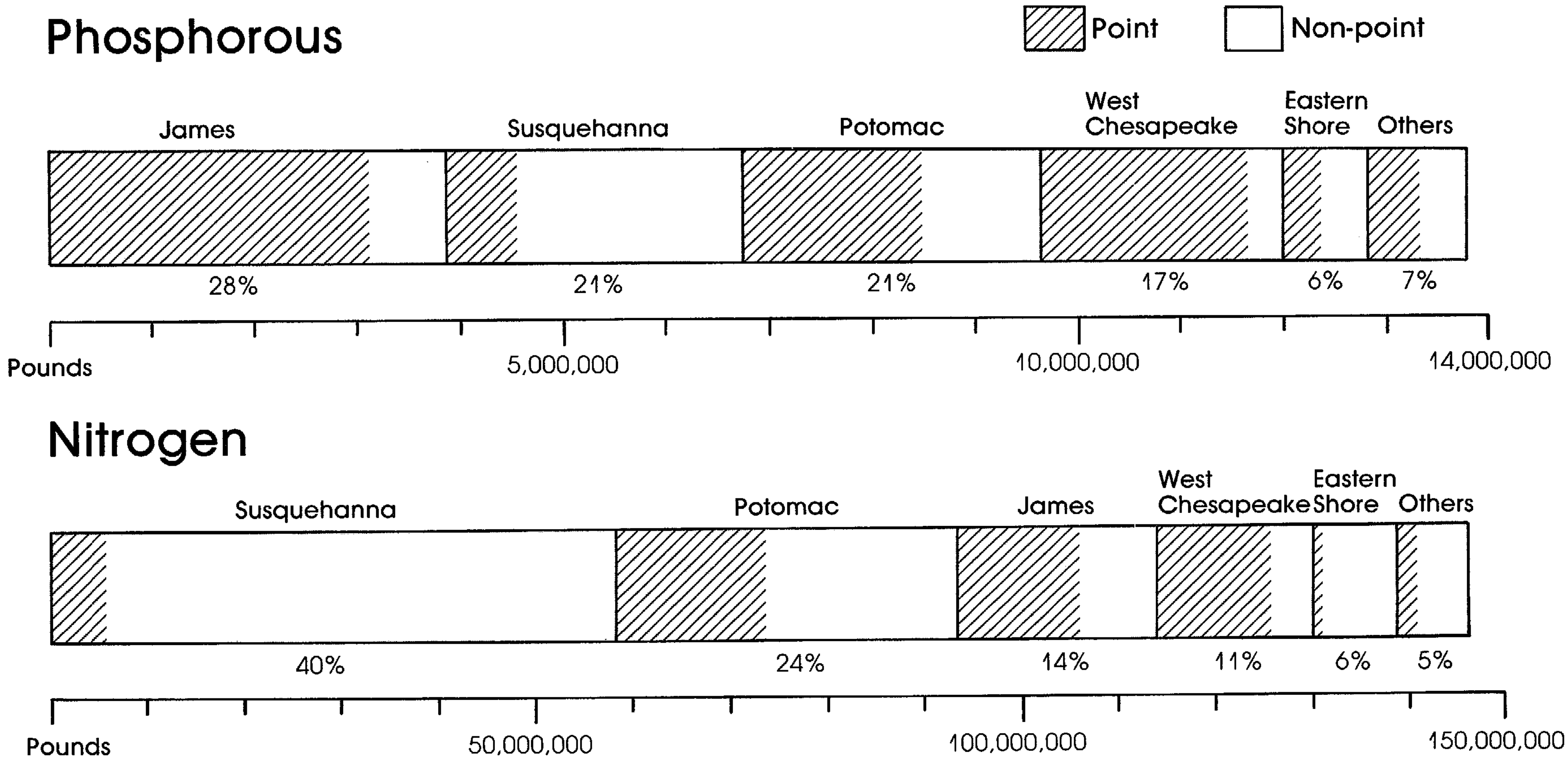


FIGURE 20. Nutrient loadings (March to October) by major basin under average rainfall conditions.

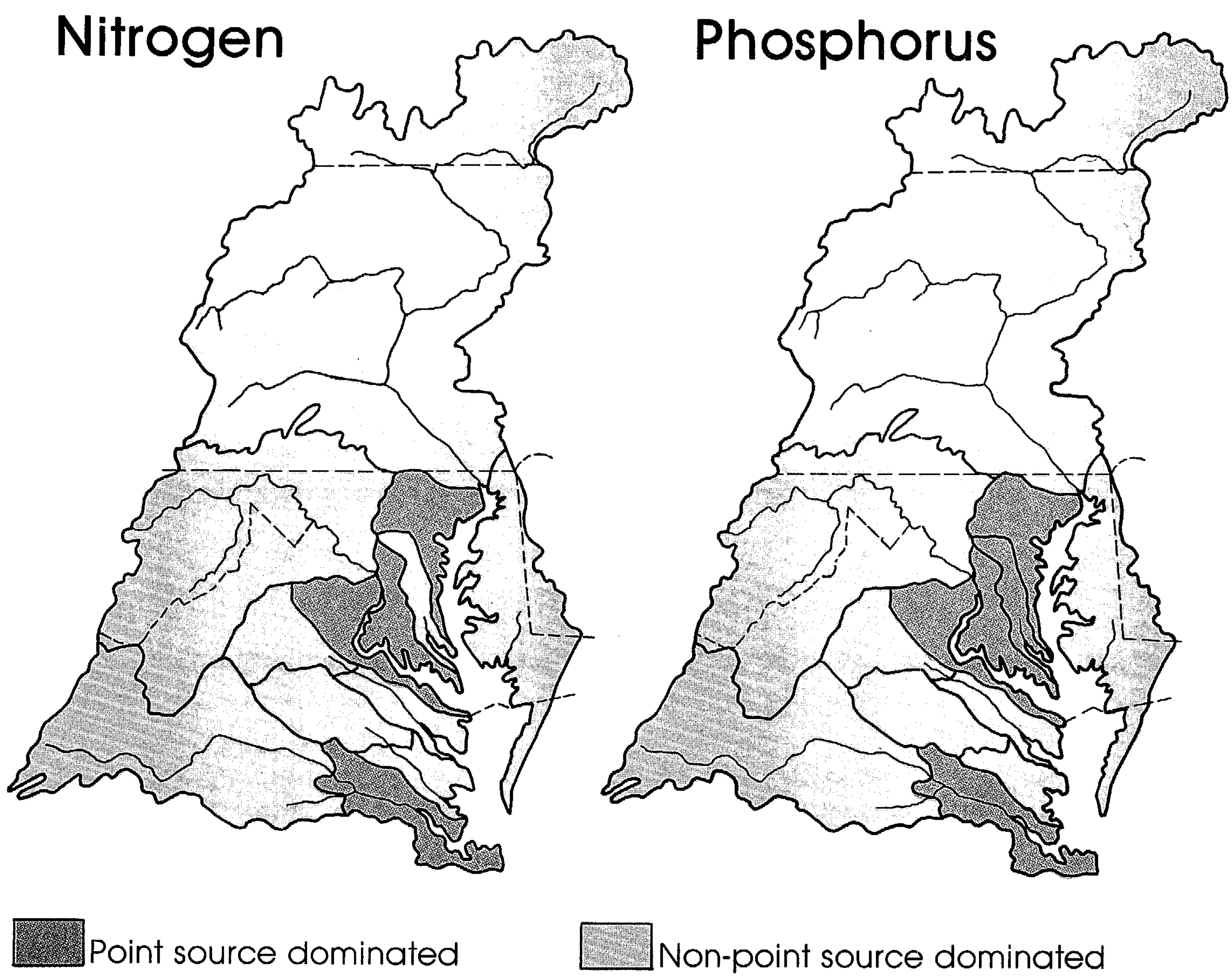


FIGURE 21. Relative importance of point and nonpoint source of nutrients within major basins.

nitrogen and phosphorus to the Bay must not only keep pace with these increases, but must reduce them to levels below today's loadings if the condition of the Chesapeake Bay is to improve. The text of this chapter provides the detailed information needed to formulate effective nutrient-reduction strategies: sources, loadings, effectiveness of current programs and policies, and alternative measures. General recommendations to reduce nutrients from the Chesapeake Bay basin as a whole are presented in this chapter; Chapter 5 includes nutrient recommendations for individual regions within the Bay basin.

POINT SOURCES AND LOADINGS

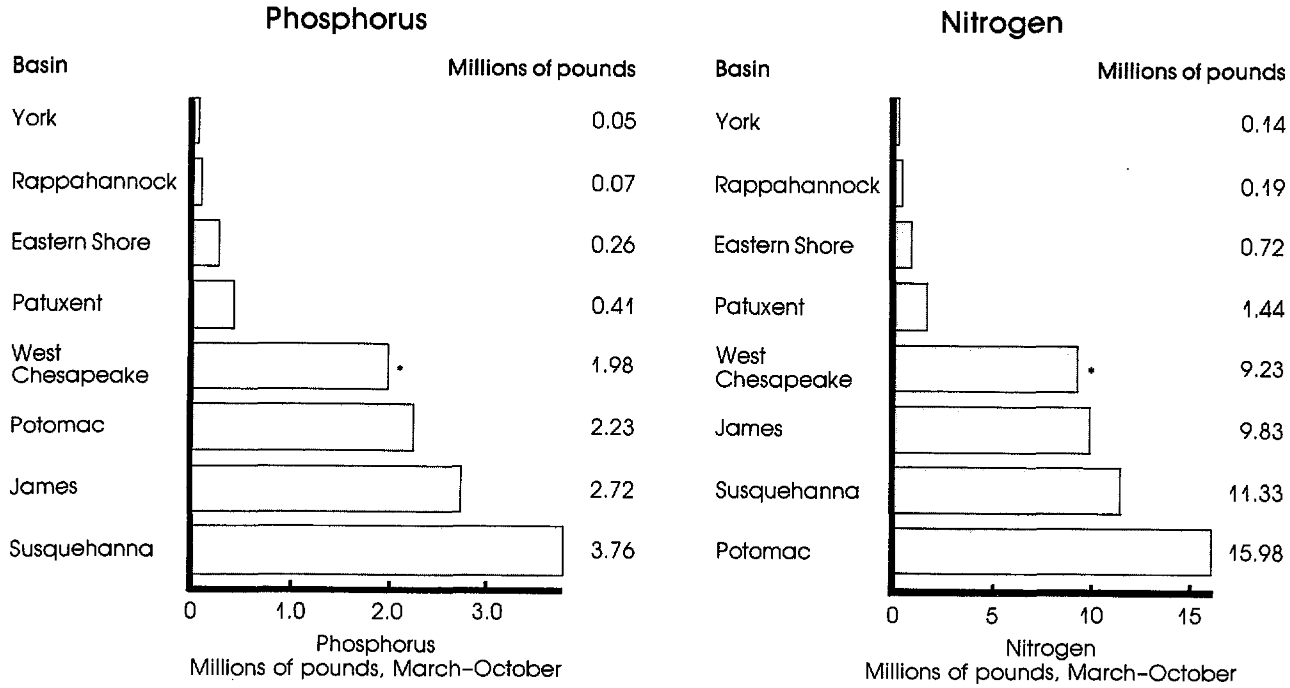
Point sources are concentrated waste streams discharged to a water-body through a discrete pipe or ditch. Although there may be daily or seasonal fluctuations in flow, including occasional starts and stops, point sources are essentially continuous, daily discharges which occur throughout the year. The significance of point sources increases during the summer and other periods of low rainfall because the freshwater flow is low and the dilution of effluent is reduced. Conversely, their relative significance decreases during periods of wet weather when rainfall, runoff, and nonpoint loadings increase. Examples of point sources include discharges from industrial production facilities and POTWs. The CBP data base contains an inventory of over 5,000 industrial and municipal point sources located within the Chesapeake Bay drainage area (Smullen et al. 1982).

Municipal Point Sources (POTWs)

Publicly-Owned Treatment Works collect and treat human wastes and wastes associated with household washing and cleaning activities. Studies have shown that household wastes may contain nutrients and toxicants in significant quantities (U.S. EPA 1982a). In addition, POTWs may collect and treat process water from industrial facilities, or indirect dischargers. These may include manufacturers of organic chemicals and plastics, metal finishers, pulp and paper mills, and commercial establishments such as restaurants, offices, and hotels. Indirect dischargers add significant variability to the concentrations and types of pollutants which must be removed by a POTW. Nonetheless, municipal wastewater can be expected to contain certain physical, chemical, and biological constituents. These substances can be grouped into the following general classes: 5-day biological oxygen demand (BOD_5), total suspended solids (TSS), nutrients, bacteria, heavy metals, synthetic organic chemicals, pH, heat, gases, chlorine, proteins, carbohydrates, and fats and oils.

Figure 22 presents the total municipal nutrient discharge by major basin. Not all of these discharges reach tidal waters, however, due to instream assimilation and decay processes (for the actual nutrient load from POTWs that is delivered to Bay waters from each major basin, see Chapter 5, Basin Profiles). It is interesting to note in Figure 22 that although the Potomac River must assimilate the largest total volume of treated wastewater [589 million gallons per day (MGD)], the total phosphorus discharge to the Potomac is less than the loadings discharged to either the Susquehanna or James Rivers because many POTWs located in the Potomac basin remove phosphorus prior to discharge. These plants do not remove nitrogen, and the nitrogen discharge reflects the large volume of waste water treated in the Potomac. In the West Chesapeake basin, 100 MGD of secondary-treated waste water containing 3,755 pounds of phosphorus and 16,189 pounds of nitrogen from the Back River wastewater treatment plant are transferred to the Bethlehem Steel Corporation where 2,000 pounds of phosphorus per day (480,000 pounds, March 1 to October 31) are removed prior to discharge. Although discharged by Bethlehem Steel, this nutrient load is attributable to a municipal source and is therefore included with municipal discharge to the West Chesapeake basin in Figure 22.

Appendix B contains an inventory of municipal treatment plants located in the Chesapeake Bay basin, including facility name; 1980 flow; year 2000 projected flow; NPDES permit number; type of treatment; and concentrations of nutrients (nitrogen and phosphorus), BOD_5, TSS, and total residual chlorine (TRC).



*Includes .42 million pounds of phosphorus in treated effluent from Back River sewage treatment plant discharged by Bethlehem Steel.

*Includes 4.0 million pounds of nitrogen in treated effluent from Back River sewage treatment plant discharged by Bethlehem Steel.

FIGURE 22. Discharge of phosphorus and nitrogen from municipal point sources based on 1980 operational flow and levels of treatment. (These are discharged loads not delivered loads. See Chapter 5 for delivered loads to the Bay.)

This inventory contains all POTWs with discharges greater than 0.5 MGD located above and below the fall line, as well as some smaller POTWs below the fall line.

Future nutrient discharges from POTWs estimated by the CBP are shown in Figure 23 (Chapter 5 for future loadings that reach Bay waters). These were developed assuming that increases in flow due to population growth will be treated at 1980 levels of treatment; in areas where increased flow exceeds existing 1980 design capacity of individual POTWs, the excess flow was assumed to be treated at secondary-level treatment. As a result, POTWs upgraded since 1980 where effluent concentrations and loads have been reduced, such as the Back River (West Chesapeake basin) and Blue Plains (Potomac River basin) POTWs, are not reflected in year 2000 loadings. Appendix B contains a listing of plants in this category and identifies effluent concentration changes resulting from upgrading. Under future conditions, it is estimated that Bay-wide POTW phosphorus loads will increase by 43 percent and total flow will increase by 35 percent.

Industrial Point Sources

Industrial manufacturing activities require water for many purposes, often in large quantities. Frequently, all of the water used during the manufacturing process is discharged into receiving waters which eventually reach Chesapeake Bay. Such discharges contain a variety of

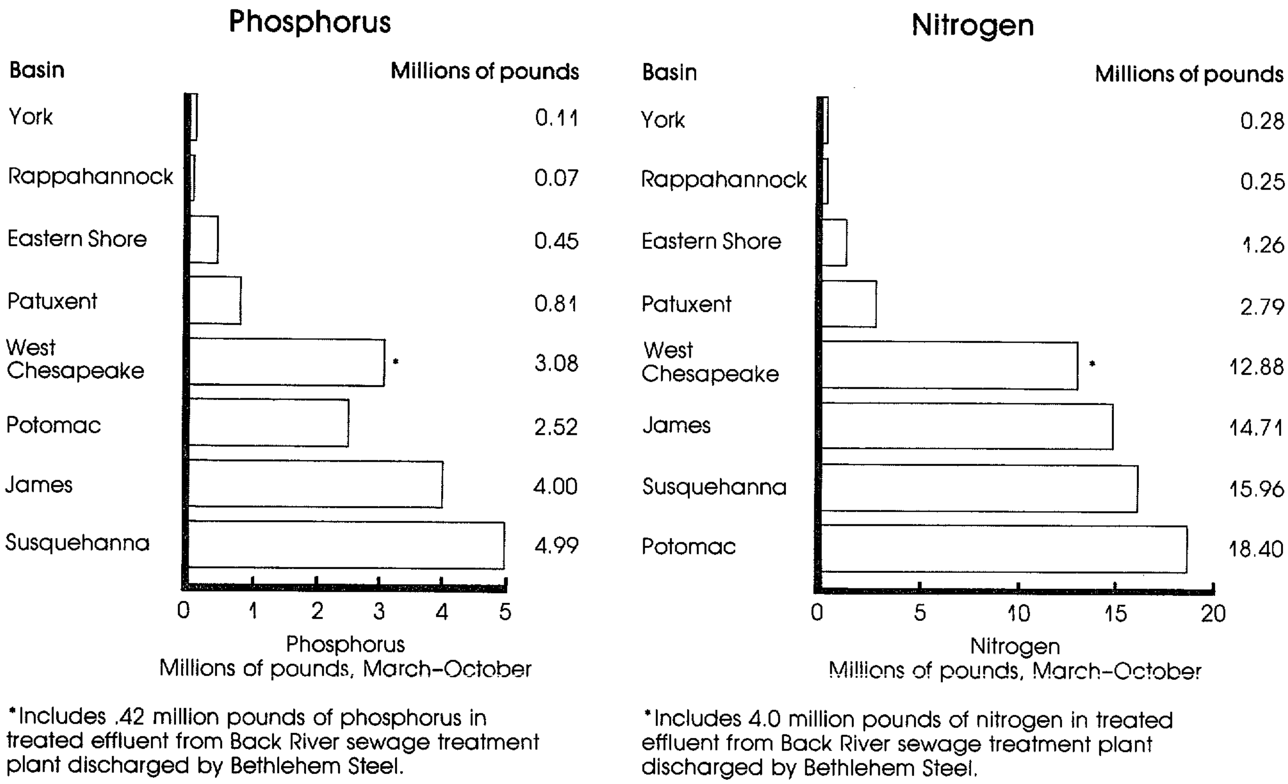


FIGURE 23. Discharge of phosphorus and nitrogen from municipal point sources based on 2000 projected flow and levels of treatment. (These are discharged loads not delivered loads. See Chapter 5 for delivered loads to the Bay.)

chemicals and, depending on the type of industry, may include nitrogen or phosphorus.

In addition to requiring water for manufacturing processes (process water), industry uses large quantities of water for cooling. The volume of cooling water required varies from one industry to another, depending on the amount of heat to be removed from process waters. A large industrial facility may discharge a total of 30 MGD, of which only 1 MGD is process water; the remainder is primarily cooling water. Cooling water can become contaminated by small leaks within the cooling system or by corrosion products. Cooling water also may contain biocides, such as chlorine, to control algal growth in cooling pipes. Pollutants generated by industrial manufacturing processes include: floating solids (lighter than water), organic matter, suspended solids, nutrients, toxic chemicals, heat, acids and/or alkalis, inorganic salts, color, and foam-producing matter.

Industries located within the Chesapeake Bay drainage area that generate and discharge significant amounts of nutrients include industrial organic and inorganic chemical manufacturers, paper mills, refineries, and food-processing industries (Smullen et al. 1982). Overall, they contribute only 20 percent of the total point source load of nitrogen and 12 percent of the total point source load of phosphorus discharged within the Chesapeake Bay basin.

Figure 24 illustrates by major basin the nutrients generated by industrial dischargers (Smullen et al. 1982). It shows that the greatest

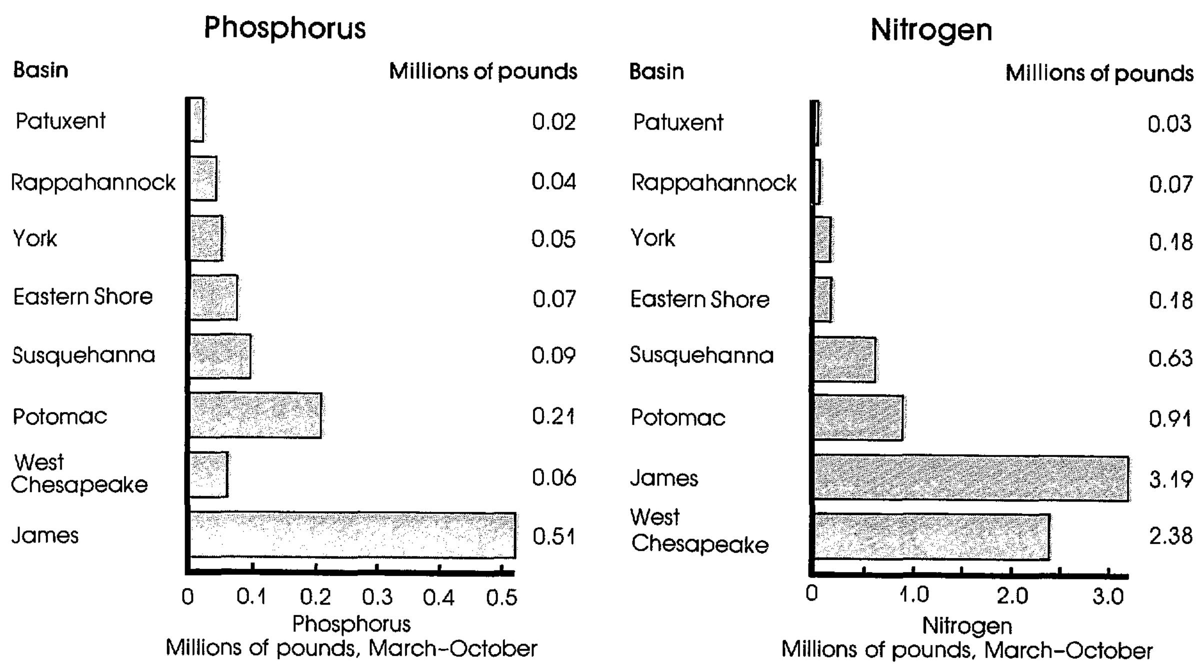


FIGURE 24. Existing (1980) and future (2000) discharge of phosphorus and nitrogen from industrial point sources. (These are dsicharged loads not delivered loads. See Chapter 5 for delivered loads to the Bay.)

industrial nutrient discharges are in the James, West Chesapeake, and Potomac River basins where several large industrial complexes account for the significant industrial contribution. Chapter 5 includes data on the industrial nutrient load from each major basin that actually reaches tidal waters. Appendix B lists major industrial nutrient dischargers and their individual nutrient discharges by major basin. Future loadings from industrial dischargers were assumed to remain at existing levels. All of the projected increases in point source nutrient loadings using the above assumptions are therefore due to the estimated increases in POTW discharges.

Figure 25 compares the magnitude of the 1980 industrial and municipal nutrient discharges in major Chesapeake Bay basins. It indicates that in all of the larger basins, municipal discharges dominate the point source nutrient contributions, ranging from 76 to 95 percent of all point source effluent. In the smaller basins (York, Rappahannock, and Eastern Shore) the municipal discharge is still generally dominant, ranging from 44 to 80 percent of the total; industrial discharges, primarily from seafood, poultry, and meat processing industries, however, still represent a significant proportion of the total point source contributions.

THE EFFECTIVENESS OF POINT SOURCE CONTROLS

The effectiveness of point source control programs to restrict nutrient loadings can be traced to the 1972 Federal Water Pollution Control Ammendments (FWPCA) and its subsequent version, the 1977 Clean Water Act (CWA). The main thrust of the water pollution control program established by the FWCPA has been to reduce the discharge of "conventional" pollutants: BOD_5,

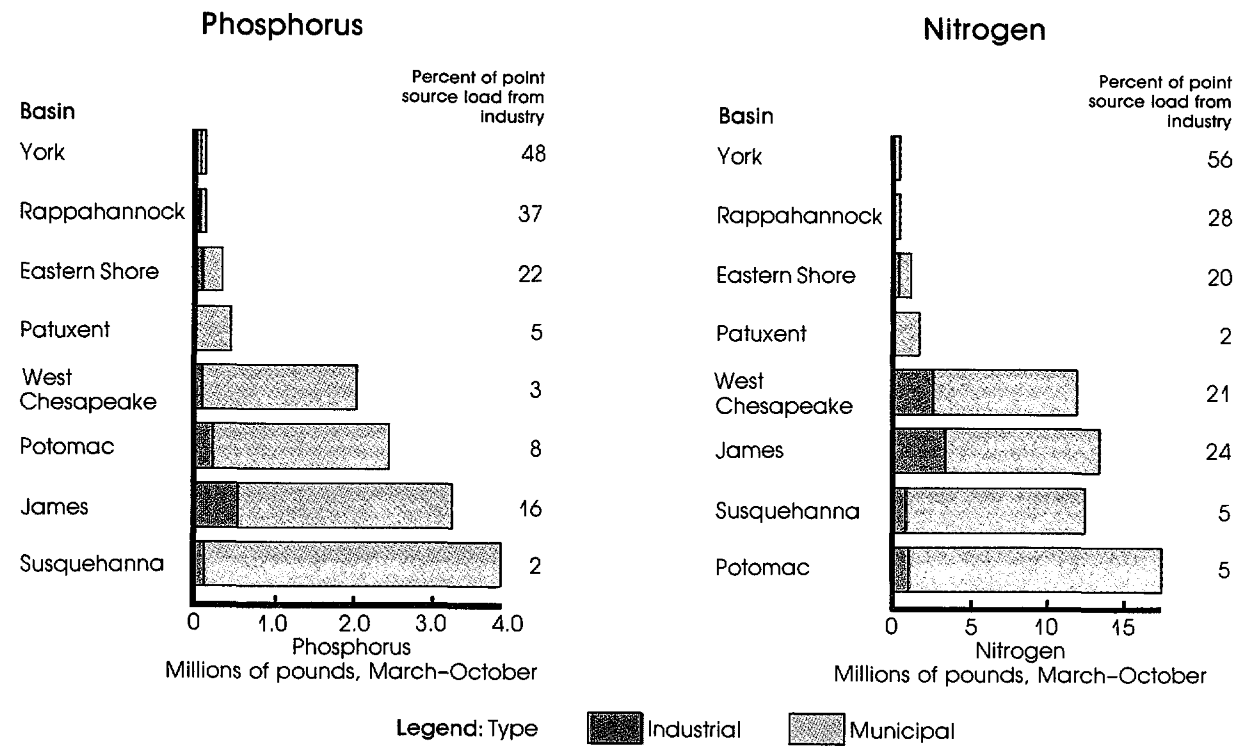


FIGURE 25. Discharge of phosphorus and nitrogen from point sources under existing (1980) conditions and percentage of point source discharge from industrial point sources.

TSS, pH, temperature, oil and grease, bacteria and, in some cases, ammonia, heavy metals, and phenols. Nutrients are not considered to be conventional pollutants; discharge restrictions for nutrients are imposed only when there is sufficient scientific evidence that their removal will result in water quality benefits.

The authority to set limits on the amounts or concentrations of pollutants discharged by point sources is delegated to the states by the CWA; this permit program is known as the National Pollutant Discharge Elimination System, or NPDES. Data indicate that the NPDES permit system has been effective in controlling the discharge of conventional pollutants from industrial point sources. For example, Virginia compliance reports show that in 1972, thirty industrial point sources collectively discharged 275,000 pounds per day of BOD_5 and 330,000 pounds per day of TSS. By 1980, NPDES monitoring data showed that the undelivered loads from these same discharges were reduced to 98,000 pounds per day of BOD_5, and 160,000 pounds per day of TSS, reductions of 64 percent and 51 percent, respectively.

While the CWA established two levels of pollution-control technology standards for industrial dischargers (best practicable technology, BPT and best available technology, BAT) to be implemented in succession, it generally established a single technology level for municipal dischargers, namely, "secondary treatment." Municipal NPDES permit limits, however, can be based either on the application of available technology (secondary treatment) or on the protection of water quality (advanced secondary, tertiary, or other treatment technologies), whichever is more stringent. Secondary-treatment technology is designed to limit conventional pollutants such as BOD_5, TSS, pH, and flow. Although nutrients are not targets for control by secondary treatment, some reductions (e.g., from 11.5 mg L^{-1} to 8.0 mg L^{-1} for phosphorus and from 22.5 mg L^{-1} to 18.5 mg L^{-1} for nitrogen) can be achieved through this process. Specific effluent limitations for nutrients may be set (as in the Upper Chesapeake Bay Phosphorus Limitation Policy and the Patuxent Nutrient Control Strategy, discussed below) if secondary treatment does not result in the protection of the desired water quality because of excessive nutrient loadings.

To assist communities with upgrading their POTWs to meet the secondary-treatment regulation, the FWPCA established the Construction Grants Program, a Federal and state cost-sharing program. The EPA, or states with delegated authority, distribute construction grants to municipal agencies to plan, design, and build new, or upgrade existing, POTWs. Grants have funded 75 percent of the eligible project costs for conventional-treatment systems and 85 percent of the eligible costs for innovative and alternative-treatment technology systems. Recent legislation has reduced the Federal cost-share percentage to 55 percent of total eligible costs beginning fiscal year 1985.

Table 2 summarizes the Federal dollars spent on the Construction Grants Program within the Chesapeake Bay basin between 1972 and 1983. Basin-wide, approximately 2.5 billion dollars were spent by the Federal government to improve the level of wastewater treatment. When added to the approximately 25 percent-share paid by the states, municipalities, and local governments, the total amount spent is nearly 3.3 billion dollars.

Data indicating what has been bought by these grants in terms of water quality improvement are scarce, but nonetheless encouraging. Chapter 2 showed that one of the areas in the Chesapeake where water quality trends are improving is the Potomac River. Approximately one billion dollars were spent there to limit POTW loadings. Figure 26 compares the loadings of BOD_5, nitrogen, phosphorus, and flow in 1970 and 1980 in the James and Potomac River basins. During this

TABLE 2.
CONSTRUCTION GRANTS PROGRAM FUNDING OF THE CHESAPEAKE BAY DRAINAGE AREA (with the exception of New York) IN MILLIONS OF DOLLARS

	Step 1 Planning		Step 2 Design		Step 3 Constr.		Step 4 Design/Constr.		State Total	
State	Number of Projects	EPA Amount	Number of Projects	EPA Amount	Number of Projects	EPA Amount	Number of Projects	EPA Amount	Number of Projects	EPA Amount
D.C.	13	$ 14.2	2	$ 0.7	5	$ 165.1	—	—	20	$ 180.0*
DE	10	0.8	8	1.2	14	33.2	5	$ 8.4	37	43.6*
MD	143	19.7	74	27.0	201	835.1	43	42.6	461	924.4*
PA	75	7.5	29	13.5	144	557.3	15	27.6	263	605.9*
VA	70	7.3	51	20.3	85	643.5	6	5.6	212	676.7*
WVA	11	1.1	12	2.4	12	23.5	—	—	35	27.0*
Region	322	$50.6	176	$65.1	461	$2,257.7	69	$84.2	1,028	$2,457.6

* This amount represents 75 percent of the eligible cost of the projects.

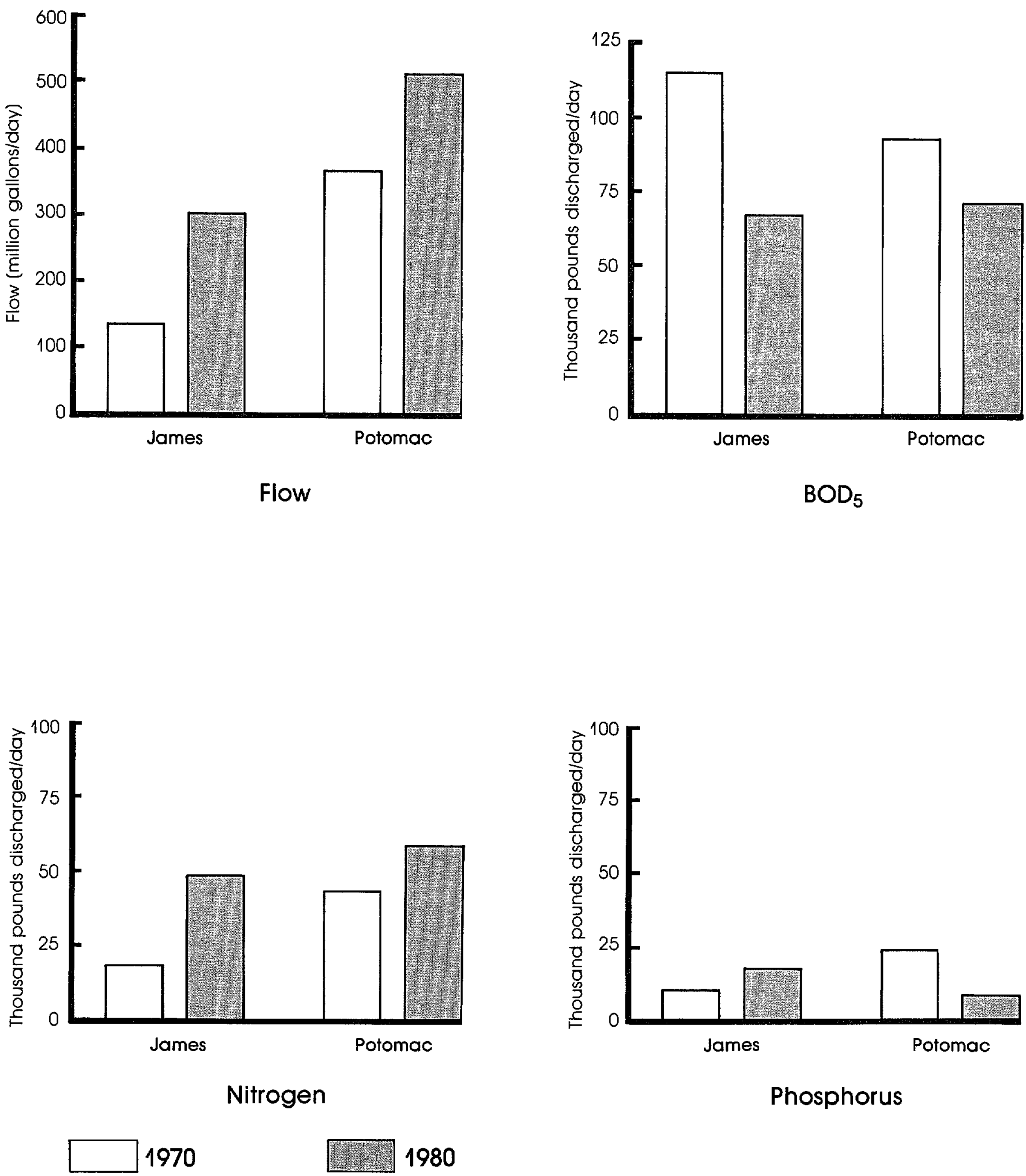


FIGURE 26. Comparison of flow, and BOD_5, nitrogen, and phosphorus loads in the James and Potomac River basins, 1970 and 1980.

period, the volume of effluent (flow) discharged by POTWs in the James more than doubled, yet the BOD_5 load was nearly halved. Nutrient discharges have continued to increase in the James relative to flow because secondary-treatment is the highest level of treatment required there. In the Potomac, there has been a similar increase in flow, but both the BOD_5 and phosphorus loads have been reduced, the latter due to implementation of phosphorus effluent limitations at Blue Plains and other sewage treatment plants discharging to the upper Potomac. Improvements in water quality observed since the late 1960's in the Potomac estuary are principally attributed to these reductions obtained through the NPDES and Construction Grants programs. The data in Figure 26 emphasize that, in areas where nutrients are contributing to poor water quality, secondary-level treatment alone is not effective in curbing phosphorus or nitrogen loadings; some form of advanced wastewater treatment will be needed to limit further nutrient enrichment due to point source loadings in problem areas of the Bay.

Nutrient enrichment in the main stem of the Bay is currently being addressed by implementation of the EPA's Upper Chesapeake Bay Phosphorus Limitation Policy. This policy, approved by the EPA for funding in 1979, was established to reduce increasing chlorophyll *a* concentrations in the upper Bay, an indication of eutrophication. Under the Upper Chesapeake Bay Policy, Maryland and Pennsylvania have imposed phosphorus effluent limits on POTWs impacting this area. In Maryland, the policy requires all point sources with flows greater than or equal to 0.5 MGD discharging into the Maryland portion of the Bay north of and including Gunpowder River (Zone I), or POTWs with flows greater than or equal to 10.0 MGD between Gunpowder River and the southern edge of the Choptank River (Zone II), to meet the effluent limitation of 2 mg L^{-1} effluent. In Pennsylvania, state regulations require 80 percent removal (approximately equal to 2.0 mg L^{-1} effluent) of phosphorus for all new or modified wastewater treatment facilities discharging to tributaries and the main stem of the Susquehanna River below its confluence with the Juniata River.

Chesapeake Bay Program modeling studies indicate that full implementation of the Upper Chesapeake Bay Policy will only maintain existing point source phosphorus loadings to the Susquehanna River in the year 2000. More stringent phosphorus limitations may be necessary in the future to improve upon the present condition of the upper Bay. Appendix B identifies the POTWs subject to the policy and their 1980 effluent phosphorus concentrations. Chapter 5, Basin Profiles, contains nutrient load reductions that can be achieved through the full implementation of this policy.

In the Potomac River basin, phosphorus limitation at the larger POTWs has resulted in water quality improvement of the tidal-freshwater portion of the river. In the Patuxent River basin, the State of Maryland is preparing to limit nitrogen effluent concentrations, as well as phosphorus, in an effort to reduce chlorophyll *a* concentrations in the tidal-freshwater portion and to alleviate low DO concentrations in the lower reaches of the river. Water quality monitoring over a number of years will be necessary to determine the effectiveness of this policy once implemented. Then, based on water quality improvements in the Patuxent, Bay-area states may choose to limit nitrogen from sources contributing to other problem areas around the Bay.

Although loadings of conventional pollutants and nutrients, to some extent, have been lowered by existing programs, compliance monitoring data indicate that nutrient loads could be further reduced if permit compliance were improved. National EPA statistics on plant performance indicate that at any point in time, 50 to 75 percent of the POTWs are somehow in violation of their NPDES permits. (Statistics may include administrative or effluent violations and do not necessarily reflect the severity or duration of the violations.)

The Maryland Office of Environmental Programs, Department of Health and Mental Hygiene, estimates that in 1983, six (17 percent) of the 35 major municipal dischargers were not in compliance with either BOD_5 or TSS permit limitations.[2] The Virginia Bureau of Enforcement, State Water Control Board, estimates that in 1982, 21 (37 percent) of the 56 major POTWs were not in compliance with either BOD_5 or TSS permit limitations (VA SWCB 1982). The Bureau of Water Quality Management, Pennsylvania

Department of Environmental Resources, estimates that approximately 20 percent of all wastewater treatment facilities in the Susquehanna River basin were not meeting their BOD_5 and TSS permit limitations. A higher percentage of facilities, however, in the lower Susquehanna River basin (below the confluence with the Juniata River) that are required to remove 80 percent of the phosphorus load, are not meeting their phosphorus permit limitations.[3]

In summary, although loading trends for both POTWs and industries indicate continuous reductions in certain conventional pollutants and nutrients in certain areas, the improvements may be inadequate. Secondary-treatment, the minimum POTW discharge limitation, is not designed to control nutrients, and permit noncompliance is evident. Another concern is the fact that many segments of the Chesapeake Bay system are showing early or advanced signs of nutrient over-enrichment and oxygen depletion that parallel historical trends in the Potomac (Flemer et al. 1983). The inability of some localities to improve waste water treatment capabilities in step with population growth and the need for water quality protection indicates that many of the gains made in point source controls during the past decade have leveled off or are being hampered by administrative and technical problems such as operation and maintenance (O & M) deficiencies and lack of pretreatment. A number of control options are offered in the following section.

POINT SOURCE CONTROL OPTIONS

Options to reduce phosphorus and nitrogen loadings can be oriented toward technological controls, such as the implementation of one of many types of nutrient-removal technologies to meet specified effluent limitations. Other options include improvements in the administration of current control programs, such as better enforcement and compliance efforts, more thorough effluent monitoring, or encouraging the application of less capital-intensive nutrient-removal technologies. This section evaluates the relative costs of technological controls and their effectiveness in terms of reducing nutrient loads. In addition, it discusses some of the major areas in which administrative or procedural changes in current programs could result in more effective point source controls.

Technological Control Options

The technology-based effluent limitations (secondary treatment for POTWs, and BPT and BAT for industries) serve as a nation-wide minimum or base-level treatment standard for point source pollution control. The option exists, however, for individual states to institute effluent limitations that are more stringent than those set by EPA for nutrients. Three such examples were described previously: phosphorus limitations in the upper Potomac River, the Patuxent River, and the upper Chesapeake Bay, including the lower Susquehanna River. For the purpose of estimating nutrient load reductions that can be achieved from technological control options, the CBP tested several policies that limit the discharge of phosphorus and nitrogen:

TP = 2:
: Phosphorus effluent limitation of 2 mg L^{-1} applied basin-wide to all POTWs with 1980 flows greater than 1 MGD, tested for existing conditions.

UCBP Policy:
: Upper Chesapeake Bay Phosphorus Limitation Policy: fully implemented in the lower Susquehanna basin only (2 mg L^{-1} P in POTWs greater than 0.5 MGD) for year 2000 flow; fully implemented in the West Chesapeake for 1980 and 2000 flows.

Patuxent Nutrient Control Strategy:
: Total daily point source phosphorus load of 420 pounds and total daily nitrogen load of 3,900 pounds to be achieved by 1987.

TP = 1, TN = 6:
: Combination of phosphorus limitation (1 mg L^{-1}) and nitrogen limitation (6 mg L^{-1}) applied basin-wide to all POTWs with 1980 flows greater than 1 MGD, tested under both existing and future conditions.

P Ban:
: Phosphate detergent limitation to 0.5 percent by weight in household detergents, resulting in a 30 percent reduction in 1980

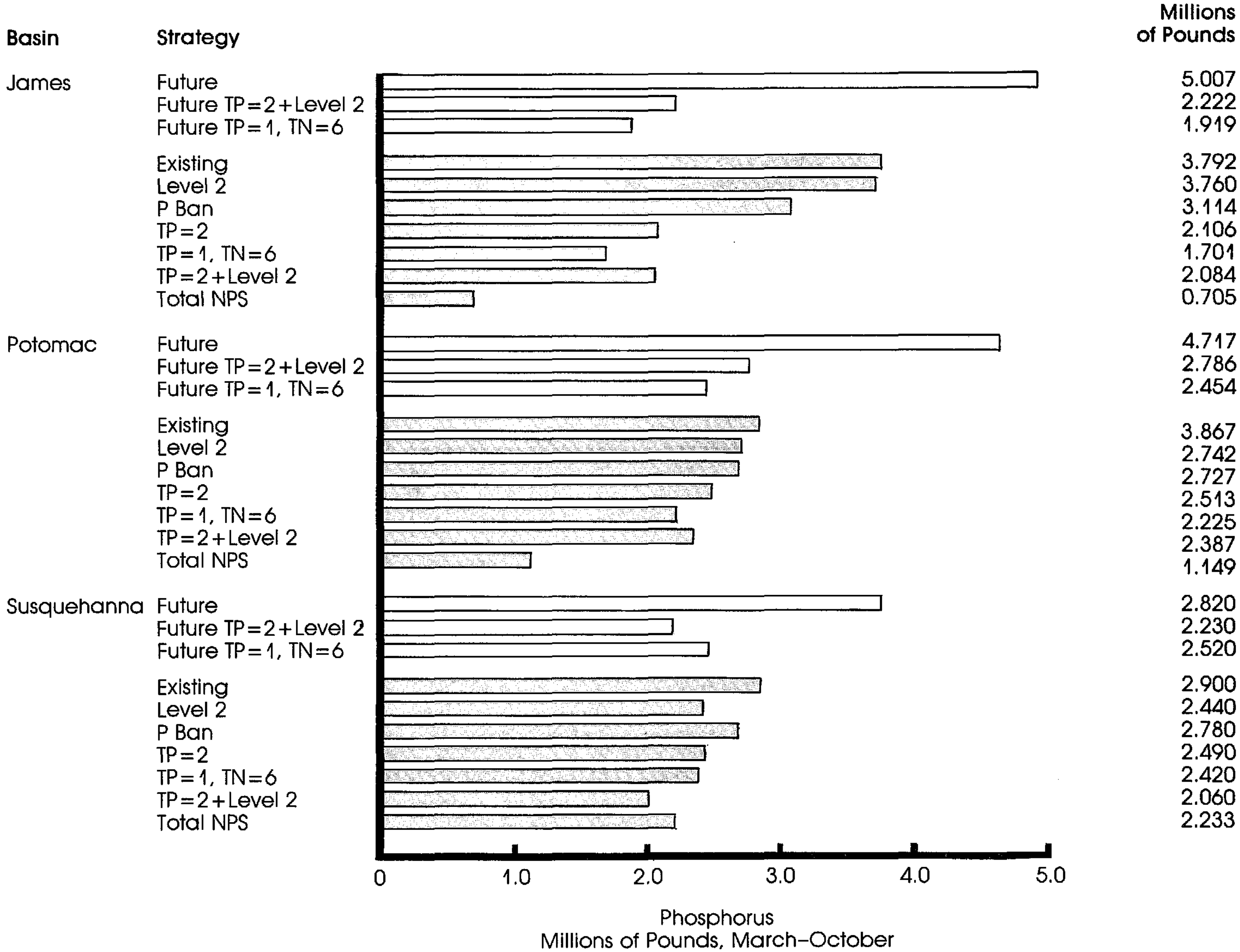


FIGURE 27. Existing (1980) and future (2000) phosphorus loads from the James, Potomac, and Susquehanna river basins under different management strategies and average rainfall conditions.

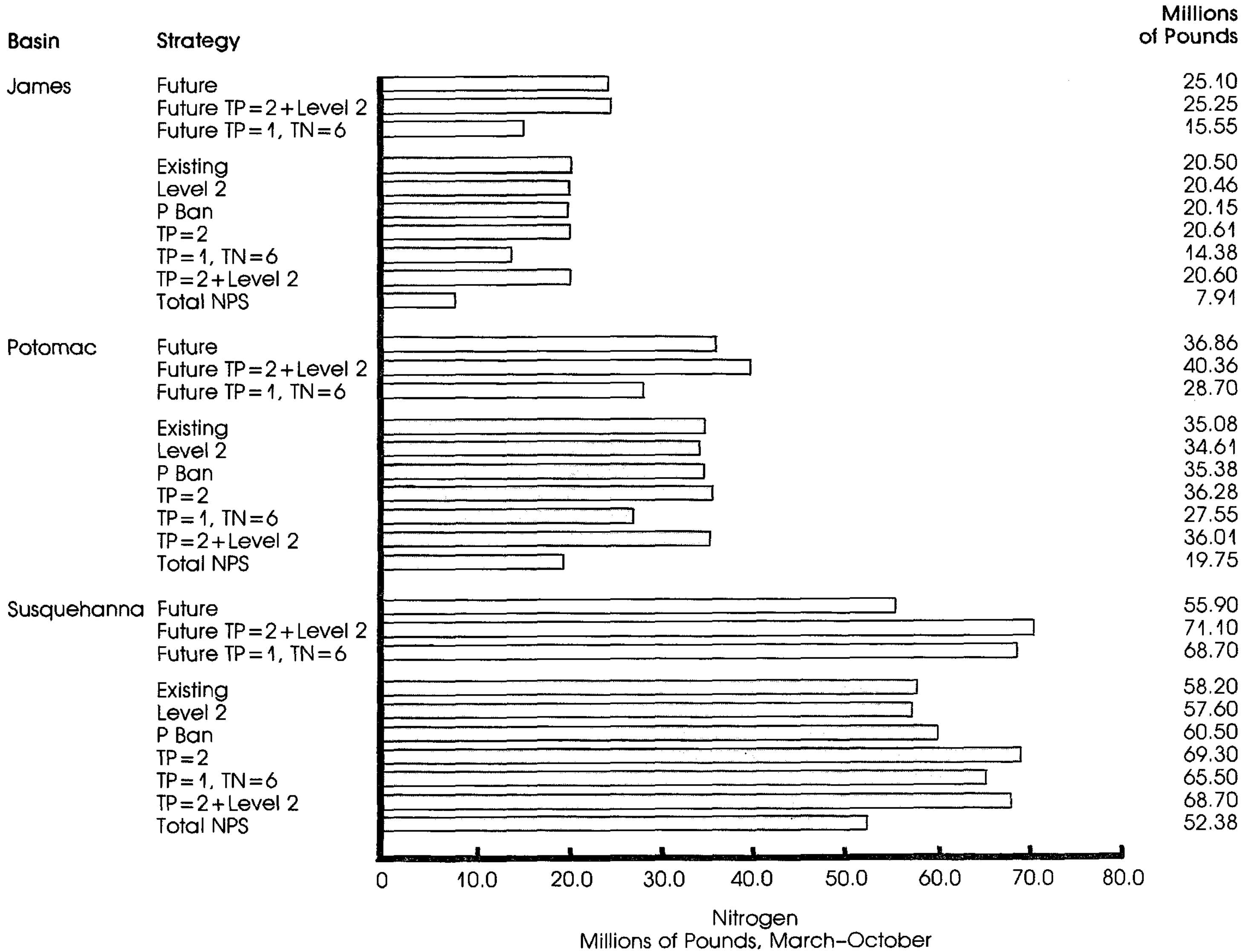


FIGURE 28. Existing (1980) and future (2000) nitrogen loads from the James, Potomac, and Susquehanna river basins under different management strategies and average rainfall conditions.

phosphorus effluent concentrations for all POTWs not providing advanced treatment, under existing conditions.

The Chesapeake Bay basin model (Hartigan et al. 1983), described below and in Appendix B, was used to test the effect of these strategies in reducing point source loadings delivered to Chesapeake Bay. Although these options were tested on POTWs only, they could be applied to industrial discharges of nutrients as well. To test the maximum point source reduction (no nutrient discharge), the model was run with zero point source nutrient loadings (the "Total NPS" control option). In addition, a combination of point and nonpoint control options (TP = 2 and conservation-tillage Level 2 measure on all cropland) was tested and is discussed in Chapter 5.

Reductions in loadings to Bay waters from both above and below the fall line for the three major river basins that can be achieved through these options are shown for phosphorus in Figure 27 and for nitrogen in Figure 28. More extensive discussions and comparisons among these options are contained in Chapter 5, Basin Profiles, for each major river basin. The major types of nutrient-removal technologies and some newly-developed systems are described in more detail in Appendix B.

The effectiveness of these options is dependent upon several factors. In river basins dominated by point sources, these options will have more effect than if nonpoint sources are dominant. The existing level of treatment affects the magnitude of load reductions; for instance, in the Potomac, where a significant quantity of phosphorus is currently being removed from POTWs, a 2 mg L^{-1} phosphorus limitation does not result in great load reductions. Also, travel time to tidal waters reduces the effect of point source load reductions. The POTW load reductions from above the fall line associated with different options were routed downstream to tidal waters. Depending on the distance from the tidal waters, load reductions to the Bay are not as great as the actual effluent reduction because of in-stream assimilation processes such as nutrient cycling, settling, conversion, etc. (Appendix B). For POTWs located below the fall line, effluent reductions result (i.e., no nutrient assimilation) in direct load reductions to tidal waters. As a result, strategies directed at controlling point sources below the fall line can be expected to be more effective in reducing nutrient loads to the Bay than those directed at point sources above the fall line. Table 3 includes the average reductions in Bay-wide nutrient loads that are achievable by implementing each of these options, based on model simulations. Chapter 5 includes this information for each major basin.

Costs Associated with Point Source Control Options

In addition to modeling the options above, data on the cost to implement these options and the cost per pound of nutrient removed were estimated to identify the least-cost pollutant controls. Bay-wide costs are shown in Table 3, and are provided for each basin in Chapter 5. The least-cost pollution control strategy can be determined by comparing the present-value cost to install and implement the option with the reduction in nutrient loadings it achieves. Present-value cost is an economic tool that allows for comparison of different amounts of money spent at different times to determine the relative cost of each option. One-time capital installation costs for new plants can thus be evaluated against retrofitting costs and annual O & M costs associated with upgrading sewage treatment plants. The present-value cost of each option can then be divided by load reductions to calculate the present-value cost per pound of nutrient removed to determine the least-cost option. A discount rate of 7.25 percent over a 20-year planning period was used in this analysis. A more detailed account of cost calculations for POTW upgrading and the phosphorus ban is presented in Appendix B.

Sewage treatment upgrading and O & M costs are based on the CAPDET computer program developed by the EPA in coordination with the U.S. Army Corps of Engineers (COE, 1981). The CAPDET program is a technique to screen wastewater treatment alternatives for preliminary cost estimating and user charge assessment in the Construction Grant's 201 facilities planning process. Capital retrofitting and O & M costs to obtain a

TABLE 3.
BAY-WIDE NUTRIENT REDUCTIONS AND COSTS ASSOCIATED WITH THE IMPLEMENTATION OF ALTERNATIVE NUTRIENT CONTROL STRATEGIES APPLIED TO EXISTING (A) AND FUTURE (B) NUTRIENT LOADS

Strategy	Present Value (millions $)	% Reduction P	% Reduction N	Dollars per Pounds Removed over 20 Years
A. Strategies tested against existing loads				
P Ban	359.1*	11	—	7.83
TP=2 mg L^{-1}	669.5	28	—	5.87
TP=1 mg L^{-1}	804.6	35	—	5.53
TN=6 mg L^{-1}**	2,533.5	—	26	3.58
TP=2 mg L^{-1} plus Level Two	678.6	33	—	5.22
Level Two	10.53	6	1.3	0.43
B. Strategies tested against future (2000) loads				
TP=1 mg L^{-1}	1,154.3	29/50***	—	9.67/4.01
TP=2 mg L^{-1} plus Level Two	1,065.3	24/46***	—	10.68/3.95
TN=6 mg L^{-1}**	3,459.1	—	10/26**	4.32/3.03

*Consumer costs only. Does not include O & M savings at POTWs.
**Does not include the Susquehanna
***"x/y"—x is the percent reduction of the existing load, and y is the percent reduction of the future load.

1 mg L^{-1} phosphorus effluent are based on treatment costs to provide activated-sludge treatment and lime addition. Retrofitting costs for a 2 mg L^{-1} phosphorus effluent are based on providing the same treatment as for the 1 mg L^{-1} effluent but with lower O & M costs because of reduced chemical and sludge disposal costs. Costs to obtain a 6 mg L^{-1} total nitrogen effluent are based on wastewater treatment process consisting of activated sludge followed by nitrification and denitrification. Table 4 illustrates additional costs required to retrofit (capital) and maintain (annual O&M) existing secondary-treatment plants with various flows, including the additional cost per contributing household per month. Sludge disposal costs (landfilling) that are associated with a policy to limit phosphorus in effluent are included in the O&M cost estimates.

Potential costs imposed by a policy to limit phosphates in detergents to 0.5 percent by weight (P ban) may cost consumers anywhere from 4.29 to 11.10 dollars per household per year due to the increased use of hot water to achieve the same level of cleaning (Folsom and Oliver 1980). Based on the average of these values (7.69 dollars per household per year), a basin-wide P ban would cost consumers 27.6 million dollars annually, an average of 10.50 dollars per pound of phosphorus removed. Consumer organizations believe that the cost to consumers would be zero. Cost savings, however, may result at sewage treatment plants subject to phosphorus effluent limitations. For example, annual O & M costs associated with effluent limitations would be cut by about 15 per-

TABLE 4.
ESTIMATED COSTS (IN MILLIONS OF 1982 DOLLARS) TO RETROFIT EXISTING SECONDARY TREATMENT PLANTS WITH NUTRIENT REMOVAL CAPABILITY; ADDITIONAL ANNUAL O&M COSTS (IN MILLIONS OF 1982 DOLLARS); AND ADDITIONAL MONTHLY HOUSEHOLD COSTS (IN 1982 DOLLARS). (SOURCE: DERIVED FROM CAPDET COST ESTIMATES, APPENDIX B.)

	Phosphorus			Nitrogen		
Flow MGD	Capital	Annual O&M	Additional $/household/mo.	Capital	Annual O&M	Additional $/household/mo.
1.0	0.77	0.14	5.39	1.63	0.24	9.88
3.0	1.55	0.26	3.47	2.73	0.59	7.47
5.0	2.22	0.38	3.07	3.80	0.95	6.94
10.0	3.63	0.68	2.67	6.17	1.80	6.60
20.0	6.56	1.23	2.41	14.13	3.47	6.37
40.0	12.85	2.31	2.29	23.02	6.79	6.01
80.0	24.27	4.42	2.18	44.03	13.37	5.88
180.0	41.30	9.51	1.96	86.51	29.73	5.69
317.0	62.88	16.39	1.87	144.54	51.95	5.60

cent. In the upper Bay area, these savings are estimated to be 5.1 million dollars annually.

Administrative and Regulatory Point Source Control Options

In addition to technological control options, there are a number of measures dealing with administrative aspects of point source control programs that, if carried out, could result in reduced nutrient loadings. Significant percentages of major POTWs in the Chesapeake Bay basin were found in violation of permit limitations for BOD_5 and TSS; the need for improved enforcement of permit limits has been often cited as a major impediment to pollution control. The need for better sewage treatment plant operators is another issue often raised. Pretreatment of industrial dischargers could improve POTW operations. With respect to construction grants, criteria used in the state priority systems to rank POTW projects could be revised to give more weight to water quality protection and use attainment. These and other issues are discussed below.

Permit compliance and enforcement — Despite a Federal investment of almost 2.5 billion dollars since 1972, plus state and local funds to construct new wastewater treatment plants or to modify and expand existing plants in the Chesapeake Bay drainage area, many are not treating waste water at the efficiency levels they were designed to achieve, as described above. Establishing accountability for new treatment plants to perform according to their design specifications would shift the burden of responsibility for proper operation of the POTW from the municipality (grantee) to an architect-engineering design firm or permitting agency (state or EPA). If the burden were placed on the permitting agency, increased time delays because of a more thorough review of plant design-specifications would have to be weighed against the potential long-term improvements in POTW performance.

Operator training incentives and technical assistance — The leading cause of poor performances by POTWs nation-wide is improper operation and maintenance, according to the U.S. General Accounting Office (1980). One way to improve plant performance and compliance is to improve existing operator training programs and educational materials. In some cases, states have taken action to require training and certification of POTW operators. Operators, however, are often poorly paid and job turnover places an enormous strain on these programs. Raising their salaries and improving job recognition would provide an incentive for better job performance and could reduce the high turnover rate. Providing technical assistance to operators to solve site-specific problems would also improve performance and protect Federal and state investments in POTWs.

Funding levels—The control of municipal sources has been more difficult, complex, and costly than Congress contemplated in 1972. Consequently, in the Chesapeake basin, as in most of the country, there is a remaining backlog of public treatment needs yet to be funded and built. According to the EPA's 1980 Needs Survey, 1.7 billion dollars are needed to address the basin's remaining secondary-treatment municipal sewage treatment needs (U.S. EPA 1981). New funding mechanisms will have to be found now that the combined state and local share of construction costs has been raised from 25 to 45 percent of the total cost.

Priority system for POTW construction grants—The money available to each state for construction grants is allocated within the state through the use of an EPA-approved priority list. Once EPA approves the prioritizing system, then any project within the fundable portion of the resulting state priority list is eligible for funding. Criteria used to rank projects vary in each state. Maryland gives approximately equal weight to pollution abatement, protection of water use, type of facility improvement, and "special program goals." Pennsylvania's system is structured to support water-use objectives established by the state. Virginia sets priorities based on public health impacts, water quality conditions, population, and maintenance of existing high quality waters. Once a state recommends a project for funding, the EPA, or a delegated state, reviews the project to determine whether the specific requirements of the CWA have been complied with. The priority system could be revised at the state or EPA-level to give added weight to criteria regarding the protection of water quality and water use or to projects that would discharge to segments of the Bay targetted for accelerated cleanup.

Grant eligibility—To receive construction grant funding for nutrient removal technology, the EPA's Draft Policy For the Review of Advanced Treatment requires that the proposed treatment works must be shown to result in significant water quality and public health improvements (U.S. EPA 1982b). Such projects must be scientifically supported by an adequate data base and technical studies which demonstrate the relationships between waste load and receiving water quality or public health. For example, the State of Maryland has decided that both nitrogen and phosphorus reductions are needed from POTWs in the Patuxent River basin to improve water quality, based on extensive modeling analyses. The EPA Region III office fully supports the State's prerogative to implement the Patuxent River Basin Plan, even though the EPA does not believe that the studies performed to date provide an adequate technical basis to support nitrogen control in addition to phosphorus control. As a result, if a funding decision were to be made today, Federal Construction Grant funds would only be provided for the cost-effective solution to achieving the technically-justified nutrient effluent requirements, that is, phosphorus removal to 1.0 mg L^{-1}. (One exception to this funding limitation is provided under current policy; additional Federal participation is possible if land treatment is utilized and the costs are not excessive.) More flexibility in this review policy would allow the State of Maryland to test the impact of nitrogen control in a limited region such as the Patuxent. Using the Patuxent as a case study could improve future decisions regarding nitrogen removal for other portions of the Bay where it may be applicable.

Pretreatment—Many industrial facilities use Bay area POTWs to handle their wastes. This practice can cause serious problems at POTWs because toxicants in industrial wastes may contaminate sludge and interfere with biological treatment processes, resulting in inadequately treated wastes. To prevent such problems, Congress directed the EPA to establish pretreatment standards for industries that discharge to POTWs. Due in part to delays in finalizing EPA pretreatment regulations and to the relatively low priority placed on program ~~development, the~~ development of state and local pretreatment programs has been slow. The State of Maryland, however, is expected to start its program in 1983, and the Hampton

Roads Sanitation District has administered a local program since 1977. In terms of nutrients, more emphasis on pretreatment Bay-wide will ensure POTW efficiency.

Monitoring—The adequacy of current monitoring requirements has frequently been called into question. Existing NPDES permits contain monitoring and reporting requirements for conventional pollutant parameters and, in some cases, for heavy metals (e.g., cadmium, mercury, lead). However, in the majority of cases (with the exception of facilities required to remove nutrients), no effluent limits and, therefore, no monitoring requirements have been established for nutrients. To develop accurate estimates of nutrient loads from POTWs, especially the larger facilities, frequent monitoring of nutrient concentrations is essential.

Bypasses and combined sewer overflows—Most systems in the Bay area are not designed to treat stormwater flows. In those communities where storm and sewer systems are combined, such as D.C., Richmond, and the Greater Hampton Roads areas, heavy stormwater flow either bypasses the treatment processes completely or floods through it. In either case, following major rain events, large quantities of sewage and urban stormwater runoff head directly to the Bay, untreated. While very effective in reducing conventional pollutants (BOD_5, TSS, etc.), secondary-treatment is not designed specifically to reduce nutrient loads; consequently, nutrient concentrations in raw sewage are not much greater (about 30 percent) than in treated effluent, so combined sewer overflows (CSOs) or bypasses at these plants do not increase the nutrient load significantly unless they occur often. On the other hand, CSOs and bypasses at POTWs with nutrient-removal technologies would result in significant load increases (e.g., secondary-treated phosphorus concentrations average around 8 mg L^{-1}, four times a limit of 2 mg L^{-1}).

Separation of storm sewers in the older cities with combined systems would be prohibitively costly and enormously disruptive. More selective, less costly measures, however, could be identified and installed to control the frequency, volume, and quality of combined sewer overflow.

Package plants—More and more, new developments provide their own sewage treatment facilities rather than hooking up to POTWs. There is some concern that in the future, these will suffer from O & M neglect and perform poorly. Owners of many small treatment plants or package plants may not assume the responsibility to solve their plant performance problems. As a consequence, their discharges may not be adequately treated and result in local water quality and resource habitat degradation. The adverse impact on habitat may be mitigated with proper treatment of effluent. In Maryland, when contracted by plant owners, the Maryland Environmental Service (MES) provides the technical, financial, and professional staff necessary to ensure adequate treatment or disposal of waste. Their services are available to any political jurisdiction, agency, business, or industry within Maryland. Expansion of this type of service would enable other jurisdictions outside of Maryland to provide adequate treatment of their wastes at a reasonable cost.

Water conservation—Reductions in the volume of waste water to be treated, will enable POTWs to provide longer retention times and better treatment and, most importantly, accomodate the projected population growth without additional construction costs. As a result, a higher quality effluent and an increase in hydraulic capacity can be realized from water conservation, allowing funds to provide these enlargements to be directed elsewhere. Steps that can be taken to bring about a reduction in water usage include eliminating minimum water allowances which establish minimum rates based on a volume of water regardless of whether it was used, and eliminating lower rates for water used in excess of a given volume.

More efficient use of the treatment system limits the frequency of storm overflows and bypasses which carry raw sewage into the water systems. It also reduces the total amount of freshwater withdrawal from the river systems feeding the Bay. Especially during low-flow warm weather periods, limiting upstream withdrawals can be critical to the maintenance of water quality in the lower regions of the Bay area's rivers.

NONPOINT SOURCES AND LOADINGS

Nonpoint sources of nutrients are those that enter waterways in the form of stormwater runoff from agricultural, urban, and forest lands and from baseflow to streams and atmospheric deposition on land and water. The diffuse nature of nonpoint sources makes them difficult both to quantify and control. In addition, nonpoint source loads are largely determined by unpredictable rainfall patterns. In wet years, nonpoint source loads are generally very high and in dry years, they are low.

Within the major river basins discharging to Chesapeake Bay, variations in population, land use, and land management affect the size and nature of non-point pollutant loadings to the Bay. In general, lands located in and around the coastal plain contain the fastest-growing populations and are being used more intensively for residential, commercial, and industrial activities than other parts of the Bay basin. Agricultural lands comprise 29 to 48 percent of the Coastal Plain that lies below the fall line. Above the fall line, agricultural lands are prevalent in the Piedmont Province, especially in the lower Susquehanna (58 percent) and central Potomac (53 percent) River basins. Future increases in urbanization and intensified agricultural activities are expected to occur in the Coastal Plain and Piedmont regions where over half of the basin's population resides. In the Appalachian Ridge and Valley, and the Appalachian Plateau provinces, the predominant land use is forest and low-intensity agricultural activities. More detailed data and a description of methodologies used to estimate land use and population trends are contained in Appendices B and C.

Extensive research was conducted for the CBP to quantify basin-wide nutrient loadings from cropland, pasture, urban, and forest land. Intensive small watershed projects—Pequea Creek, lower Susquehanna (Lietman et al. 1983); Chester River, upper Eastern Shore (Bostater et al. 1983a); Patuxent River (Bostater et al. 1983b); Occoquan basin, Potomac River (Occoquan Watershed Monitoring Laboratory 1982); and Ware River, Mobjack Bay (Anderson et al. 1982)—were conducted to establish nutrient loading factors for use in a nonpoint source runoff model (described in Appendix B and Hartigan et al. 1983). In addition, the U.S. Geological Survey (USGS) monitored water quality for two years at the fall lines of the three major tributaries (Susquehanna, Potomac, and James Rivers) for use in calibrating and verifying the basin model. Land-use data for the entire Bay basin were developed using LANDSAT scenes taken in spring 1977, 1978, and 1979 (for summary of data and methodology, see Appendix B or Hartigan et al. 1983).

The Chesapeake Bay basin model (Hartigan et al. 1983) simulated nonpoint source loadings between March 1 and October 31 because this period is the most important in terms of algal growth in Chesapeake Bay. The USGS rainfall records from a wet year (1975), dry year (1966), and an average year of rainfall (1974) were used in the modeling simulations. The basin model routed these loads from each of 35 sub-basins to the fall line, simulating the processes which transform the pollutants as they are transported downstream. Because point sources above the fall line were also added by sub-basin and routed to the fall line, the percentage of the fall line load attributed to point and nonpoint sources was determined for each tributary. For basins located below the fall line, the 'unrouted' point and nonpoint source loadings determined the total load.

Cropland Loadings

Basin-wide—Modeling results indicate that cropland generates the largest share of the nonpoint source load basin-wide, as shown in Tables 5 and 6. Basin-wide, cropland contributes between 27 and 53 percent of the phosphorus load and 60 and 75 percent of the nitrogen load in average and wet years. Its contribution during dry years was not estimated (although total NPS contributions were estimated). Loadings from cropland in the Susquehanna, Potomac, and James Rivers contribute 60, 23, and 12 percent of the total phosphorus load of each river basin in an average year, and 77, 50, and 29 percent in a wet year. Collectively, cropland loadings from these three rivers represent 19 and 37 percent of the Bay-wide phosphorus load in average and wet years, respectively. Of the nitrogen load from the three major rivers, cropland contributes 85, 48, and 29 percent of the average-year load and 91, 66, and 49 percent of the wet-year load (collectively representing 49 and 51 percent of the

Bay-wide nitrogen load in average and wet years, respectively).

By major river basin — Actual loadings of phosphorus and nitrogen, in pounds, can be compared by basin, as illustrated in Figure 29. It is important to note that in all basins the loadings double between average and wet years. This finding has strong implications for nonpoint nutrient controls; they should exhibit the greatest effectiveness during relatively wet periods, and during dry to average-rainfall years they may not result in nutrient reductions that are proportional to wet-year reductions.

Cropland activities are diverse across the basin, and it is important to note that these loadings are based only on the major factors affecting runoff loads, including tillage (conservation or conventional), soil type, soil moisture, slope, vegetative cover, and rainfall. Other factors, especially fertilizer and manure management, can also have significant influence on runoff. The model in this case estimated the nutrient content of the soil, or potency factor, based on results from the intensive watershed studies; they are accurate to the extent that these represent the variability within each basin. Also, in areas with concentrated livestock or areas receiving high quantities of nitrogen fertilizer, baseflow contributions of nitrogen would be expected to be higher than in other regions. The model, however, used baseflow loadings to help calibrate the model, and these were not estimated for each land use separately, but by sub-basin (i.e., forest produced the same amount of baseflow loadings, on a per acre basis, as cropland for individual sub-basins). Baseflow loadings were included in the estimates for cropland and nonpoint source loads from other land uses on an acreage basis.

The purpose of the basin model was to compare total nutrient loads from various sources among the major sub-basins to evaluate in which areas to focus either point or nonpoint source control efforts to improve Bay water quality. On this basis, it was not necessary to include all of the minor variables affecting nutrient loads from nonpoint sources. The excellent model calibration and verification results (Hartigan et al. 1983) indicate that the nonpoint source loading estimates can be used with confidence in guiding water quality management planning for Chesapeake Bay. Now that the basin model has been developed, it can be refined in the future to include additional data collected at a finer level of detail for planning assessments within individual sub-basins of the Chesapeake Bay drainage area.

Above versus below the fall line — Cropland above the fall line represents a significant portion of the total load under average conditions (46 to 60 percent) and wet conditions (63 to 86 percent) (Table 5) for all basins except the Patuxent, where most of the phosphorus load, even under wet conditions, is of point source origin. Nitrogen loadings from cropland above the fall line (Table 6) represent a greater percentage of the total nutrient load than phosphorus. In individual basins, nitrogen ranges from 72 to 85 percent during average conditions and 78 to 91 percent during wet conditions, with the exception of the Patuxent River basin where cropland supplies 29 and 53 percent of the total average and wet-year loads.

Below the fall line, phosphorus loadings from cropland, by basin, range from 3 to 14 percent in the James River to 50 to 79 percent in the Eastern Shore for average and wet conditions; overall, cropland contributes between 12 and 36 percent of the total below-fall-line phosphorus load. Nitrogen loadings from cropland below the fall line range from 15 and 32 percent in the James during average and wet years to 83 and 92 percent in the Eastern Shore; for the entire area below the fall line, cropland contributes 30 to 54 percent of the total nitrogen load for average and wet conditions.

Other Nonpoint Sources

Runoff loadings from the entire land surface of the basin (forest, pasture, and urban lands) are included in this category, with the exception of cropland. Basin-wide, they contribute only 11 to 12 percent of the phosphorus load and 6 to 7 percent of the nitrogen load under wet and average conditions, respectively. These low percentages, however, do not necessarily indicate that these nonpoint sources, especially urban, are not a problem in Bay waters.

According to LANDSAT analysis, only three percent of the land in the 64,000 square mile

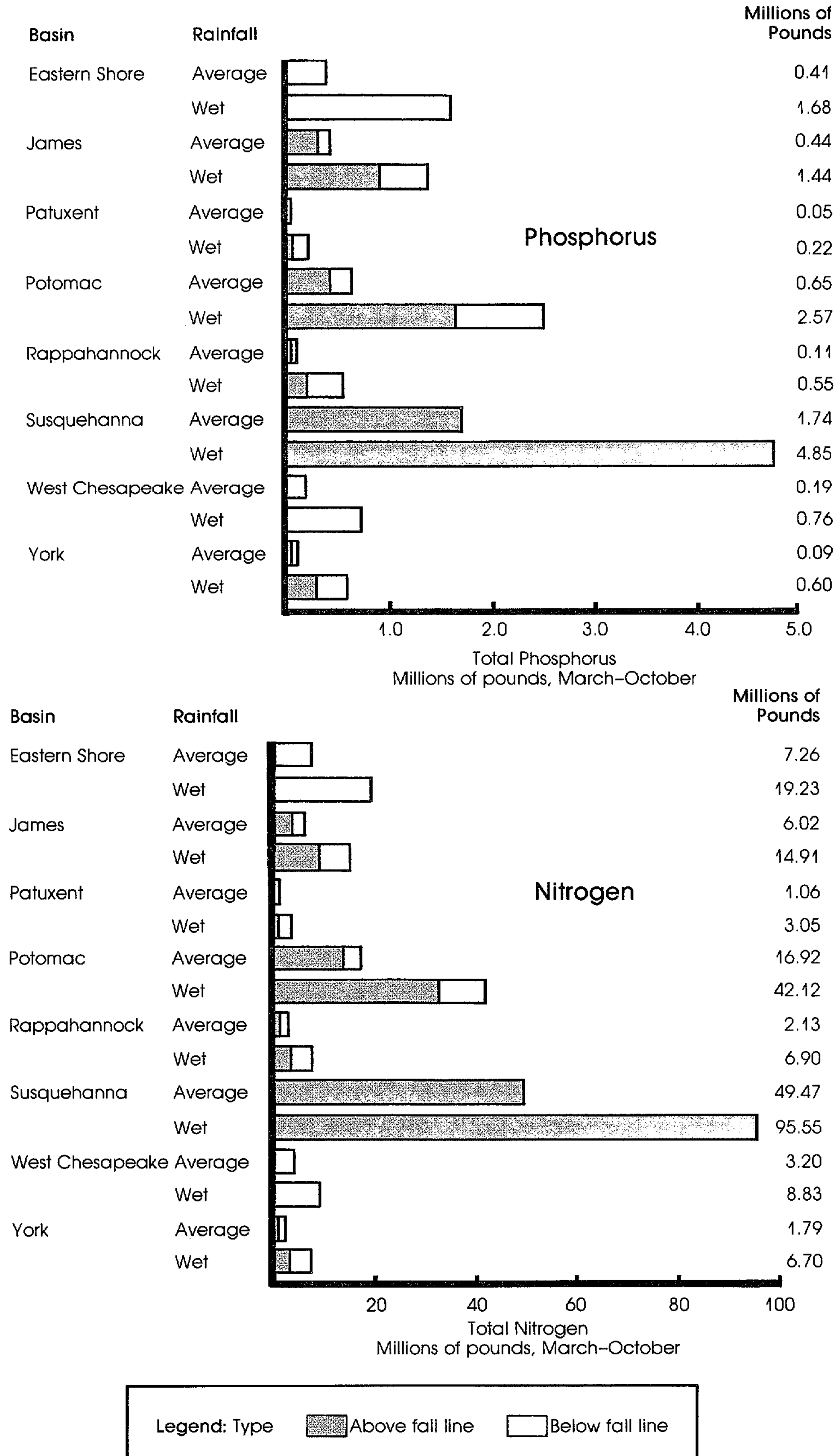


FIGURE 29. Existing (1980) nutrient load from cropland above and below the fall line by basin during average and wet rainfall conditions and 1980 land uses.

TABLE 5.
PHOSPHORUS LOADINGS TO CHESAPEAKE BAY BY MAJOR BASIN (MARCH-OCTOBER)

Basin	Nitrogen (Lbs)			% Point Source Contribution			% Cropland Load Contribution			% Other Source Load Source Contrib.			† Total Nonpoint Contribution		
	Dry	Avg.	Wet	Dry	Avg.	Wet	Dry	Avg.	Wet	Dry	Avg.	Wet	Dry	Avg.	Wet
PART A: AT THE FALL LINE															
Susquehanna	2,070,000	2,900,000	6,300,000	24	23	12	—	60	77	—	16	11	76	76	88
Patuxent	344,000	328,000	383,000	92	90	76	—	7	19	—	3	5	8	10	24
Potomac	717,000	854,000	2,370,000	27	15	7	—	52	72	—	33	21	73	85	93
Rappahannock	107,000	104,000	285,000	1	1	1	—	58	75	—	41	24	99	99	99
York	66,500	78,000	332,000	7	7	2	—	74	86	—	19	12	93	93	98
James	657,000	768,000	1,517,000	45	36	21	—	46	63	—	18	16	55	64	79
TOTAL	3,961,500	5,032,000	11,187,000	33	28	14		53	72		19	14	67	72	86
PART B: TO TIDAL WATERS (BELOW THE FALL LINE)															
W. Chesapeake	2,173,000	2,391,000	3,045,000	93	85	67	—	8	25	—	7	8	7	15	23
Patuxent	130,000	150,000	286,000	79	69	36	—	19	51	—	12	13	21	31	64
Potomac	1,940,000	2,012,000	2,779,000	82	79	57	—	10	31	—	11	12	18	21	43
Rappahannock	119,000	174,000	486,000	89	61	22	—	27	69	—	12	9	11	39	78
York	85,000	143,000	457,000	84	50	16	—	27	68	—	10	8	16	50	84
James	2,915,000	3,023,000	3,453,000	96	93	81	—	3	14	—	4	5	4	7	19
Eastern Shore	760,000	833,000	2,117,000	44	40	16	—	50	79	—	10	5	56	60	84
TOTAL	8,122,000	8,726,000	12,623,000	87	81	56		12	36		7 8	13	19	44	
PART C: PART A + PART B															
Susquehanna	2,070,000	2,900,000	6,300,000	24	23	12	—	60	77	—	17	11	76	77	88
Patuxent	474,000	478,000	669,000	88	83	58	—	10	33	—	7	9	12	17	42
Potomac	2,657,000	2,866,000	5,149,000	67	59	34	—	23	50	—	18	16	33	41	66
Rappahannock	226,000	278,000	771,000	47	39	14	—	39	71	—	22	15	53	61	86
York	151,500	221,000	789,000	50	35	10	—	44	76	—	6	14	50	65	90
James	3,572,000	3,791,000	4,970,000	86	81	63	—	12	29	—	7	8	14	19	37
W. Chesapeake	2,173,000	2,391,000	3,045,000	86	73	49	—	15	39	—	13	12	14	28	51
Eastern Shore	760,000	833,000	2,117,000	44	40	16	—	50	79	—	10	5	56	60	84
TOTAL	12,084,000	13,758,000	23,810,000	69	61	36		27	53		12	11	31	39	64

TABLE 6.
NITROGEN LOADINGS TO CHESAPEAKE BAY BY MAJOR BASIN (MARCH-OCTOBER)

Basin	Nitrogen (Lbs)			% Point Source Contribution			% Cropland Load Contribution			% Other Source Load Source Contrib.			† Total Nonpoint Contribution		
	Dry	Avg.	Wet	Dry	Avg.	Wet	Dry	Avg.	Wet	Dry	Avg.'	Wet	Dry	Avg.	Wet
PART A: AT THE FALL LINE															
Susquehanna	47,300,000	58,200,000	105,000,000	10	10	5	—	85	91	—	5	4	90	90	95
Patuxent	1,268,000	1,180,000	1,780,000	71	65	41	—	29	53	—	6	6	29	35	59
Potomac	13,800,000	16,600,000	39,100,000	10	10	10	—	83	84	—	7	6	90	90	90
Rappahannock	1,530,000	1,600,000	3,710,000	10	10	10	—	72	78	—	18	12	90	90	90
York	693,000	816,000	2,720,000	10	10	10	—	78	82	—	12	8	90	90	90
James	3,872,000	5,076,000	11,070,000	10	9	8	—	73	78	—	18	14	90	91	92
TOTAL	68,463,000	83,472,000	163,380,000	11	11	7		83	88		6	5	89	89	93
PART B: TO TIDAL WATERS (BELOW THE FALL LINE)															
W. Chesapeake	13,594,000	15,984,000	22,084,000	85	72	52	—	20	40	—	8	8	15	28	48
Patuxent	965,000	1,313,000	2,813,000	48	35	16	—	55	75	—	10	9	52	65	84
Potomac	17,807,000	18,477,000	25,067,000	77	74	55	—	17	37	—	9	8	23	26	45
Rappahannock	615,000	1,345,000	4,505,000	37	17	5	—	73	89	—	10	6	63	83	95
York	693,000	1,513,000	4,963,000	34	15	5	—	76	90	—	9	5	66	85	95
James	13,799,000	15,429,000	19,609,000	88	79	62	—	15	32	—	6	6	12	21	3
Eastern Shore	7,191,000	8,741,000	20,901,000	13	10	4	—	83	92	—	7	4	87	90	96
TOTAL	54,664,000	62,802,000	99,942,000	72	62	39		30	54		8	7	28	38	61
PART C: PART A + PART B															
Susquehanna	47,300,000	58,200,000	105,000,000	10	10	5	—	85	91	—	5	4	90	90	95
Patuxent	2,233,000	2,493,000	4,593,000	61	49	26	—	43	66	—	8	8	39	51	74
Potomac	31,607,000	35,077,000	64,167,000	48	44	28	—	48	66	—	8	6	52	55	72
Rappahannock	2,145,000	2,945,000	8,215,000	17	13	7	—	72	84	—	15	9	83	87	93
York	1,386,000	2,329,000	7,683,000	22	13	7	—	77	87	—	10	6	78	87	93
James	17,671,000	20,505,000	30,679,000	71	62	43	—	29	49	—	9	8	29	38	57
W. Chesapeake	9,620,000	12,034,000	22,084,000	78	63	41	—	26	49	—	11	10	22	37	59
Eastern Shore	7,191,000	8,741,000	20,901,000	13	10	4	—	83	92	—	7	4	87	90	96
TOTAL	123,127,000	146,225,000	263,273,000	38	33	19		60	75		7	6	62	67	81

(165,760 km^2) Chesapeake drainage basin is in urban use. Nonetheless, the flushing of pollutants from urban lands during wet weather contributes significant quantities of both conventional and toxic pollutants. Moreover, the largest metropolitan areas—Baltimore, MD; Washington, D.C.; Richmond, VA; and Greater Hampton Roads, VA—are all located in or adjacent to the Coastal Plain and therefore have a great potential for influencing the Bay's water quality. About 7 percent of the Coastal Plain land draining directly to tidal waters is considered urban; in the upland portion of the basin (80 percent of the total Bay watershed) only 1.8 percent of the land is urban. The CBP estimates that urban land use will reach 8 percent by the year 2000 below the fall line and 2.3 percent above the fall line.

By the nature of nonpoint source pollution, loadings enter tidal waters in pulses following rain events. These pulses can temporarily elevate receiving water concentrations of nutrients, sediment, heavy metals, and other conventional and toxic pollutants. In heavily-developed watersheds adjacent to critical habitats, such as tidal-freshwater spawning grounds, temporary changes in water quality can, over the long-term, cause more permanent ecosystem damage. The impact of urban runoff, however, in regions characterized by a mixture of contributing land uses and point sources is very difficult to determine solely on the basis of relative loadings. In urban areas, pollutants that have built up on the land surface between rain events are washed into receiving streams. The length of time between storms, the amount of paved surfaces, housing density, vegetative cover on unpaved surfaces, automobile traffic, and other factors determine urban nonpoint source loads. The watershed model simulated these influencing factors in each river basin to estimate the nutrient contribution to the Bay from urban runoff. However, the nutrient loads from urban runoff, when compared to those from cropland and point sources, are relatively minor on a Bay-wide scale. As a result, the nutrient load from urban runoff was combined with the nutrient load from forest and pasture land uses and presented as "other" nonpoint sources. Nutrient loading factors used in the basin model were based on extensive studies conducted in the Washington, D.C. metropolitan area (Hartigan et al. 1983). Pasture and forest loading factors were developed using data from CBP intensive watershed studies cited above.

Figure 30 shows the actual other-nonpoint source loadings by basin. Other nonpoint source loads in the Potomac River basin approximately equal those from the Susquehanna for both nitrogen and phosphorus. The other NPS loads from the James and West Chesapeake basins follow in magnitude. The Eastern Shore, Rappahannock, York, and Patuxent River basins contribute the remainder.

Future loadings from urban runoff were estimated to determine whether the expected increases in urban land use would significantly raise future nutrient loads. In the area below the fall line, where most of the new development is expected to occur, model estimates of the year 2000 nonpoint-source nutrient loads from all land uses indicate increases of 5.0, 3.0, and 1.4 percent for phosphorus and 2.0, 1.3, and 0.8 percent increases for nitrogen in dry, average, and wet years, respectively. All of this estimated increase is due to expansion of urban land (at the expense of forested land to show the largest possible loading increase) and is based on projected population growth (Appendix B). When compared to future point source load increases, described above, urban runoff increases are not very significant on a Bay-wide perspective. In certain tidal watersheds, however, future urban development could result in sizable nutrient load increases (described in detail in Appendix B). The estimates of future nutrient loads in Chapter 5 include the additional loadings from both POTWs and urban runoff.

THE EFFECTIVENESS OF NONPOINT SOURCE CONTROLS

In general, government agencies and the general public on the whole lack a commitment to reduce pollution from nonpoint sources. While there are many reasons that account for this, some explanations include the low-visibility of nonpoint source pollution as compared to point source pollution, and also the fact that scientific tools to estimate loadings from nonpoint sources were developed just in the last decade. The Clean Water Act of 1972 attempted to balance the lop-

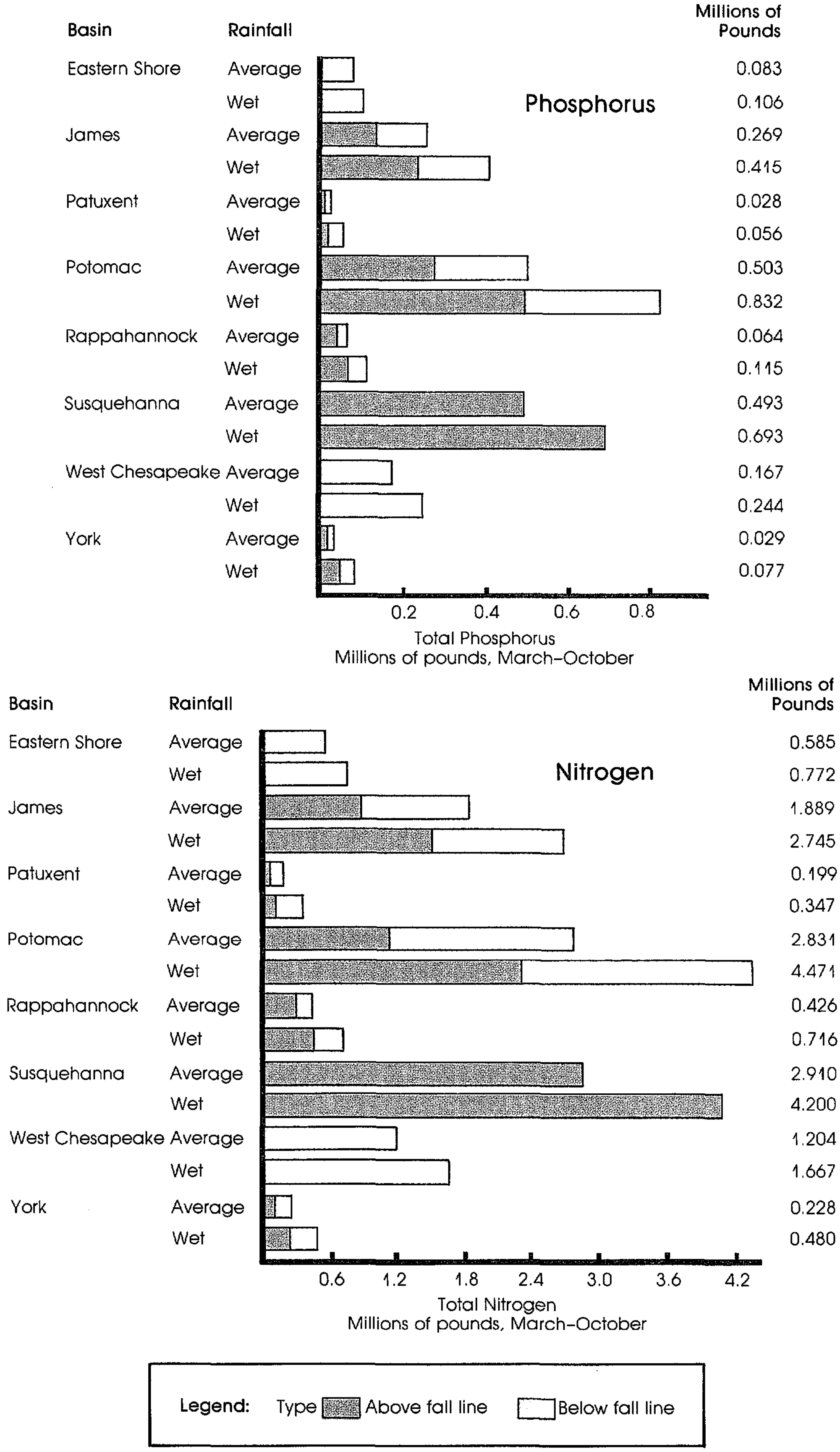


FIGURE 30. Existing (1980) nutrient load from other land uses above and below the fall line by basin during average and wet rainfall conditions and 1980 land uses.

sided approach toward pollution control by requiring Section 208 Water Quality Management Plans to evaluate both point and nonpoint sources of pollution in a given area and to develop strategies to deal with nonpoint sources more specifically. By 1980, most area-wide and state-wide 208 plans had been prepared and these recommended, in some cases, very specific actions. In other cases, general guidance on agricultural, urban, and silvicultural nonpoint source and management is recommended. The following discussion focuses on the control of agricultural sources, the largest nonpoint contributor of nutrients to Chesapeake Bay, and highlights what has been accomplished toward urban runoff management.

Agricultural Runoff

The 208 process has been successful in bringing together agencies that for many years have dealt with either soil and water resource protection or water quality management. In the U.S. Department of Agriculture (USDA), both the Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS) have over 40 years experience in working with farmers to curb soil erosion and to conserve water. State agencies dealing with water quality, sediment and erosion control, health, fisheries, etc. were involved in 208 planning to varying degrees (see Appendix E for more detail). In addition, local governments, with authority over land-use planning, zoning, soil conservation, sediment and erosion control, stormwater management, etc., assisted in the development of 208 plans. While the process helped tremendously to educate, focus attention, and instigate research on agricultural, urban, and silvicultural runoff, it has not generally resulted in strong programs to reduce nonpoint source loadings.

State-wide 208 plans to deal with agricultural runoff were developed to identify critical problem areas; select suitable techniques, or best management practices (BMPs), to reduce pollution; and to designate management agencies responsible for agricultural nonpoint source planning and implementation. All three states in the Chesapeake Bay basin have completed their plans. All are voluntary approaches to nonpoint source control with one exception: Pennsylvania requires all farmers to submit an erosion and sedimentation control plan for approval. This regulation, however, is enforced only on the basis of complaints of water pollution impacts. While Maryland and Virginia do not require such conservation plans, both states have laws requiring a farmer to apply the necessary BMPs if his farm is the cause of a water quality problem.

State Agricultural Water Quality Management Efforts—The states' approaches toward agricultural nonpoint source management vary greatly from one state to another, in contrast to state point source control programs which are administered using fairly uniform structures based on Federal regulations. Therefore, the effectiveness of present agricultural nonpoint source programs must be evaluated in terms of each state's programs and accomplishments, described below. Summaries of additional nonpoint source programs are included in Appendix E.

Virginia—The Virginia Soil and Water Conservation Commission (SWCC) is the lead management agency in Virginia for agricultural runoff. The State Water Control Board (VA SWCB) has also been actively involved in the preparation and implementation of the state-wide, voluntary 208 water quality management plan for agriculture (VA SWCB 1980a). A Best Management Practices Handbook for Agriculture was prepared by these two agencies, the SCS, and other organizations to assist farmers and soil conservation districts in reducing nonpoint source runoff (SWCB 1979a). The districts are the designated local lead management agencies.

The SWCB, in addition, conducted an assessment of potential nonpoint sources of pollution in cooperation with the SCS. This project was conducted in three phases over a two-year period for agricultural as well as forestry-related water pollution. In phase three, the two agencies selected 26 small watersheds which showed a high potential for contributing to water quality problems, of which 11 are situated in the Chesapeake Bay basin (SCS 1983a). Each watershed, listed in Table 7 and illustrated in Figure 31, was examined to determine the severity of water pollution originating from soil loss, animal waste, fertilizer, herbicides, and pesticides. The total cost to install

TABLE 7.
POTENTIAL CRITICAL WATERSHEDS DEVELOPED BY STATE-WIDE WATER QUALITY MANAGEMENT PLANS

VIRGINIA

Potomac River Basin
- Dry Run
- Happy Creek
- Passage Creek
- Lower and Upper S. Fork Shenandoah River
- Lower and Upper N. Fork Shenandoah River
- Christians Creek
- Opequon Creek
- Upper Goose Creek
- Holmes Run—Difficult Run
- Cedar Run—Kettle Run
- Westmoreland County

Eastern Shore
- Exmore area

Rappahannock River Basin
- Mine-Walnut Runs
- Conway River

Additional data on these watersheds are included in SWCB (1980) and SWCB (1983)

MARYLAND

Potomac River Basin
- Double Pipe Creek
- Lower and Upper Monocacy R.
- Seneca Creek
- Main Stem of Potomac R. (Frederick & Montgomery Co.)

West Chesapeake
- Liberty Reservoir
- Loch Raven Reservoir
- South Branch Patapsco River
- Prettyboy Reservoir
- Little Gunpowder River
- West River

Eastern Shore
- Lower Elk River

Additional data on these watersheds are included in Maryland State Soil Conservation Committee (1979)

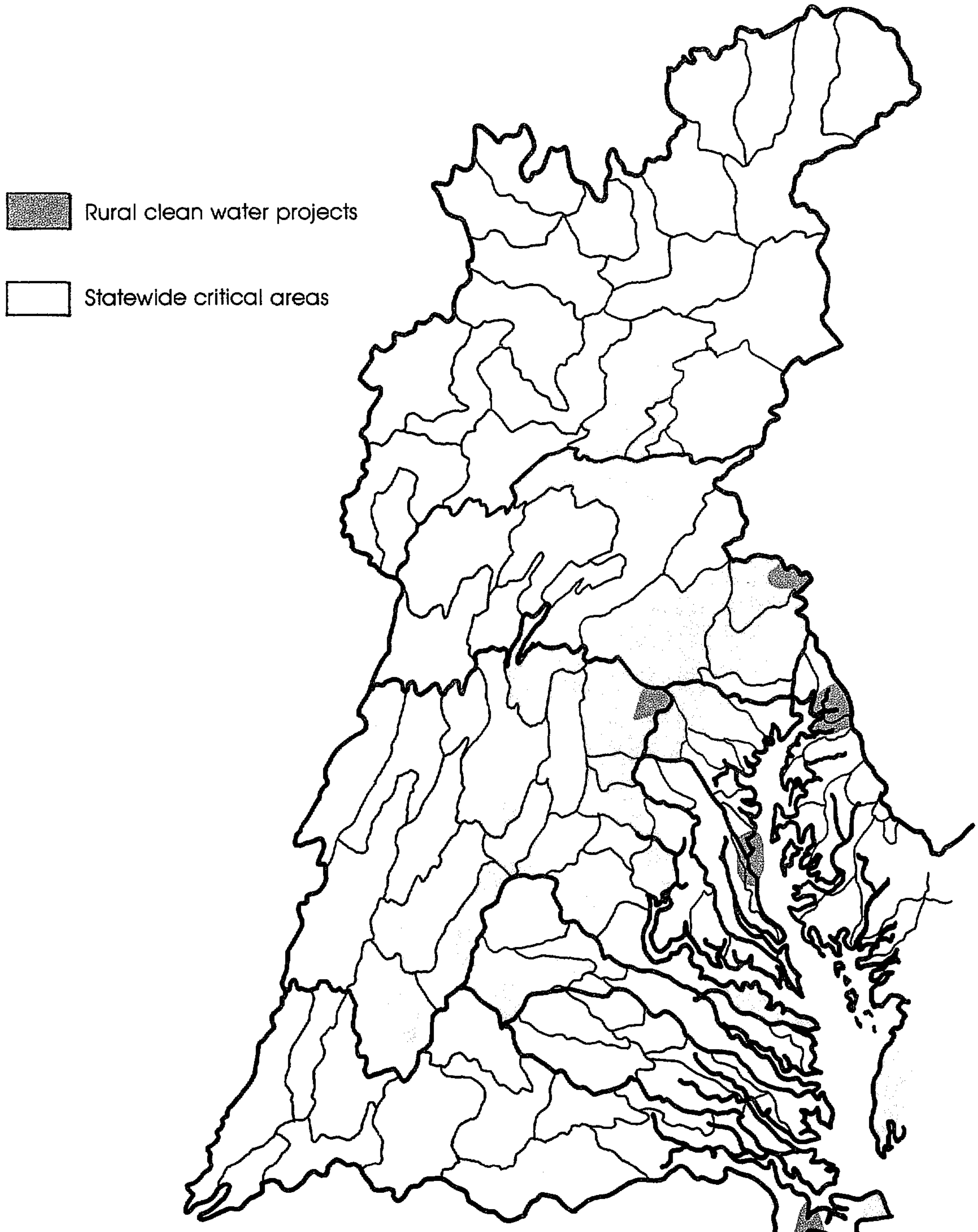
PENNSYLVANIA

Susquehanna
- East side of River from Staman's Run to and including Conestoga Creek
- Conewago Creek
- East side of River from Swatara Creek to and including Staman's Run at Washington
- East side of River from Conestoga Creek to Maryland state line
- From Conewago Creek to and including Codorus Creek
- West side of River from Codorus Creek to Maryland state line
- West side of River from Sunbury to north of Mahantango Creek
- East side of River from Loyalsock Creek to Sunbury
- West side of River from Mosquito Creek to Sunbury

Potomac
- from Green Ridge to eastern basin boundary
- from Cove Mountain to Green Ridge (at Blue Ridge Summit)

Eastern Shore
- Elk and Northeast Creeks

Additional data on these watersheds are included in PA DER (1979) and PA DER (1983)



Virginia— Agricullitural Nonpoint pollution assessment of selected Virginia Watershed (combined Phase II & Phase II Watersheds) SCS/State Water Control Board, 1983.

Maryland— Statewide Critical Areas for Nonpoint Sources of soil erosion and animal wastes—Method of Selection, Md State Oil SoilConservation Committee, 1979.

Pennsylvania—Statewide plan for agriculture and earthworming activities. Pennsylvania Bulletin, 1979.

FIGURE 31. State-wide critical areas for agricultural runoff pollution in Pennsylvania, Maryland, and Virginia located within Chesapeake Bay drainage area.

needed BMPs and to provide technical assistance, water quality monitoring, soil tests, and information in the 11 priority watersheds in the Bay basin was estimated at nearly 30,000,000 dollars or 6,800 dollars per farm, over a combined priority-watershed acreage of 1,025,000 acres, or 29.27 dollars per watershed acre. To put this estimate in perspective, the ASCS Agricultural Conservation Program (ACP) cost-sharing funds allocated to the entire State of Virginia (covering 25.5 million acres of which approximately 54 percent drain to Chesapeake Bay) amounted to 2,681,917 dollars in fiscal year 1979 and 3,916,394 dollars in fiscal year 1983.

Maryland—Maryland's State Soil Conservation Committee (MD SSCC) is the designated management agency for coordinating and guiding the implementation of the Maryland State-wide Agriculture Water Quality Management Program for the Control of Sediment and Animal Waste (MD DNR 1979). Soil conservation districts have the lead responsibility for implementing soil-conservation and water-quality plans on a priority basis in critical areas. The MD SSCC identified 13 critical watersheds on the basis of sediment and bacteria severity scores (Table 7 and Figure 31). The MD SSCC (1981) estimates that 24 million dollars would be needed to implement BMPs in the top three priority watersheds. Maryland's allocation of ASCS-ACP funds totalled 2,070,000 dollars (including long-term agreements and special projects) in fiscal year 1983. Soil conservation districts in Maryland worked with landowners to apply conservation practices on 23,200 acres of farmland in 1980. At this rate, it would take 197 years to protect the 1.1 million acres of crop and pasture land needing treatment in Maryland. The Office of Environmental Programs, Department of Health and Mental Hygiene, estimates that at least 90 million dollars are needed to address soil erosion and animal-waste needs in Maryland (Maryland Department of Legislative Services, in press).

Districts are now focusing on areas with the greatest potential for pollution, but much remains to be done according to a recent MD SSCC assessment (1981). The report notes that "the amount of assistance currently obtainable, both cost-sharing, and technical, is not sufficient to meet the goals of the Maryland Agricultural Water Quality Program." To develop conservation plans on 40 percent of the operating units in the districts' critical areas would require an additional 20 soil conservationists and 35 technicians, at a cost of over 1 million dollars per year.

To increase the availability of funds needed to implement BMPs in priority areas, the Maryland legislature approved an agricultural cost-sharing water pollution control program in 1982 with a 5 million dollar budget. This program supplements the Federal cost-sharing program and is designed to assist farmers in priority areas in implementing BMPs to lessen water pollution caused by nutrients, sediment, animal wastes, or agricultural chemicals. Regulations, adopted in June, 1983, were established jointly by the Maryland Departments of Agriculture (MDA) and Health and Mental Hygiene (MD DHMH 1983). The MDA and soil conservation districts will implement the program.

In addition to the State-wide Agricultural Water Quality Management Plan, Section 208 river basin plans were developed for other areas of the state not included in these two regional plans. The 208 Water Quality Management Plan for the Patuxent River Basin (MD DHMH 1983) is note-worthy because it has been prepared with the Patuxent River Policy Plan (Patuxent River Commission 1983) to ensure that the programs work together to accelerate the development of a watershed approach to planning. If successful, these two plans will guide Maryland efforts toward integrated watershed planning in other river basins of Chesapeake Bay. The policy plan contains watershed-wide policies directed at agricultural runoff control. These include the establishment of: 100-foot wide filter strips along the streams and river banks, accomplished through conservation easements; incentive and compensatory programs such as cost-sharing and education; annual reports from soil conservation districts that document current efforts and accomplishments in critical areas, obstacles encountered, further actions that are needed, etc. The plan urges the MDA to work with the districts to direct all cost-sharing funds to critical areas. The plan also stresses that conservation plans should be prepared and carried out for all publicly-owned lands in the watershed that are leased for agricultural operations and that prime agricultural land should be reserved from intense development to maintain water quality.

Pennsylvania — Pennsylvania's State-wide 208 Plan for Agriculture and Earth-moving Activities [Pennsylvania Department of Environmental Resources (PA DER) 1979] is based upon the 1970 Clean Streams Law of Pennsylvania which provides the PA DER with authority to regulate any activity that creates a danger of pollution. These regulations stipulate that all farmers must have either an erosion and sedimentation control plan or have applied to their county conservation district for the plan; the implementation schedule in the plan must be followed, and plans must reflect current operations. These regulations have not been enforced, however, and as the data in Appendix C indicate, about half the farms lack plans, while a small percentage of the remainder have up-to-date or implemented plans.

In addition, the state-wide plan incorporated existing state regulations concerning manure management, and herbicide and pesticide control. Manuals for agricultural soil erosion control and manure management were developed in 1974 and 1977, respectively. The State-wide Plan for Agricultural and Earth-moving Activities also identified 21 high-priority watersheds (9 of which are located in the Susquehanna River basin and 2 in the Potomac River basin) shown in Table 7 and Figure 31, and 26 medium-priority watersheds (10 in the Susquehanna River basin).

In June 1983, the Bureau of Soil and Water Conservation, DER, published an "Assessment of Agricultural Nonpoint Source Pollution in Selected High Priority Watersheds in Pennsylvania" (PA DER 1983). This document evaluated 10 of the high-priority watersheds (including 4 Susquehanna and 1 Potomac River watersheds) to identify potential nonpoint sources of agricultural pollution, to develop recommendations to prevent these potential sources from creating water pollution problems, and to develop an educational program to encourage BMP implementation. The study identified two major on-farm problems — soil and nutrient management. Soil management problems include lack of BMPs on rented land, high soil loss on half of the farm acreage with conservation plans, a high percentage (60 percent) of row crops on farmland, traditional reliance on conventional tillage, and over-grazed pasture lands. The study found the following nutrient management problems: poor use of soil test recommendations; over-applications of manure and commercial fertilizers; and inadequare animal-waste control measures. The major recommendations of the report suggest:

Special cost-sharing for chronic problems;

- Tax incentives to reduce the financial burden on landowners who apply best management practices;
- More research to improve nutrient testing and application and tillage equipment;
- Installation of stream-improvement devices to reduce bank erosion and livestock use;
- Installation of livestock-waste facilities for improved storage, application, and distribution of manure;
- Increased technical and financial assistance to improve livestock-holding areas that prevent uncontrolled runoff; and
- Continuation and initiation of water quality monitoring programs in selected watersheds to determine the impact of agricultural pollutants on stream ecology.

Summary

The above review of selected state nonpoint source management efforts indicates that much progress has been made in placing increased emphasis on nonpoint problems, evaluating critical watersheds, and identifying appropriate BMPs. The states' voluntary agricultural runoff control programs, however, have not resulted in increased implementation of BMPs, with the major exception of the three EPA/USDA Rural Clean Water Program (RCWP) projects. These projects — Conestoga Headwaters, PA, 16,000 critical acres; Double Pipe Creek, MD, 18,180 critical acres; and Nansemond-Chuckatuck Rivers, VA, 18,750 critical acres — have together received 7.4 million dollars for targetted cost-sharing, education, and technical assistance. While these projects should result in the installation of needed measures, quantify the effectiveness of specific BMPs, and alleviate water quality problems within local waterways, it is less likely that they will result in measurable reductions in sediment and nutrient loadings to Chesapeake Bay waters. CBP nonpoint source modeling results suggest that many more of these intensive projects are needed to reduce substantially the loading to the Bay.

Figure 31 illustrates the location of state-wide potential critical watersheds identified by each state (Table 7) as well as the three RCWP watersheds. Every acre in these broad regions, centered around the Piedmont Province, does not contribute excessive amounts of nutrients or sediment; nonetheless, Figure 31 indicates that, collectively, the critical watersheds are not isolated regions. Implementation of BMPs in these areas has not been possible largely because of the lack of adequate cost-sharing, education, and technical assistance resources, as well as other incentives to encourage BMP adoption. The cost to apply needed BMPs in critical watersheds was estimated (discussed below); however, alternative financial mechanisms to obtain the necessary resources have not been fully explored by the states. A concerted effort to reduce agricultural runoff pollution, with the goal to improve Chesapeake Bay water quality, and not simply local freshwater streams, is also currently missing from the state-wide 208 plans.

Another oversight of the state plans deals with the identification of BMPs. The BMPs selected by the 208 process are primarily oriented toward soil loss and animal-waste control. While these BMPs will reduce phosphorus and nitrogen loadings to varying degrees, they are designed primarily for sediment and bacteria control rather than nutrient control. There is a need, especially in light of CBP findings concerning increases in nutrients to the Bay, that BMPs which are particularly effective in reducing nutrients be identified and incorporated into 208 plans.

Scientific, Economic, and Administrative Issues — An evaluation of agricultural nonpoint source programs must look beyond specific 208 planning efforts to scientific, administrative, and economic factors that could potentially impede or improve the progress of these programs.

Scientific Uncertainties — The effectiveness of certain programs to reduce nonpoint source pollution from agricultural activities has been limited by a high degree of scientific uncertainty. The Pennsylvania State-wide Plan for Agriculture and Earth-moving Activities (1979), for example, states that the effectiveness of its erosion and sedimentation control program "cannot be affirmatively demonstrated with any existing water quality data." The plan also states that unless at least ten years of water quality data collected prior to program implementation and at least ten years of data collected following program implementation were available, meaningful conclusions could not be drawn regarding effectiveness; even with sufficient data, assumptions must be made to distinguish between natural and man-made sediment and nutrient contributions. With recent improvements in nonpoint source runoff models and receiving water quality models, management and planning agencies are now able to test the relative effectiveness of specific BMP strategies before implementing them. Although models will help in developing successful runoff control programs, the actual effectiveness in terms of water quality improvements can be determined only through long-term monitoring of the quality of the receiving water.

Other indicators of the effectiveness of runoff controls can be evaluated, however, such as the number of acres needing treatment to meet tolerable levels of soil loss, the number of acres covered by conservation plans and how many of these plans are up-to-date and being followed, the number of farmers testing their soils for the correct amounts of fertilizers and manure needed for application, the percentage of leased land that is adequately protected, and so forth. Some of these indicators were evaluated by the CBP, in cooperation with the SCS, and are presented in Appendix C of this report. In summary, data collected from soil conservation districts in Maryland and Pennsylvania indicate that soil loss exceeds tolerable levels in most areas; the percentage of district cooperators (farmers who have developed conservation plans with the help of the local soil conservation district) who have updated, implemented conservation plans is low — especially in rapidly developing counties where district resources are also utilized for reviewing sediment and erosion control permits for construction earth-moving activities; farmers who lease farmland generally install far fewer conservation practices than on their own land because of the short-term nature of leases; and animal-waste handling and storage facilities are needed in areas with concentrated livestock operations. As indicators, these data infer that the voluntary approach toward agricultural nonpoint source control may not be sufficient to achieve a tolerable level of runoff control. On the basis of this report, much clearly remains to be done toward adequate agricultural runoff management. Scientific uncertainties still remain and will continue to hinder the effectiveness of agricultural nonpoint source management programs. Unresolved questions include:

- The processes of dissolved nutrient movement;
- Relationships between sediment transport and water quality, specifically an understanding of the relative rates and volumes delivered to the Bay from land-use activities, receiving water channels, and shorelines under different storm frequencies and intensities in each major sub-basin;
- The relative magnitudes of nutrient loadings associated with various levels of erosion and sediment delivery and how these vary throughout Chesapeake Bay basin;
- What happens to nutrients attached to sediments after being transported to the Chesapeake Bay and what is the short and long-term bioavailability of these nutrients;
- Suitable techniques for analyzing nitrogen content in soil to develop optimum fertilizer application rates;
- Whether alternative types of fertilizer materials and application methods increase or reduce nutrient loadings; and
- Techniques to pinpoint individual sources (i.e., farms) of agricultural pollution for enforcement purposes.

Lack of priority setting—A major failure of the districts has been that available staff and financial resources have not been directed toward solving the most critical erosion problems in any area. Instead, districts have tended to provide assistance on a first-come, first-served basis. The districts are busy enough working with those willing to cooperate, regardless of the severity of the erosion or runoff problems of farmers who do not voluntarily seek assistance. This policy is slowly changing, however. With fewer Federal cost-sharing and technical assistance funds, and with the targetting of critical watersheds, improvements in setting priorities are becoming evident.

A problem related to the lack of priority setting is insufficient record-keeping by conservation districts in their efforts to encourage the installation of erosion and animal-waste control practices. Two recent documents dealing with agricultural runoff in the Chesapeake Bay basin (Patuxent River Policy Plan, July 1983; Assessment of Agricultural Nonpoint Source Pollution High Priority Watersheds in Pennsylvania, June 1983) site the need for districts to keep improved records of their accomplishments to assess program effectiveness and to redirect their operations, if necessary to meet goals. This issue was also highlighted in a national report on the implementation status of state 208 programs (U.S. EPA 1980). The report indicated the need to produce a statement of objectives or goals, by which the programs the states have developed can be judged, that are tied to milestones. Such milestones would provide the needed incentive for states and districts to focus educational, financial and technical assistance—the key elements of a voluntary approach—on the implemention of measures required to meet goals. The report further suggests that deadlines for evaluating implementation measures be established when voluntary methods are shown not to be successful.

Limited Financial Incentives—Cost-share funding available to farmers is another major economic constraint on agricultural BMP installation. As mentioned, at current rates of cost-sharing assistance, it would take nearly two hundred years to address conservation needs, assuming that other incentives for adopting BMPs remain constant. Cost-sharing is one of the primary incentives for accelerated implementation of nonpoint source control practices on farmland. Unlike other sources of water pollution, such as industries or municipal sewage treatment plants, farmers do not receive tax relief for installing pollution control measures and cannot pass on the cost of control to consumers because individually they have little influence on the price of their products. Farmers generally must shoulder the cost of capital improvements, including BMP installation, unless cost-share funding can be acquired.

Present Federal agricultural cost-sharing and technical assistance programs are not sufficient to meet conservation needs. The maximum Federal cost-sharing assistance (3,500 dollars per farm per year) is adequate to meet conservation needs on most farms, but it is not sufficient to meet the conservation needs on farms needing animal-waste handling and storage facilities which can cost between 10,000 and 100,000 dollars.

State assistance, such as the 5 million dollar agricultural cost-sharing program in Maryland, will provide some additional assistance. The Maryland State Soil Conservation Committee, however, has estimated that it will need approximately 24 million dollars to abate soil erosion and animal-waste problems just in the top three critical areas of the state. Virginia and Pennsylvania have not adopted cost-sharing programs. In Virginia, 30 million dollars are needed to achieve tolerable soil and nutrient losses in the state's priority agricultural watersheds draining to Bay waters (Table 8).

The SCS has developed a proposal to address a large portion of the critical watersheds in the Piedmont region of Maryland and Pennsylvania, the Mason-Dixon Erosion Control Area (SCS 1983b). This area includes parts of the lower Susquehanna, upper Eastern Shore, West Chesapeake, upper Patuxent, and Potomac River basins, as well as part of the Delaware River basin. Of the 14 counties in the Pennsylvania portion, nine drain to the Bay, and all of the eight Maryland counties in the project are located in the Chesapeake drainage area. The SCS has allocated 700,000 dollars in targetted technical assistance funding for fiscal year 1984 to this region; the estimated cost to apply needed resource management systems to the entire region is 21 million dollars per year for 10 years. For the portion of this area within the Chesapeake Bay basin, the cost is estimated at about 15.7 million

TABLE 8.
COST ESTIMATES OF RESOURCE MANAGEMENT SYSTEMS IN SELECTED[1] VIRGINIA WATERSHEDS (SCS-SWCB 1983)

	Acreage	$/Farm	$/Watershed/Acre	Total Cost[2]
Cedar-Kettle Runs	72,778	$ 8,388	$14.98	$ 1,090,500
Christians Cr.	66,290	4,063	33.72	2,234,850
Conway R.	112,190	7,604	24.26	2,722,250
Happy Cr.	14,189	3,672	8.28	117,500
Lower S. Fork Shenandoah R.	99,449	2,024	6.73	670,200
Mine-Walnut Cks.	76,220	4,121	20.16	1,537,300
Opequon Cr.	95,280	5,191	18.74	1,785,750
Passage Cr.	47,484	8,831	22.13	1,051,000
Upper Goose Cr.	161,842	4,375	22.33	3,614,260
Upper N. Fork Shenandoah R.	228,215	11,941	52.06	11,881,000
Westmoreland	50,669	9,287	58.10	2,944,000
Total	1,025,000[3]	$ 6,777	$29.27	$29,648,610

[1]11 out of 26 Priority Watersheds for Agriculture.
[2]Includes cost-sharing, owner/operator expenditures, technical assistance, water quality monitoring, soil tests, and education.
[3]7.5 percent of Virginia's Bay drainage area

dollars per year over 10 years (9.6 million dollars in Pennsylvania and 6.1 million dollars in Maryland), as shown in Table 9. Based on existing program funding, the SCS estimates that, over the entire region, an additional 9.1 million dollars per year in cost-sharing assistance and 34 additional personnel are needed. Like the state 208 agricultural plans, the needed funding for implementation of BMPs has not been provided as yet.

Increased cost-sharing funding at the Federal or state level, in addition to some other financial incentives, is one of the most important components of an accelerated effort to meet soil conservation and nutrient runoff control needs. State and local governments should look more seriously at the establishment of innovative financial incentives or disincentives for agricultural pollution controls. A recent conference on Chesapeake Bay management held for Maryland legislators discussed the feasibility of instituting user fees, dedicated taxes, and a trust fund for agricultural pollution control efforts (Maryland Department of Legislative Services, in press). Other measures could be explored to limit additional government expenditures. For example, Federal taxation of local cost-share assistance is a disincentive to BMP installation; the EPA, the U.S. Treasury Department, and the Council on the Environment could evaluate existing disincentives in the Internal

TABLE 9.
COST ESTIMATES FOR ACCELERATED SOIL CONSERVATION IN THE MASON-DIXON EROSION CONTROL AREA, ADJUSTED TO THE CHESAPEAKE BAY BASIN (SCS 1983)

Acreage Proposed for Treatment in Mason-Dixon Erosion Control Area

		Chesapeake Bay Basin Portion	
	Entire Area	**Pennsylvania**	**Maryland**
Total Cropland (acreage)	2,796,527	1,291,568	794,960
Cropland Needing Treatment (acreage)	1,833,642	839,519	532,623
Cropland Proposed for Treatment			
at $ 178 per acre[1]	1,085,315	496,904	315,254
at $ 89 per acre[2]	187,082	85,654	54,342
Total Estimated Treatment Cost	**$ 209,836,368**	**$ 96,072,118**	**$ 60,951,650**
Estimated Number of Operating Units	24,351	11,519	6,500
Total Cost per Unit	$ 8,617	$ 8,340	$ 9,377
Treatment Cost per Year for 10-Year Program	**$ 20,983,637**	**$ 9,607,212**	**$ 6,095,165**

[1]Total cost to apply resource management systems.
[2]Total cost to apply benefitting conservation practices.

Revenue Code and propose changes to encourage land-owner investment in BMPs. It is essential for any program to integrate water quality-based practices with Federal soil conservation programs (U.S. EPA 1980).

Priority of Education—For voluntary programs to achieve maximum success, a strong educational effort is crucial. While cooperative extension agencies provide an excellent network for education, their programs work toward many ends, and the reduction of agricultural runoff is one of several. Current educational programs could be strengthened to reach more farmers and inform them about the effects of runoff on water quality and the range of BMPs that can be utilized to curb loadings. Educational and public-awareness efforts should be used more aggressively to increase the number of farmers with conservation plans. Through wide publicity and by encouraging participation, cooperative extension services could take the fullest advantage of demonstration projects, model farms, and other means to convince farmers of the benefits of BMPs to them and to water quality improvement; to describe techniques used to implement BMPs; and to document the need to control runoff. An aggressive education campaign in an Indiana watershed draining to Lake Erie utilized demonstration projects on model farms and resulted in significant adoption of BMPs by local farmers (Morrison 1983). Descriptions and results of special projects funded by the SCS and the three Rural Clean Water Projects in the Bay region could be publicized outside of their immediate areas for greater exposure. Pennsylvania's high-priority watershed assessment (PA DER 1983) places strong emphasis on a coordinated educational program to promote conservation tillage and other low-cost BMPs, the protection and maintenance of riparian vegetation, sound nutrient application and management, BMPs for pasture improvement, proper pesticide and herbicide handling and application, and integrated pest management.

Changes in Federal Agricultural Programs—The Soil and Water Resource Conservation Act of 1977 (RCA) was passed amidst concern that present soil conservation efforts were not being adequately administered. The act formalized a process to review annually soil and water conservation goals and program performance. It was also designed to develop programs to address these goals effectively. Appendix C includes responses from Maryland and Pennsylvania concerning goals outlined in the RCA Report (1980) and describes the USDA's preferred program to improve efforts to deal with soil conservation. Appendix E includes maps of nonpoint source problem areas in Bay-area states and specific projects funded by the EPA to address these problems.

Urban Runoff

Research conducted by the Chesapeake Bay Program indicates that a primary cause of degraded water quality in populated areas is urban runoff. In particular, stormwater runoff from the four largest cities in the drainage basin (Baltimore, Washington, Richmond, and Hampton-Norfolk) carries relatively high concentrations of pollutants such as sediment, nutrients, bacteria, heavy metals, and oil and grease. Because the four fall-line cities drain into the tidal-fresh zones of the Bay where prime spawning grounds for much of the biological resources are located, they have the potential to place long-term stress on the system. Similarly, the Hampton Roads area drains into the lower James River and, while this more saline area is less sensitive to pollutants than the tidal-fresh zones, the potential for long-term impacts is an important consideration because the receiving water contains one of the most productive oyster regions in the Bay.

The problem of urban runoff is not unique to these four major metropolitan areas. For example, field studies in the Occoquan River basin in Virginia indicate that urban land-uses contribute more nitrogen and phosphorus to receiving waters than do most rural-agricultural land uses (Northern Virginia Planning District Commission 1979). The main focus of current urban runoff control programs lies in the growing portions of urban centers where they are designed to minimize sediment loss from construction sites and to mitigate future impacts of increased volumes and rates of discharge through proper development and site planning. In general, it is more difficult to control urban runoff in already-established urbanized areas where stormwater quantity and quality management may require large-scale retrofitted, structural solutions, as opposed to pre-development stormwater planning in developing areas.

To date, governmental efforts to deal with urban runoff have been directed largely toward determining urban nonpoint source loads and identifying effective control measures. This has contributed to a greater awareness of the problem and what needs to be done to reduce it. However, very few regulatory programs have been initiated. In addition, many of the programs currently in place have not been vigorously implemented.

Federal Programs: The Environmental Protection Agency—In 1978, the EPA initiated the Nationwide Urban Runoff Program (NURP). The program's major objectives were to collect the necessary data to assess urban nonpoint-source problems and evaluate the impacts of those sources on receiving water quality. The program was also designed to identify and evaluate various BMPs which could be utilized to control the pollution from urban runoff. As part of this program, major studies, discussed below, were completed in 1983 in the Washington, D.C. and Baltimore areas.

The EPA has also dealt with urban runoff planning and management through three other programs. Under Section 208, a number of "area-wide," or metropolitan area water quality management plans were developed. Area-wide 208 plans in the Baltimore, Washington, D.C., and Greater Hampton Roads areas have all been completed (Regional Planning Council 1980, Metropolitan Washington Council of Governments 1978 and 1980, and Hampton Roads Water Quality Agency 1979). The EPA has the authority to grant NPDES permits for separate storm-sewer discharges, although none have been issued. The EPA also estimates the cost to treat separate storm sewers; in the 1980 Needs Survey, the cost was estimated at 114 billion dollars (U. S. EPA 1981).

State and Local Programs—States and local governments are more active in regulating urban runoff through programs authorized by state and local ordinances. Current state efforts fall into two broad categories of requirements for communities or counties: sediment and erosion control and stormwater control ordinances. In most states, urban stormwater control has been left a matter of local decision although, in 1983, Maryland enacted state-wide regulations for the control of stormwater quality and quantity. Pennsylvania has enacted a law requiring local stormwater control plans, but the lack of state funding has limited its implementation. All three states and D.C. have laws requiring the adoption and enforcement of sediment and erosion control measures to minimize runoff from construction or earth-moving activities. More detailed information on these programs is contained in Appendix E.

Responsibility under Section 208 for developing nonpoint-source control plans in urban areas is shared by state and local planning agencies. In most of the major urban areas of the Chesapeake Bay region, these "area-wide" responsibilities are held by regional planning agencies. Each of the states are then responsible for "state-wide" urban runoff controls outside of these major urban areas.

Of the state-wide 208 programs, only Virginia's deals with the problem of urban runoff separately [Maryland's twelve 208 river basin plans and Pennsylvania's Comprehensive Water Quality Management Plans (COWAMP) identify urban runoff problem areas, but generally cover the more rural areas of the states]. The Virginia state-wide 208 program developed Best Management Practice Handbooks on a number of non-point source problems, including handbooks on urban BMPs and sediment and erosion control practices (VA SWCB 1979b, VA SWCC 1980) to accompany their state-wide urban runoff management plan (SWCB 1980). In addition, Virginia has identified priority watersheds for urban areas (South Fork of the Shenandoah River near Staunton; the James River and York River drainage around Richmond; and the lower James River draining the Newport News-Hampton and Norfolk-Portsmouth regions). As with area-wide 208 plans, all three states chose to adopt voluntary rather than regulatory implementation of their urban nonpoint source control strategies.

Numerous other state laws and local ordinances exist to reduce the quantity of runoff in urban areas and to prevent receiving water quality impacts of urban runoff. Flood prevention laws are designed to reduce runoff volumes and velocities and thus encourage proper stormwater management planning. Land-use and transportation planning, zoning, and subdivision regulations at the local level help in keeping development away from sensitive areas with the potential for erosion, flooding, or water quality problems. Other municipal services such as garbage, used oil and leaf collection, street-sweeping, and road-salting play important roles in managing urban runoff quality.

With the exception of Richmond, the regional planning agencies in the four major urban areas have addressed the problem of urban runoff in their 208 plans. The following descriptions summarize their activities.

Baltimore, Maryland—The Jones Falls Watershed Urban Stormwater Runoff Project, a NURP study run by the Regional Planning Council (RPC), examined the problems associated with urban stormwater runoff in a densely populated section of Baltimore. The project also evaluated the feasibility of implementing structural and nonstructural BMPs in the area. Major conclusions from the study include: urban runoff contributed significant amounts of copper, lead, and zinc to stream loadings; implementation of structural BMPs was found to be prohibitively expensive due to the extensive infrastructure changes required; nonstructural BMPs such as manual and mechanical street-sweepers were judged to be of variable effectiveness; and implementation of nonstructural BMPs such as removal of animal waste by dog owners was highly dependent on the population's level of awareness regarding the relationship between animal-waste removal and water quality. Based on these latter findings, the investigators concluded that education, particularly of urban dwellers, is a prerequisite for the adoption and success of nonstructural BMPs (RPC 1983).

Washington, D.C.—In contrast to the Jones Falls Project, the Metropolitan Washington Council of Government's NURP study investigated control measures in developing areas. During the four year study, the efficacy and cost-effectiveness of twelve types of BMPs (including wet ponds, dry ponds, porous pavement, etc.) were studied at several suburban sites in Virginia and Maryland. The investigators concluded:

- Wet ponds are among the most effective means of controlling urban runoff, although the initial costs for constructing these structures is significantly higher than for dry ponds. These initial outlays tend to be offset by increased property values which wet ponds tend to generate;
- Porous pavement is an effective BMP for reducing the rate of stormwater runoff and pollutant loads; and
- Grassy swales, long favored by developers, are no more effective than the curb-and-gutter systems they were designed to replace.

The study's recommendations, call for the strengthening of existing stormwater regulations to make them an instrument for improving water quality, as well as reducing stream-bank erosion; and regulations requiring the government and developers to absorb BMP-implementation and O&M costs, rather than leaving this responsibility to homeowners' associations, which have fewer resources.

Norfolk-Hampton Roads, Virginia—The Hampton Roads Water Quality Agency (HRWQA) has funded extensive water quality analyses of Hampton Roads and the James River tributaries draining Norfolk, Portsmouth, Newport News, and Hampton. The HRWQA has also evaluated the existing urban runoff control practices in the region and is currently testing the effectiveness of selected practices in the Lynnhaven River, an urban watershed.

In summary, urban runoff is gaining attention with respect to legislation. The implementation of these laws, however, has not been entirely adequate. The lack of inspectors to enforce laws, inadequate personnel to review permit proposals, poor funding for BMPs, and other factors contribute to the problem (Martin and Helm 1981). A more thorough evaluation of these issues is contained in each of the three area-wide 208 plans.

NONPOINT SOURCE CONTROL OPTIONS

Agricultural runoff contains nutrients from three main sources: eroded sediments, dissolved fertilizers, and animal wastes. There are dozens of specific agricultural practices that reduce nutrient loadings from these sources. Because farmers have a wide choice of alternative practices to combat erosion and runoff, for most situations, a mix of practices will control the problem. From a soil conservation perspective, the goal is to reduce soil loss to a "tolerable" (T) level, the rate at which soil can be lost without reducing the productive capacity of the soil. It should be kept in mind that meeting a goal of "T" tons of soil loss per acre per year does not necessarily protect water quality; however, many acres of cropland and pasture land are presently not meeting T-values. It is used here as an interim goal that is currently desired by the agricultural community.

Technical Control Options: Agricultural Runoff

Although the effectiveness of BMPs is dependent upon site-specific factors such as soil type, slope, proximity to streams, tillage, drainage, and cropping factors, the options described briefly below represent general levels of effort designed to offer steps necessary to reduce sediment and nutrient runoff problems. For example, Level One should be implemented on all farms simply as sound farm management. For light soil loss problems, Level Two should be carried out and, as problems require additional BMPs to meet "T", Levels Three and Four should be implemented. Level Five refers to BMPs specific to animal-waste management.

Level One:
Soil testing, timing of fertilizer applications to meet crop needs, avoiding fertilizer application on frozen land, use of crop residues for winter cover and mulch, manure incorporation, spring versus fall plowing, etc.

Level Two:
Conservation tillage (plow-plant, minimum or no-tillage)

Level Three:
Contour farming, strip cropping, use of grassed waterways, buffer and filter strips, and other practices

Level Four:
Diversions, terraces, sub-surface drains, ponds, and etc.

Level Five:
Animal-waste collection, handling, storage, and disposal practices.

The Level Two option was tested basin-wide using the Chesapeake basin model. The conventional-tillage cropland in each basin was converted to conservation tillage. The factor in the model that represents percent vegetative cover was the primary adjustment made to simulate this option. Level Two was also combined with a point source strategy (TP = 2 mg L^{-1}) and tested under existing and future conditions. Agricultural land-use was assumed to remain unchanged in the year 2000 model simulations.

Table 10 contains the estimated reductions in nutrient loads, by major basin, achieved in the conservation-tillage model simulation. The conservation-tillage BMP is more effective in reducing phosphorus loads than in reducing nitrogen loads because phosphorus is transported in the particulate form adsorbed to sediment particles. This Level Two BMP minimizes disturbances of the soil surface and significantly reduces soil loss. Nitrogen, however, is mostly soluble and what does not wash off is taken up by plants, or transformed to gas, and percolates down into the groundwater, some of which flows into adjacent water bodies. The complicated nutrient forms and pathways, along with diverse crop and pastureland management systems, illustrate the need to implement separate BMPs to control both nitrogen and phosphorus.

The percent reductions achieved by this option are related to the amount of cropland converted to conservation tillage, as well as soil type, slope, and other factors that vary among river basins. The amount of land estimated to be presently in conventional tillage is thought to be an under-estimate when compared to other land-use data sets (Appendix B); therefore, reductions achieved from large-scale adoption of this option could be even greater than these data indicate.

Because of funding limitations, Level Two was the only nonpoint-source option tested basin-wide, with the exception of a Level Two plus Level Three option tested in the lower Susquehanna River basin, discussed in Chapter 5. Modeling results however, provide a good indication of the sensitivity of total nutrient loads to changes in cropland practices by region (Table 10). Other options should be tested in the future using the Chesapeake Bay basin model which is presently set up as a management tool for basin-to-basin comparisons and can be refined to evaluate river basins individually. The CBP is not suggesting, by testing Level Two basin-wide, that it should be adopted by all farmers. In some areas, physical conditions prevent its use, and its benefits in preventing sediment and nutrient losses must be weighed against the increased use of herbicides and other farm management considerations. The Level Two results should only be considered in the development of much broader agricultural strategies that leave the decision of what mixes of specific BMPs are needed to the discretion of farmers and soil conservationists.

Costs for agricultural runoff options—

Level One—Fertilizers represent the largest cost to farmers to grow crops; therefore, proper fertilizer and manure management can reduce costs. For example, the baseline model runs in the Susquehanna found that, under average rainfall conditions, 49,470,000 pounds of nitrogen and 1,740,000 pounds of phosphorus are delivered to Chesapeake Bay from the 3.17 million acres of cropland in the Susquehanna drainage area between March and October. Some of this loss is inevitable and not all is from fertilizer or manure application. Nevertheless, in terms of dollars lost, these nutrient losses represent 6.42 million dollar losses to farmers, at current commercial fertilizer prices,[4] 24.25 cents per pound of nitrogen and 24.40 cents for phosphate (56.12 cents per pound phosphorus), assuming that only 50 percent of the cropland nutrient losses are attributable to fertilizer applications. Because the estimated cropland nutrient losses are based on the eight-month period between March 1 and October 31, these dollar losses represent an under-estimate over a twelve-month period. Nonetheless, millions of dollars could thus be saved by farmers in the Susquehanna basin and elsewhere by adopting better fertilizer management practices that

TABLE 10.
ESTIMATED NUTRIENT REDUCTIONS ACHIEVED IN LEVEL TWO MODEL SIMULATION UNDER AVERAGE AND WET CONDITIONS (MARCH TO OCTOBER)

	% Phosphorus Load Reduction (lb. reduction)		% Nitrogen Load Reduction (lb. reduction)	
Basin	**Avg. Year**	**Wet Year**	**Avg. Year**	**Wet Year**
Susquehanna	16.0 (464,000)	32.0 (2,016,000)	1.3 (780,000)	8.0 (8,400,000)
West Chesapeake	2.3 (55,000)	14.4 (439,000)	1.7 (264,000)	10.9 (2,415,000)
Eastern Shore	14.3 (119,000)	43.7 (926,000)	6.3 (549,000)	23.9 (5,000,000)
Patuxent	1.1 (5,000)	14.2 (95,000)	0.8 (20,000)	11.6 (531,000)
Potomac	4.3 (123,000)	25.4 (1,306,000)	1.3 (455,000)	11.1 (7,102,000)
Rappahannock	5.1 (14,000)	35.0 (269,000)	1.9 (54,000)	18.0 (1,472,000)
York	6.7 (18,000)	37.0 (310,000)	2.5 (57,000)	20.0 (960,000)
James	0.8 (32,000)	9.5 (470,000)	0.5 (107,000)	7.6 (2,345,000)
Basin-wide	6.5 (830,000)	24.5 (5,831,000)	1.6 (2,286,000)	10.7 (28,225,000)

decrease losses and, in most cases, result in minimizing the amount needed for application.

Level Two — Table 11 compares national energy costs in conventional and conservation-tillage farming methods. When total costs, including additional costs for the insecticides and herbicides required by reduced and no-tillage farming, are compared with those for conventional farming, conservation-tillage is less expensive than conventional-tillage. The major reason farmers are adopting conservation tillage is the economic benefit of reduced labor and fuel requirements (Batic 1983). Yields achieved using conservation tillage can be greater, the same, or less than those achieved with conventional tillage depending on the circumstances (Christensen and Norris 1983).

District conservationists in Pennsylvania, responding to a CBP/SCS worksheet (Appendix C), estimated that total costs for implementation of no-till farming would be zero dollars. However, if accelerated adoption of conservation tillage is desired, education, technical assistance, and cost-sharing may be necessary to demonstrate to farmers the benefits of this practice. Significant costs can be attributed to the accelerated technical assistance required to assist the farmers in the implementation of a conservation-tillage management system on farms. The Lake Erie Wastewater Management Study (U.S. Army Corps of Engineers 1982) estimated that a conservation-tillage system program in the Lake Erie basin would cost 11,290,000 dollars over 10 years. None of these costs were capital outlays by farmers, but instead were for increased technical assistance by conservation districts to promote, educate, and assist in the installation of conservation-tillage systems. The Lake Erie program would result in the adoption of conservation tillage on approximately 950,000 acres, or 1.19 dollars per acre per year. Using this estimate, the total cost to convert lands in the Chesapeake Bay basin presently farmed using conventional-tillage methods is estimated to be 10.53 million dollars.

Levels Three, Four, and Five — Every farm must be evaluated separately to determine the optimum combination of BMPs required to reduce excessive nutrient and sediment losses. For this reason, the Chesapeake Bay Program did not estimate basin-wide costs for installing Levels Three, Four, and Five. Future nonpoint source model tests can be conducted for priority sub-basins to evaluate the effectiveness of applying these levels to various lands, and then costs may be estimated. Presented below are cost estimates of a number of BMPs (in Levels Three and Four) derived from estimates to install resource management systems and developed by the SCS for the Mason-Dixon Erosion Control Area (1983a).

Pipe Outlet Terraces	$300/acre
Terraces	$250/acre
Diversions	$100/acre
Sub-surface Drains	$100/acre
Waterways	$ 50/acre

TABLE 11.
ESTIMATES OF NATIONAL COSTS PER ACRE FOR CONVENTIONAL TILLAGE AND CONVENTIAL TILLAGE IN 1979. (Source: Crosson, 1981)

	Conventional Tillage			Conservation Tillage		
	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat
Labor	$ 13.24	$ 12.21	$ 9.25	$ 6.62	$ 6.10	$ 4.63
Machinery	36.32	31.28	25.30	31.32	26.28	20.30
Fuel	9.02	6.83	5.57	7.02	4.83	3.57
Pesticides	8.72	9.13	1.21	11.63	12.17	1.61
TOTAL COSTS	$165.00	$105.00	$79.00	$154.00	$95.00	$68.00

Strip-cropping	$ 20/acre
Contour Farming	$ 20/acre

Level Five costs of 10,000 to 25,000 dollars for animal-waste management systems per farm were estimated by The Soil Conservation Service in an assessment of priority sub-basins in Virginia (SCS 1983a).

Administrative Control Options: Agricultural Runoff

In addition to what can be done technically to reduce agricultural runoff loadings, there are many issues surrounding administrative options that could redirect current control programs to make them more effective at curbing runoff impacts. Generally, these options define the purpose of agricultural control programs: how to implement a program, set its policies, priorities, and funding to achieve an effective water quality management plan for nonpoint source control. The major agricultural administrative issues and options were discussed in the previous section, regarding scientific uncertainties, lack of priority setting, limited financial incentives, education, and changes in Federal programs. In summary, specific policy options to improve agricultural water quality management programs include the following:

- The EPA and the states could include, as part of the monitoring program proposed in Chapter 2 and described in Appendix F, long-term monitoring efforts designed to detect trends in nonpoint pollution loadings before and after implementation of control measures. These efforts are necessary to determine the effectiveness of a nonpoint source control program once in place.
- The EPA and the states could utilize the Chesapeake Bay basin model to determine which individual sub-basins are the most significant contributors of nutrients to Bay waters from cropland and other nonpoint sources. This information is known for areas below the fall line but cannot be compared to unit-area loadings from sub-basins above the fall-line without additional model tests. These model tests could determine which areas in the Bay basin should be targetted for nonpoint source programs to improve the conditions of degraded segments in the Chesapeake Bay. The model should be further utilized to run additional tests on a full range of agricultural and urban runoff control alternatives to determine the most effective strategy from a technical standpoint. Additional data on land use activities, slope, soils, etc. should be incorporated in the model for more detailed modeling studies in the identified priority sub-basins.
- Agricultural research could focus on answering questions on the processes of dissolved nutrient movement, sediment and nutrient relationships, improved soil-testing techniques, and other unresolved scientific concerns outlined above.
- Soil conservation districts could be required to keep detailed records of accomplishments to improve their ability to assess the effectiveness of their programs and to redirect their activities accordingly. This effort could be accomplished through annual reports which evaluate whether their activities are meeting specific objectives and milestones, and which explain obstacles encountered in the administration of nonpoint source control efforts.
- All levels of government could consider expanding their funding for implementing of nonpoint source control programs, and alternative sources of funding should be explored. Accelerated efforts to reduce nutrient runoff from agricultural lands depend upon increased cost-sharing funds as the primary financial incentives, and present sources do not even approach the amount needed in each state's critical watersheds. Other incentives could be considered such as incentives to maintain sensitive or marginal farmland idled through the USDA Payment-in-Kind Program, or similar state or Federal efforts. Educational efforts could be strengthened to reach farmers and other landowners in priority watersheds. Existing projects, model farms, etc. could be utilized to the fullest extent to demonstrate the problem of agricultural and urban runoff and what techniques reduce the pollutant loadings. In addition,

a nonpoint source clearing-house could be established to coordinate information on BMPs, etc.

- The states in the Chesapeake Bay basin could coordinate an effort to target special program funds from the U.S. Department of Agriculture to accelerate soil conservation and water quality improvement in the Chesapeake Bay.
- The EPA and the states could pursue the full implementation of existing water quality mangement plans, ensure that they are updated with Chesapeake Bay Program findings and revised to address nutrient control. This effort and those above could be accomplished through a comprehensive nonpoint source implementation program with improved Bay water quality as the primary goal.

Technical Control Options: Urban Runoff

Urban runoff control practices can be grouped into a number of categories. Urban Level One control options, the base level of effort, include practices that remove or reduce the sources of urban runoff pollutants. Urban Level Two controls reduce the volume of runoff reaching waterways. Urban Level Three controls are needed usually in the severest cases of urban runoff pollution, and consist of runoff collection and treatment measures. One special category of urban runoff control is sediment and erosion control on construction sites; BMPs in this category contain both Level One and Level Two practices. The most commonly used practices are source controls, which stabilize or trap sediments, and volume controls, which enhance infiltration or detain stormwater to reduce the rate of stormwater discharge. The following BMPs are examples of meausres represented by each level of control:

Level One:

Source controls, planning (street-sweeping, sewer catch-basin cleaning, vegetative cover, straw bales, educational programs on the disposal of used oil and use of fertilizers and pesticides, domestic animal waste ordinances, controls on the use and storage of street de-icing compounds, land-use planning and pre-development landscape planning), etc.;

Level Two:

Volume or discharge controls (rooftop and parking lot storage, infiltration pits, modular concrete-grid pavement, porous pavement, vegetative cover, grassed swales, detention basins, etc.;

Level Three:

Sewer conveyance-system storage, conventional and fluidic flow-regulators in sewer lines, off-site retention basins, waste-water treatment, etc.

Level one — These controls are generally amenable to urbanized and devloping areas because most are designed to reduce lawn or street-surface pollutant build-up. The effectiveness of each depends on many factors. The value of a street sweeping program, for example, is determined by the type of sweeper (broom versus vacuum sweepers), number of times a street or curb is swept per week, percentage of curbs swept, pavement conditions, percentage of pollutants attached to fine particles (the most difficult to remove), and public reactions. Runoff studies in the Washington, D.C. area have found that street-sweepers used three times a week can remove up to 50 percent of the phosphorus from the street surface, depending on the land use (Northern Virginia Planning District Commission, 1979). Conclusions in the EPA's Nationwide Urban Runoff Program, however, suggest that street-sweeping is not as effective in reducing nonpoint source pollution as once thought (U.S. EPA 1982c).

Source-control urban runoff programs are administered at the local level. The county planning and zoning offices have control over where development will occur, and local standards dictate whether development takes place with the necessary sediment and erosion controls. Also, municipal public works programs, directly or through contractors, administer street-sweeping, sewer cleaning, solid-waste collection, and road-salting operations. Funding and attitudes toward the importance of reducing urban runoff loadings largely determine the level of effort applied. The effectiveness of voluntary controls, such as those generally applicable to used-oil disposal or application of lawn and garden chemicals, depend upon an informed and responsible public. Educational programs will enhance the public's feeling of personal responsibility for protecting water quality and increase the effectiveness of voluntary controls.

Level two — Volume controls reduce the amount of stormwater entering receiving waters by detaining runoff temporarily, allowing particulate pollutants to settle out, and by slowing the rate of stormwater discharge to receiving streams. They also improve infiltration, which takes advantage of soil processes to remove pollutants. Volume controls can achieve higher nonpoint source control benefits than other runoff controls due to the removal of both dissolved and suspended pollutants through infiltration and natural nutrient-removal processes within the soil profile. They are multipurpose controls because they also reduce peak-flow rates, usually extending the runoff discharge over a longer period of time, and because they minimize flooding, although the potential for stream-bank erosion and channel souring may be increased. Research in the Washington, D.C. area on volume controls such as wet ponds indicates they are very effective urban BMPs (Northern Virginia Planning District Commission 1979; Metropolitan Washington Council Of Governments 1983).

Their effectiveness is dependent on how much of an area's runoff is collected or slowed down by volume controls. Their use is not generally feasible in established urban areas because they are structural in nature, and installation requires expensive retrofitting. Developing areas offer a better potential for the application of volume controls because they can be incorporated into site-design plans; much more of the runoff can be controlled at less expense if source and volume control measures (Levels One and Two) are an integral part of the design of new developments. The EPA NURP study found that these two types of controls are the most effective, although they are not as effective for water quality purposes as once thought (U.S. EPA 1982c).

Level three — These practices are structural engineering solutions that reduce peak flow during a runoff event through off-site storage and, in extreme situations, remove pollutants from the runoff by natural processes or through some type of wastewater treatment. These practices are often implemented in areas with combined sewer overflows and flooding problems. Although these are the most costly urban runoff controls, they may be the only type that could significantly reduce pollutant loadings from established urban areas with severe runoff problems. Source and volume controls may not provide sufficient coverage to reduce large runoff volumes, rates of discharge, and pollutant loads from these areas, and Level Three could offer the best solution.

SUMMARY

Over the past seven years, the Chesapeake Bay Program has received many comments from scientists, administrators, sport and commercial fishermen, landowners, and interested Bay citizens expressing a desire to see the Bay in an improved condition. The overall nutrient strategy, then, is to reduce nutrient concentrations to a range that does not limit healthy populations of finfish, shellfish, aquatic vegetation, waterfowl, etc. Any reduction in nutrient loads will lower nutrient concentrations to some extent; unfortunately, without an adequate water quality model, it is difficult to predict with confidence what would be the water quality or ecological response to successive reductions in nutrient loadings to the Bay. Instead of using scientific uncertainty as an excuse for inaction, and thereby testing the ultimate experiment in Bay eutrophication, enough is known to call for limiting nutrient loads to Bay waters.

CBP research, described in Chapter 2, points to some major conclusions between water quality and nutrient loadings. Phosphorus was found to limite algal production in tidal-fresh and brackish waters year-round, and nitrogen can be the limiting nutrient in summer in estuarine waters (e.g., mid-Bay and lower portions of tributaries). The low dissolved oxygen levels in the deeper waters of the Bay appear to be closely associated with increased nutrient concentrations (and resulting stimulation of algal growth). Also, the decline of SAV appears to be associated with nitrogen increases. From a Bay-wide perspective, both phosphorus and nitrogen loadings should be reduced. To improve water quality in the upper Bay and upper and middle segments of tributaries, phosphorus load reductions are essential.

The Bay-wide point and nonpoint source nutrient strategies presented below are intended to be carried out in tandem. In addition, they are designed as a phased approach: a) instituting or reinforcing nutrient-reduction controls in what CBP considers to be the most critical problem areas in the Bay (see Figure 7, Chapter 2) with respect to nutrients, b) using the results of these strategies to guide nutrient control efforts elsewhere in the Bay, and c) tightening up or improving the efficiency of existing point source programs that aim to protect water quality.

BAY-WIDE NUTRIENT RECOMMENDATIONS

OBJECTIVE:

REDUCE POINT AND NONPOINT SOURCE NUTRIENT LOADINGS TO ATTAIN NUTRIENT AND DISSOLVED OXYGEN CONCENTRATIONS NECESSARY TO SUPPORT THE LIVING RESOURCES OF THE BAY.

General Recommendations

1. *The states*[5] *and the EPA, through the Management Committee, should utilize the existing water quality management process to develop a basin-wide plan that includes implementation schedules, to control nutrients from point and nonpoint sources by July 1, 1984.*

2. *The states and the EPA, through the Management Committee, should continue the development of a Bay-wide water quality model to refine the ability to assess potential water quality benefits of simulated nutrient control alternatives. This model should be continuously updated with new information on point source discharges, land use activities, water quality, etc.*

Point Source Recommendations

3. *The states and the EPA should consider CBP findings when updating or issuing NPDES permits for all point sources discharging directly to Chesapeake Bay and its tributaries. Furthermore, the states should enforce NPDES permit limitations.*

4. *Technical data from CBP findings should be considered when evaluating funding proposals for POTWs under the EPA's Advanced Treatment Policy.*

5. *The states of Maryland, Virginia, and the District of Columbia should consider by July 1, 1984, as one of several control alternatives, a policy to limit phosphate in detergents to 0.5 percent by weight, in light of the immediate phosphorus reductions achieved.*

6. *The following administrative procedures should be reviewed for action by January 1, 1985, by the states, counties, and/or municipalities:*
   - Improve operator training programs and provide or encourage incentives for better job performance, such as increased salaries, promotions, bonuses, job recognition, etc.
   - The states should consider CBP findings when ranking construction grant projects.
   - Accelerate the development and administration of state and local pretreatment programs.
   - Continue to evaluate the application of innovative and alternative nutrient removal technologies.
   - Improve sampling and inspection of point source discharges.
   - Develop plans to ensure long-term operation and maintenance of small, privately-owned sewage treatment facilities.
   - Institute educational campaigns to conserve water to reduce the need for POTW expansion as population in the Chesapeake Bay basin increases.

Nonpoint Source Recommendations

7. *The states and the EPA, through the Management Committee, should develop a detailed*

nonpoint source control implementation program by July 1, 1984 as part of the proposed basin-wide water quality management plan.

Initial efforts should concentrate on establishing strategies to accelerate the application of best management practices in priority sub-basins to reduce existing nonpoint source nutrient loadings. Long-term strategies should seek to maintain or further reduce nutrient loads from other sub-basins to help restore Chesapeake Bay resources.

The implementation program should not be limited to traditional approaches toward soil and water conservation; an intensified commitment of resources for educational, technical, and financial assistance is warranted and may require innovative administration of available resources. Long-term funding must be assured at the outset of the implementation program, and a detailed plan to track accomplishments, including water quality improvement, should be developed by the states through the Management Committee. The framework for this program should include the following stages:

Stage 1 —
A program that emphasizes increased education, technical assistance, and cost-sharing, as well as other financial incentives, should be in place by July 1, 1985 in priority sub-basins (i.e., those determined through nonpoint source modeling to be significant contributors of nutrients to identified problem areas of the Bay). Full implementation of the abatement program should occur by July 1, 1988.

Stage 2 —
The Stage 1 program should be expanded to intermediate priority sub-basins based on additional basin-wide nonpoint source modeling and Bay-wide water quality modeling assessments that should determine both the need for additional nonpoint source nutrient reductions and the additional sub-basins to be targetted for nonpoint source control.

Stage 3 —
Provide the necessary educational, technical, and financial assistance to maintain or improve the level of soil and water resource protection throughout the Chesapeake Bay basin. Soil conservation districts should establish annual conservation goals and report annually on accomplishments and technical, financial, educational, and research needs.

Concurrently with stages 1 through 3, the states and the EPA, through the Management Committee, should initiate research to evaluate the effectiveness of BMPs in reducing the loss of soluble nutrients from farmland, to improve soil-testing procedures to refine recommended fertilizer application rates (especially with respect to nitrogen), and to explore a range of financial incentives, disincentives, or other measures that would accelerate the BMP-adoption process. Regulatory alternatives should be evaluated, and when necessary, implemented, if the above approaches do not achieve the needed nutrient reductions.

8. *The USDA and the EPA, in consultation with the Management Committee, should strengthen and coordinate their efforts to reduce agricultural nonpoint source pollution to improve water quality in Chesapeake Bay.*

Specifically, an agreement that establishes a cooperative commitment to work toward the goal of improved water quality in Chesapeake Bay and its tributaries should be developed. The agreement should outline ways that programs could be targetted to reduce loadings of a) nutrients (from soil, fertilizer, and animal wastes), b) sediment, c) agricultural chemicals, and d) bacteria from animal wastes. Also, the agreement should encourage the targetting of EPA and USDA technical assistance and computer modeling personnel to Chesapeake Bay priority sub-basins.

9. *Federal agencies, states, and counties should develop incentive policies by July 1, 1984, that encourage farmers to implement BMPs.*

Policies that could be considered include: incentives to maintain sensitive or marginal farmland out of production, such as the USDA Payment-in-Kind Program or other similar state or local efforts; cross-compliance; changes in the Internal Revenue Code, or state and local tax structures that will encourage landowner investment in BMPs or discourage the lack of adequate BMPs; the establishment of Federal, state, or local agricultural conservation trust funds for additional cost-share, education, or technical assistance resources; user fees; dedicated taxes; or expanded implementation funding.

10. *The state, counties, and municipalities located in sub-basins adjacent to tidal-fresh and estuarine segments of Chesapeake Bay and its tributaries should implement fully and enforce existing urban stormwater runoff control programs.*

Although nonpoint source loadings of nutrients from urban land were not found to contribute significantly to overall nutrient loads, unnecessary loadings of nutrients, sediment, heavy metals, and other pollutants from urbanized or developing watersheds should be avoided because of their potential impact on living resources in isolated or sensitive reaches of the Bay. In addition, stormwater management programs should place equal emphasis on runoff quality quantity control techniques; they should also either establish owner-developer responsibility for long-term maintenance of urban stormwater BMPs or else include innovative finance mechanisms to pay for long-term BMP maintenance.

11. *The states of Maryland and Virginia and local governments should consider strengthening wetland protection laws to include non-tidal wetlands because of their value nutrient buffers and living resource habitat.*

CHAPTER 4
TOXIC COMPOUNDS

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Gail B. Mackiernan
Joseph Macknis

INTRODUCTION: THE PROBLEM

Toxic materials enter the Bay from a variety of sources, including industrial effluents and other point sources, runoff from urban areas and agricultural lands, atmospheric inputs, and disposal of contaminated dredge spoil (Table 12). Except for long-range atmospheric deposition, the primary sources are located within the basin. The materials include heavy metals, synthetic organic compounds (including pesticides and herbicides), petroleum hydrocarbons, and other chemical substances such as chlorine. While some of these materials are transitory, others have been shown to accumulate in the sediments or water column, or within tissues of Bay biota. The variety of toxic materials already present in the estuarine environment, as well as continued inputs, represent potentially serious threats to the integrity of the Chesapeake ecosystem (Figure 32). In addition, some toxicants can become human health-hazards if bioaccumulated in the tissues of food organisms. For these reasons, control and monitoring of toxic substances is necessary.

This chapter indicates what the primary sources of toxicants are; discusses types and amounts of metals, organic compounds, and other substances contributed to the Bay and to major river basins; summarizes what controls are currently in place to reduce toxicant loadings and their effectiveness to date; and describes the range of controls or other measures that could be instituted to further reduce inputs of toxic substances. This information on toxicant sources, loadings, and alternative measures provides the raw material needed to formulate objectives and strategies for the improvement of Chesapeake Bay. Recommendations are proposed for Bay-wide policies and for more specific action within tributary systems (Chapter 5).

TABLE 12.
MAJOR SOURCES OF ORGANIC AND INORGANIC TOXICANTS

Source	Inorganic	Organic
INDUSTRY	most metals	PNAs
POTWs	most metals, chlorine	PNAs, chlorinated organics
RIVERS	most metals	pesticides
ATMOSPHERE	zinc, lead	
URBAN RUNOFF	lead, cadmium	hydrocarbons
SHORE EROSION	iron, chromium	
MARINE ACTIVITIES	copper	hydrocarbons, organotins

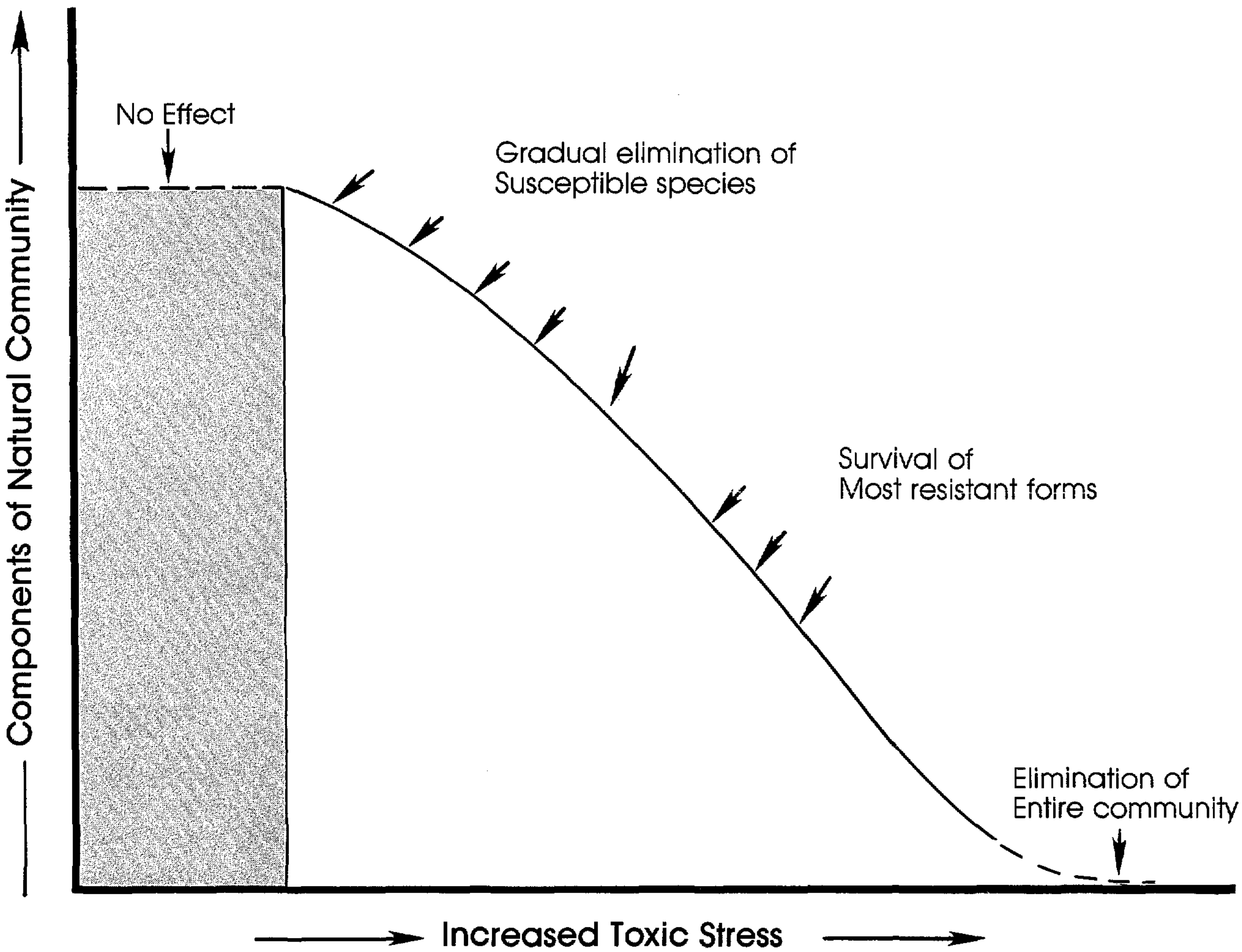


FIGURE 32. Hypothetical response of an ecosystem to increasing stress.

SOURCES AND FATES OF TOXICANTS: AN OVERVIEW

Industrial facilities and POTWs discharge a variety of metals and synthetic organic compounds, such as polynuclear aromatic hydrocarbons, which are produced in part by high temperature combustion of fossil fuel. Chlorine and chlorinated organics are common constituents of effluent from industries, POTWs, and power plants (Wilson et al. 1982). The three major tributaries to Chesapeake Bay, the Susquehanna, Potomac, and James Rivers, deliver similar products from similar urban and agricultural activities (Lang and Grayson 1980). Atmospheric deposition is delivered directly to the water and also indirectly through runoff. Automobiles contribute large amounts of Pb from gasoline (Bieri et al. 1982a). Iron (Fe) is a primary constituent of shore erosion (Bieri et al. 1982a). Maritime ships and leisure and work boats occasionally leak or spill petroleum and are regularly treated with Cu- or tin (Sn)-based anti-fouling paints. Some toxicants may reach their highest levels in harbors and tributaries where human activities are most concentrated and natural flushing is low. A number of these areas represent significant habitat for living resources.

Metals

The James, Potomac, and Susquehanna River systems are by far the major suppliers of each metal examined by the CBP. Collectively, they account for 69 percent of the Cd, 72 percent of the Cr, 69 percent of the Cu, 80 percent of the Fe, 51 percent of the Pb, and 54 percent of the Zn discharged to the Bay system. The other principal source of each metal is: Cd, industry (13 percent); Cr and Fe, shore erosion (13 percent and 18 percent, respectively); Cu, industrial and municipal point sources (21 percent); Pb, urban runoff (19 percent); and Zn, atmospheric (31 percent) (Table 13, Figure 33). Sources and loadings of metals are discussed more fully in *Chesapeake Bay Program Technical Studies: A Synthesis* (Bieri et al. 1982a).

Except for Fe, which is not a toxic trace metal and is largely a natural constituent of shore erosion, the most commonly found metal in Bay sediments is Zn. More than 16,000 pounds of Zn are delivered from the major tributaries, or deposited directly to the Bay, each day. More than 4,000 pounds each of Cr and Cu are contributed daily to Bay waters (Bieri et al. 1982a). Based on EPA water quality criteria, Cu is the most toxic metal in estuarine and marine waters and Cd is the most toxic in freshwater (U.S. EPA 1980). Thirty-six hundred pounds of Pb are contributed daily, primarily from urban areas and largely from Baltimore, MD; Washington, D.C.; Richmond, VA; and Hampton Roads, VA (Bieri et al. 1982a). (Calculations based on data developed by Hartigan et al. 1981, Appendix D.) Sediment metal concentrations are highest in the upper and mid Bay, upper western shore tributaries, and near industralized areas (Figure 10).

Analyses in which total or (estimated) dissolved metals data (in water column) were screened against published EPA water quality criteria showed highest values to be found primarily in the main Bay and western shore tributaries (Flemer et al. 1983). Many of these exceeded the EPA acute criteria; some exceeded even chronic criteria. The highest water column metal concentrations in Maryland are in the Potomac River (Zn in the fresh portion, Cu in the estuarine), Baltimore Harbor (Cu and Zn), and the main Bay between the Gunpowder River and Cove Point (Cu, Cd, Cr, Zn). In Virginia, the estuarine segments of the Rappahannock, York, and James Rivers contain levels of Ni and Cu that exceed both acute and chronic criteria. A similar pattern exists for the western half of the main Bay in Virginia. Details of the analyses, and implications for the Bay ecosystem, are discussed in *Chesapeake*

TABLE 13.
LOADINGS OF METALS FROM MAJOR SOURCES TO THE CHESAPEAKE BAY IN POUNDS/DAY (PERCENTAGE OF TOTAL LOAD)
(LATER IN THIS CHAPTER REFERENCES ARE GIVEN FOR SPECIFIC SOURCES)

	Cd	Cr	Cu	Fe	Pb	Zn
Industry	84 (13)	378 (8)	454 (10)	22,877 (1)	302 (8)	418 (3)
Municipal Wastewater	54 (8)	288 (6)	501 (11)	9,395 (—)	379 (11)	917 (5)
Atmospheric	18 (3)		169 (4)	525 (—)	205 (6)	4,975 (31)
Urban Runoff	42 (6)	66 (1)	54 (1)	5,891 (—)	670 (19)	380 (2)
Rivers	452 (69)	3323 (72)	3118 (69)	1807083 (80)	1851 (51)	8708 (54)
Shore Erosion	7 (1)	587 (13)	205 (5)	404,404 (18)	198 (5)	679 (4)
TOTAL	657	4642	4501	2250175	3605	16077

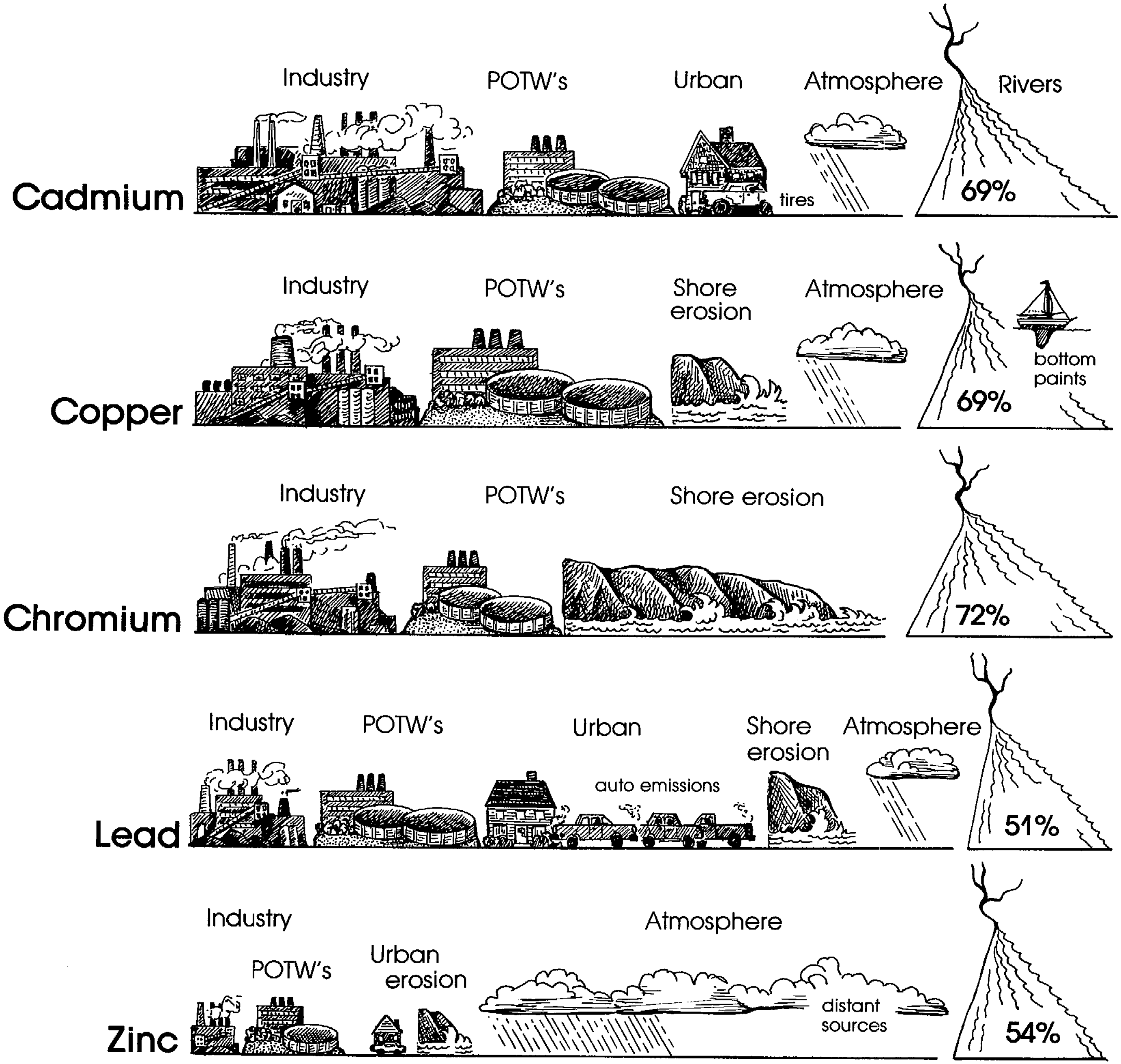


FIGURE 33a. Major sources of metals to Chesapeake Bay. Size of symbol indicates relative importance of each source.

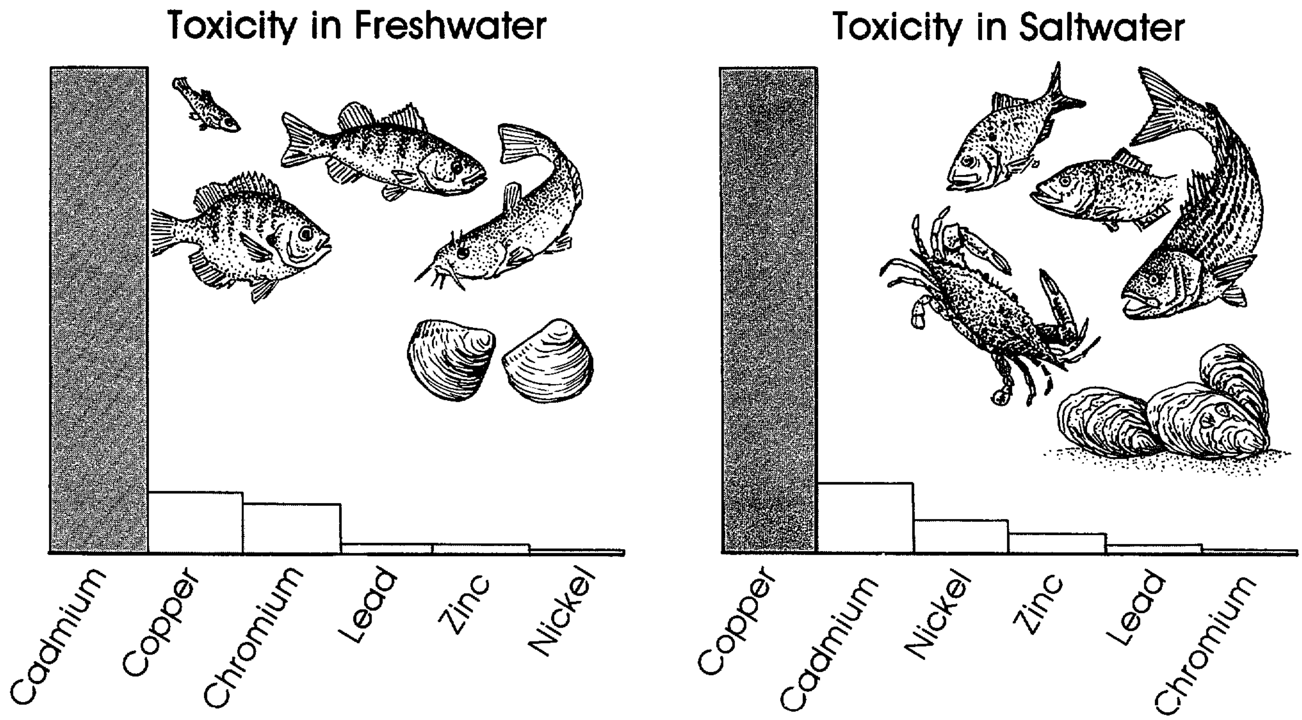


FIGURE 33b. Relative toxicities of heavy metals in freshwater and in saltwater.

Bay: A Profile of Environmental Change (Flemer et al. 1983).

High enrichment of metals is found in suspended material in the mid-Bay, and is associated with organic matter. This suggests that biological activity is the proximal cause of accumulation (Bieri et al. 1982a). Highest concentrations of metals in oyster and other shellfish tissues were observed in samples from heavily industrialized areas such as the Elizabeth River (Flemer et al. 1983).

Organic Compounds

Synthetic organic compounds have been detected in the water and sediments of the Bay (Bieri et al. 1982 b and c). The Virginia Institute of Marine Science (VIMS) found that many of the compounds detected in sediments were unidentifiable and most were toxic (Table 14)(also Figure 9). The mean concentrations of all organic compounds detected were often in hundreds of parts per million, particularly in industrialized or urbanized areas. Priority pollutants were detected in all areas sampled and some were at relatively high concentrations (Bieri et al. 1982b and c). The results are shown in Table 15. Although the industrial facilities, circulation patterns, and bed sediments vary between the regions, the overall patterns suggest that large contributions of PNAs from the fossil fuel combustion processes are associated with urbanized environments. The methodology known as gas chromatography/mass spectrophotometry (GC/MS) fingerprinting, which was developed and used by the CBP to identify and evaluate organic compounds in effluents, sediments, or tissues, is described in Appendix D. An example of a "fingerprint" is shown in Figure 34. Each GC/MS effluent scan is unique and can be used to identify and compare effluents or to detect specific compounds within the discharge.

In the VIMS study of the main Bay, over 300 organic compounds were found during the spring

TABLE 14.
ORGANIC COMPOUNDS IN CHESAPEAKE BAY SEDIMENT (BIERI ET AL. 1982a and b)

Location	# compounds detected	unidentified compounds	priority pollutants
Main-stem Chesapeake Bay	327	yes	yes
Baltimore Harbor	480	yes	yes
Elizabeth River	310	yes	yes

TABLE 15.
ORGANIC PRIORITY POLLUTANTS DETECTED IN SEDIMENTS OF MAIN BAY, BALTIMORE HARBOR, AND ELIZABETH RIVER (BIERI ET AL. 1982)

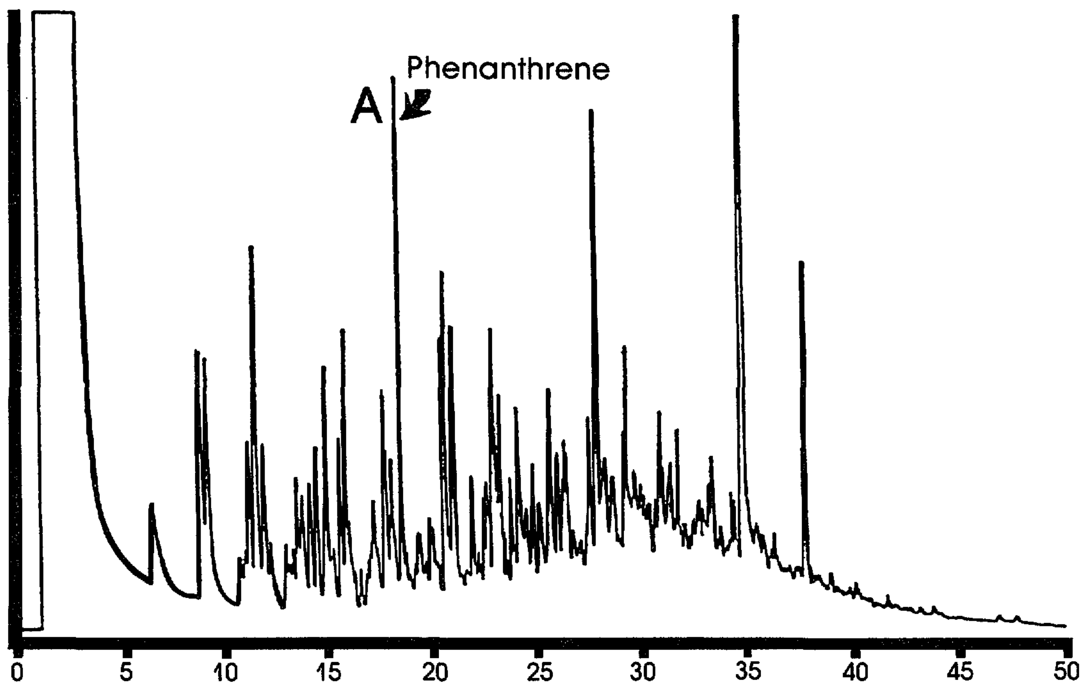
Acenaphthene	Benzo(ghi)perylene	Ideno(1,2,3-cd)pyrene
Anthracene	Benzo(k)fluoranthene	Naphthalene
Benzo(a)anthracene	Chrysene	Phenanthrene
Benzo(a)pyrene	Fluoranthene	Pyrene
Benzo(b)fluoranthene	Fluorene	Polychlorinated Biphenyls

and fall of 1979. It is likely that more extensive analysis would have revealed thousands of undetected compounds. Nonetheless, the compounds observed showed a trend of increasing concentrations from below the Potomac River mouth toward the Baltimore Harbor mouth (Figure 9). North of Baltimore, the total concentration of organic compounds decreased and then increased to another maximum toward the mouth of the Susquehanna River.

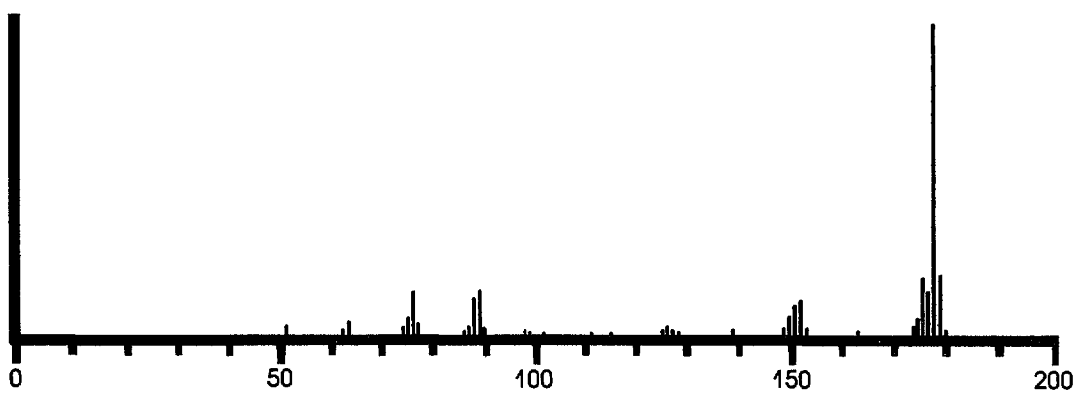
Polynuclear aromatic compounds (PNAs) were the most abundant organic compound found in the sediments. They are released during the combustion of fossil (i.e., carbonaceous) fuels and transported from point and nonpoint sources with sediment, water, and air-borne particulates. The concentration trends for PNAs are similar to the total concentrations of all organic substances. The highest concentrations are found in the northern Bay; the highest levels in the southern Bay are near river mouths; concentrations increase northward from the mouth of the Potomac toward Baltimore Harbor; and high (but varied) concentrations are found at the mouth of the Susquehanna.

Twenty-eight surface samples from the Elizabeth River were analyzed for the presence of primarily aromatic and polar organic compounds. The highest concentrations of total aromatics reached 440,000 ppb at the sampling site farthest up the Southern Branch. Concentrations declined toward the mouth of the river, suggesting export of pollutants from the Elizabeth River. Polynuclear aromatic compounds composed 40 percent of the largest concentration. The similar overall composition of the samples reflects a large input of coal tar creosote, apparently from a single source.

Total aromatic concentrations in the Patapsco River ranged from 2.7×10^6 to 6,100 ppb with unsubstituted PNAs contributing about half of the



Gas Chromatograph or "Fingerprint" showing location of phenanthrene.



Mass Spectrograph of phenanthrene.

FIGURE 34. "Fingerprint" and mass spectograph showing phenanthrene.

resolved concentrations. The highest total concentration, found in Bear Creek at Coffin Point, was primarily unresolved but contained the largest single concentration of unsubstituted PNAs (89,000 ppb). The presence of several submaximas in undredged areas suggest multiple point sources and poor pollutant transport beyond a few hundred meters. Samples taken within the dredged channel indicate transport toward the main Bay. Sources and loads of organic compounds are discussed more fully in *Chesapeake Bay Program Technical Studies: A Synthesis* (Bieri et al. 1982a).

Chlorine

Chlorine is used in the Chesapeake Bay basin for disinfection of drinking water and municipal and industrial wastewaters, for control of biofouling in power plant condensors, and in a variety of industrial processes. The majority of municipal, industrial, and power plant dischargers are located on the Bay's western shore, predictably near urban or industrial centers. Many of these release effluents to portions of tributaries in the freshwater or brackish (oligohaline) reaches; these areas are often critical habitats for important resource species. In recent years, concern has grown about the use of chlorine because of its powerful biocidal nature, and the resulting potential adverse environmental impacts. A detailed discussion of the use, chemistry, impacts, and control strategies for chlorine is presented in Appendix D. Many organisms which inhabit Bay waters (for example eggs, larvae, and juvenile fish, oyster and clam larvae, zooplankton, and phytoplankton) have shown sensitivity to relatively low concentrations of chlorine in laboratory studies. Microcosm research and other controlled experiments have demonstrated community changes in phytoplankton and benthic organisms. It has been suggested that chlorinated effluent plumes in streams may hinder spawning runs of migrating fish. The CBP research concluded that chlorine was a possible cause of moderate or high toxicity to bioassay organisms at six POTWs and three industrial facilities in Chesapeake Bay waters (Wilson et al. 1982). Screening of measured water column values of total residual chlorine against proposed EPA water quality criteria showed high values exceeding criteria in fresh and oligohaline (brackish) areas of major western shore tributaries (Flemer et al. 1983).

POINT SOURCES AND LOADINGS

Municipal Treatment Plants: Metals

Wastewater discharged from municipal point sources often contains metals and other toxic substances (Figure 35). Concentrations of metals in the effluent from major POTWs were determined from plant measurements. In cases where no information was available, default values were assigned. Measured and default values used in calculating POTW loads are presented in Table 16.

Loadings from POTWs were computed by multiplying discharge flow rates (MGD), obtained from the EPA 1980 Needs Survey, by concentration values obtained from results of pilot-scale studies conducted by the EPA Municipal Environmental Research Laboratory (MERL) (Petrasek 1980). Discharge flow-rates are compiled in the Needs Survey for use in Congressional allotment of construction grant funds to upgrade or expand existing POTWs. Using this procedure, estimates of the municipal metal load by major basin are presented in Table 17. The West Chesapeake basin and Potomac River are the largest sources of metals discharged from POTWs.

Industrial Plants: Metals

The concentration of metals in various industrial effluents was obtained from EPA effluent sampling data from Resources for the Future in the "Pollution Matrix Lookup Routine." Concentration values were assigned based on the industry's Standard Industrial Classification (SIC) code. The discharge rates for each industry were obtained from data collected for an EPA project referred to as the "Industrial Facilities Discharger File" (IFD). Loadings of metals in pounds per day were computed by multiplying the effluent discharge rate in millions of gallons per day by the concentration of the various metals in milligrams per liter, and applying the appropriate conversion factors. However, when assigning effluent concentration values, the industries discharging cooling water were assigned concentrations representative of cooling water, not wastewater. Those industries discharging cooling water and process wastewater were assigned concentration values approximately 85 percent less than those industries in the same SIC code but discharging all process wastewater. These numbers were then evaluated and adjusted, when necessary, by officials of Maryland's Office of Environmental Pro-

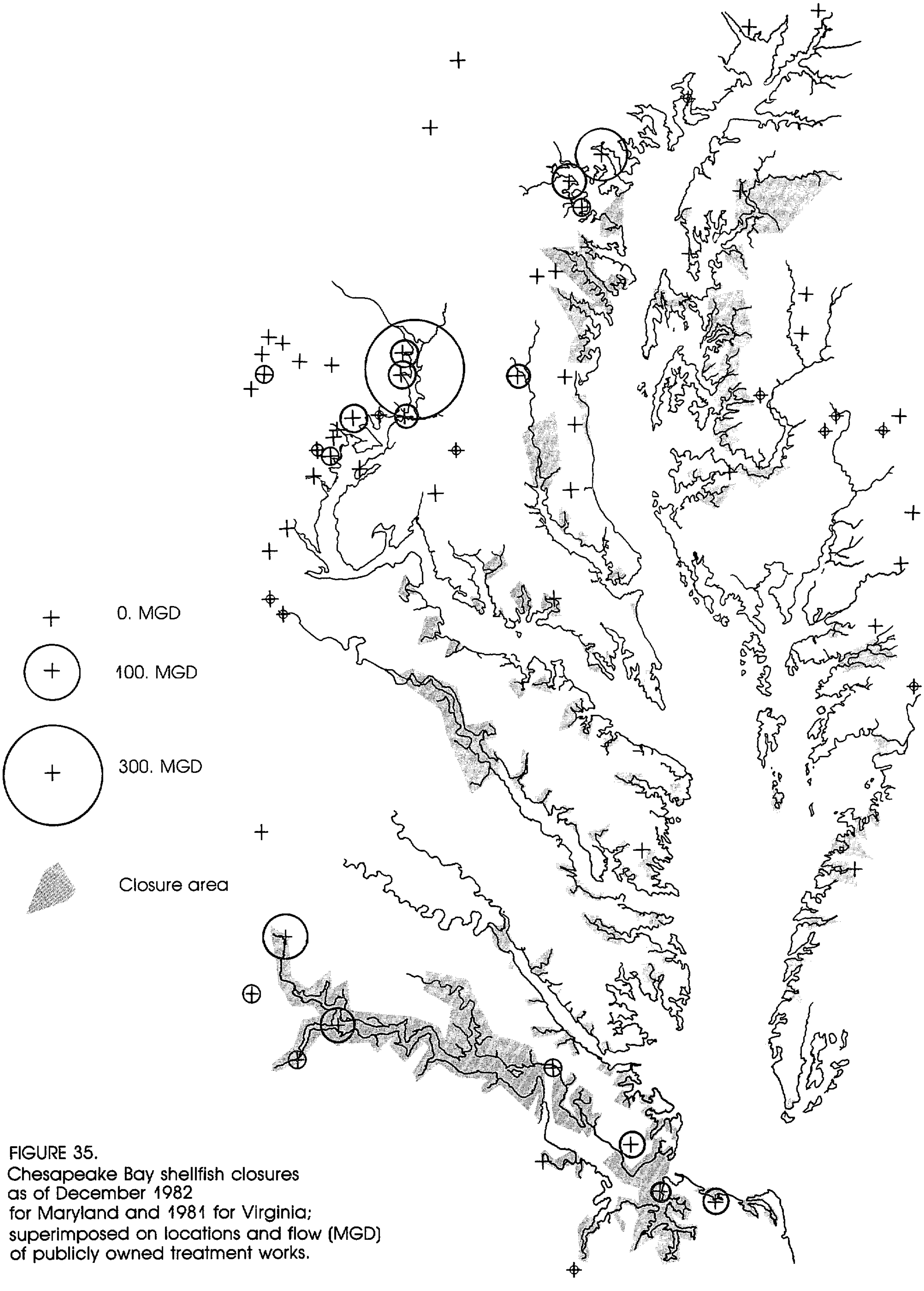


FIGURE 35.
Chesapeake Bay shellfish closures
as of December 1982
for Maryland and 1981 for Virginia;
superimposed on locations and flow (MGD)
of publicly owned treatment works.

TABLE 16.
METAL CONCENTRATIONS ASSIGNED TO POTWs (mg L^{-1})

Basin	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Zinc (Zn)
Default Value	.009	.042	.034	1.01	.036	.192
Alexandria (27 MGD)	.00978	.00978	.0098	—	.0098	.038
Arlington (22 MGD)	.0018	.0086	.034	—	.0038	.052
Army Base (12 MGD)	.01	.03	.04	1.67	.13	.23
Back River (81 MGD)	.01	.05	.06	1.5	.04	.16
Blue Plains (317 MGD)	.002	.041	.029	.101	.009	.103
Chesapeake-Elizabeth (20 MGD)	.0003	.01	.02	.77	.05	.03
Fredericksburg (2 MGD)	.0012	.0012	.033	.66	.0264	.108
Patapsco (30 MGD)	.0062	.17	.45	1.48	.038	.26
Western Branch (1.9 MGD)	.0007	.007	.048	1.2	.039	.31
James River (13.7 MGD)	.0042	.005	.026	.44	.0011	.06
Lamberts Point (20.6 MGD)	.0004	.023	.023	1.7	.05	.09
Boat Harbor (17.6 MGD)	.004	.01	.04	1.8	.003	.10

grams (MD OEP) and the Virginia State Water Control Board (VA SWCB). The metal loadings from major facilities are given in Appendix D. Industrial metal loads by major basin are shown in Table 18.

Comparison of Tables 17 and 18 shows that, for most metals, overall loads to the Bay from POTWs and from industrial dischargers are similar. The exceptions are Fe (2.5 × greater in industrial dischargers) and Zn (2 × greater in POTW flows). By far the largest input of metals from industrial sources comes from the West Chesapeake basin, an area which contains the heavily industrialized Patapsco River. Major municipal loads come from the Potomac, West Chesapeake, and James River basins.

Municipal and Industrial Plants: Organic Compounds

Industrial and municipal effluents were evaluated as part of the Monsanto Research Corporation's (MRC) characterization of point sources (Wilson et al. 1982). The results showed that significant concentrations of identified and unidentified organic substances (some chlorinated), as well as metals, were present in the ef-

TABLE 17.
1980 MUNICIPAL METALS LOAD IN POUNDS/DAY BY MAJOR BASIN

Basin	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Zinc (Zn)
Eastern Shore	0.5	4.5	9.0	176.6	7.3	19.4
James	5.4	39.9	79.1	2055.4	78.4	195.8
Patuxent	0.3	3.0	6.0	117.1	4.8	12.8
Potomac	11.3	103.8	207.7	4035.2	167.8	443.4
Rappahannock	—	0.8	1.7	33.6	1.3	3.6
West Chesapeake	35.7	135.3	197.2	2965.1	119.0	255.9
York	—	0.3	0.6	12.0	0.5	1.3
Total	53.2	287.6	501.3	9395.0	379.1	932.2

TABLE 18.
1980 INDUSTRIAL METALS LOAD IN POUNDS/DAY BY MAJOR BASIN

Basin	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Zinc (Zn)
Eastern Shore	2.0	3.2	25.0	—	—	—
James	11.5	40.8	55.2	43.8	28.0	16.7
Patuxent	—	0.1	—	—	0.2	—
Potomac	—	5.9	2.0	—	9.8	1.5
Rappahannock	—	—	—	0.2	—	—
West Chesapeake	69.8	322.5	357.6	22831.2	255.3	346.9
York	0.1	4.8	0.8	—	1.8	8.9
Total	83.4	377.3	440.6	22875.2	295.1	374.0

fluent of power plants, industrial facilities, and sewage treatment plants. Some of these are EPA priority pollutants.

Monitoring and evaluation of organic compound loadings from these point sources are difficult to quantify. The flows at industrial facilities can vary greatly and process changes within the plants can alter the nature of the effluent. Municipal facilities tend to have more regular flows, but monitoring of organic material is usually limited to the EPA's priority pollutants and is not routinely required for NPDES permits under normal conditions.

Many of the priority pollutants detected in Chesapeake Bay sediments in high concentrations were found to be present in the effluent of forty POTWs around the United States, according to a study by the EPA (U.S. EPA 1982a). Many of these pollutants were also detected in the effluent of POTWs in the Chesapeake Bay basin. Synthetic organic compounds such as pesticides, phthalate esters, and polychlorinated biphenyls (PCBs) were found in the effluent of local industrial and municipal facilities. The organic degradation products of domestic sewage were also found at municipal facilities. The concentrations of total organic compounds and the presence of unknown and priority pollutants for twenty-eight facilities in the Chesapeake basin are listed in Table 19.

Municipal Sewage Treatment Plants: Chlorine

A major use of chlorine in the Bay area, and

TABLE 19.
LOADINGS OF ORGANIC COMPOUNDS FROM MUNICIPAL AND INDUSTRIAL SOURCES (WILSON ET AL. 1982)

Plant Code	Total Sum of Organic Compounds (mg L^{-1})	Flow (MGD)	Priority Pollutants Present?	Unknown Compounds Present?
A 109	3.62	NA	no	yes
B 112 D	2.78	NA	yes	yes
B 119 D	0.30	0.22	yes	yes
C 150 D	0.91–0.96	2.45	yes*	yes
C 155 D	0.29–0.40	19.0	yes*	yes
C 156 D	0.80	26.4	yes	yes
C 157 D	0.05	21.3	yes*	yes
C 161 D	2.24	10.5	yes*	yes
C 164 D	0.12–0.34	8.0	yes	yes
C 169 D	0.63	31.0	yes	yes
B 133 S	0.68–0.74	NA	yes*	yes
B 141 S	3.06–3.19	NA	yes	yes
B 142 S	0.93	NA	yes	yes
B 149 S	3.58	NA	yes	yes
A 101	0.01	4.1	no	no
B 111 D	0.01	1.3	yes*	no
B 113 D	0.02	6.57	no	no
B 124 D	0.33	1.4	yes*	no
C 151 D	0.01	4.1	no	no
C 153 D	0.01	2.8	no	no
C [illegible]1 D	0.02	NA	yes*	no
C [illegible]3 D	0.03	70.0	yes*	no
C 159 D	0.03	1.2	yes*	no
C 160 D	0.02	0.094	no	no
B 126 S	0.07	NA	yes	no
B 143 S	0.10	NA	yes*	no
B 147 S	0.03	NA	no	no
C 169 S	0.04	NA	no	no

*10 ug L^{-1} is the quantitative limit of the computerized identification system.
NA: not available

a significant source of chlorinated effluent, comes from the discharge from municipal sewage treatment plants (STPs) (Figure 35). Disinfection of sewage effluents is done for public health reasons, and is considered necessary for waters which are a source of drinking water, which are used for shellfish harvest, where water contact recreation occurs, or where water is used for the irrigation of crops (MD OEP 1982). Presently, it is estimated that STPs discharge some 12,500 pounds of residual chlorine per day to tidal waters (below the fall line) (Table 20). This estimate is based on discharge monitoring reports of residual chlorine and flow from POTWs (MD OEP 1982, VA SWCB 1982). Effluents of sewage treatment facilities are of particular interest because of the greater potential for the production of chlorinated organic compounds, particularly in plants receiving significant industrial wastewater (Roberts et al. 1980, U.S. EPA 1982a). Currently, all Chesapeake STPs disinfect throughout the year.

Industrial Dischargers: Chlorine

Chlorine is also used in a variety of industrial processes, including fiber, pulp and paper, meat and poultry packing, seafood processing, other food industries, laundries, and etc. Many of these discharge to municipal treatment plants, and others directly to natural receiving waters. In the Chesapeake area, chlorine is generally used for treatment of industrial wastewater, or for the disinfection of food or equipment during processing (Brinsfield 1982, Carr 1982, Schlimme 1982). The magnitude of the source depends primarily on the process involved and the amount of flow. Large paper or packing plants can also supply significant loads with high concentrations of chlorine in effluents. On the other hand, many small seafood houses do not use chlorine, or use it only in a "clean-up" mode or for the depuration of shellfish (VA SWCB 1983, MD OEP 1982). Effluents may be concentrated however, and could cause significant local effects in small receiving streams. Brinsfield (1982) found a number of processors whose residual chlorine effluents discharges exceeded 85 mg L^{-1}. This is in part due to relatively ineffective means of application of the chlorine to the wastewater. Both Maryland and Virginia have existing guidelines for discharges of chlorine from municipal and industrial effluents; these are specified in NPDES permits (Appendix D).

Power Plants: Chlorine

The second major use of chlorine in the Chesapeake region is at steam electric power plants, where it is used as a biocide to prevent biofouling of the heat exchange condensors.

TABLE 20.
TOTAL RESIDUAL CHLORINE (TRC) DISCHARGES TO TIDAL BASINS BY POTWs

Basin	TRC (lbs/day)	POTW flows (MGD)
Eastern Shore	365	21
James River	3,694	220
Patuxent River	177	30
Potomac River	5,205	479
Rappahannock River	67	4
West Chesapeake River	2,938	134
York River	24	1
TOTAL	12,470	889

Typically, plants initiate chlorination when ambient water temperatures reach 50 or 54°F (10 or 12°C) in spring (when fouling becomes a problem), and continue until temperatures drop below these values in the fall. Thus, the majority of plants in the Chesapeake area use chlorine for about 200 days a year (MD DNR 1983). Chlorine may be applied intermittantly (as per EPA regulations), but in some parts of the estuary continuous chlorination is necessary and permitted by the EPA. Not all steam electric plants use chlorination as an anti-fouling measure; necessity for chlorination depends to a great extent on the nature of the water at the site and major fouling organisms present. Plants at the oligohaline/mesohaline boundary typically have the most serious problems with fouling.[6] Only plants with "once-through" cooling systems have the potential of discharging significant amounts of chlorine residuals to the environment. Table 21 gives the chlorine use (in pounds per day), discharge limit, and hours per day chlorination takes place for steam electric plants discharging to tidal waters. Although use of chlorine (in lbs/day) is high at some plants, the volume of water passing through the plants is so large ($\sim 10^8$ to 10^{11} gal/day) that residual chlorine concentrations in the effluent are low. For example, measured residual chlorine at the discharge of the Westport plant in 1979 ranged from 0.09 to 0.4 mg L^{-1} with a mean of 0.17 mg L^{-1}; for Wagner, the range was 0.019 to 0.23 mg L^{-1}, with a mean of 0.03. Conversely, however, the large flows mean that significant volumes of water are exposed to some concentration of chlorine.

An important point is that the characters of chlorinated effluents from sewage treatment, industrial, and power plants differ. Typically, power plant effluents are less concentrated and contain significantly less organic material. The potential for forming halogenated organic compounds at power plants would depend to a great extent on the nature of the ambient water at each site. Incoming cooling water containing high organic loads represents the major problem (below).

The Formation of Chlorinated Compounds During Chlorine Disinfection

One concern with the chlorination of effluents containing significant organic matter is the potential of forming chlorinated (or brominated) compounds. Jolley et al. (1976) identified a number of halogenated organic substances from wastewater, and Helz (1980b) found brominated compounds in sea water to which chlorine was added. Some of the resulting organic materials are toxic and can be bioaccumulated by organisms.

It was noted in the EPA study of 40 plants nation-wide that certain chlorinated hydrocarbons listed as priority pollutants increased in concentration following chlorine disinfection at secondary and tertiary facilities. Chloroform concentrations increased the most—in 39 instances a pre-chlorinated average of 2 ug L^{-1} increased to a post-chlorinated average of 10 ug L^{-1} (U.S. EPA 1982a). Chloroform was also detected in the effluent from all eight POTWs in the Chesapeake Bay basin; values at five plants ranged from 17 to 28 ug L^{-1}. It should be noted that chloroform is a carcinogen for humans and the EPA's 10^{-6}risk level (which results in one additional human death in one million) is set at 15.7 ug L^{-1}. A comparison of concentrations of purgeable organic materials, between Chesapeake Bay POTWs and national POTW averages shows correspondingly high concentrations of chloroform and toluene, and frequent detection of methylene chloride, tetrachloroethylene, 1,1,1-trichloroethylene, 1,2-trans-dichloroethylene, and trichlorofluoromethane at local facilities (Table 22).

THE TOXICITY OF POINT SOURCE EFFLUENTS

Seventy-five percent of the point source effluents tested during a CBP analysis of wastewater from 28 plants were rated as being moderately or highly toxic to bioassay organisms (Table 23, Wilson et al. 1982). The acute, static bioassays were conducted using mysid shrimp and fathead minnow. Based on this analysis, seven of the eight municipal effluents were moderately or highly toxic, 13 of 19 industrial effluents were moderately or highly toxic, and the power plant wastewater was evaluated as having moderate toxicity. An LC_{50} value (i.e., concentration causing 50 percent mortality of test organisms) was used as a starting point for further evaluation. Therefore, those effluents in which 50 percent or more of the test species died in a 50/50 effluent/dilutent solution were further evaluated to determine the possible causes of the toxicity. To determine if significantly high levels of organic compounds were present in effluent, those effluents with total organic carbon (TOC) greater than or equal to 50 mg L^{-1} were checked and evaluated. If bioaccumulative compounds were present, then the objective was to identify them, evaluate their potential toxicity, and determine whether or not they were the cause of aquatic toxicity. Monsanto's site-specific toxicity reduction program is shown in Figure 36. It is essentially a "decision tree." The Monsanto Protocol for toxicity screening is discussed further in Appendix D.

The possible causes of toxicity and high organic and bioaccumulative compound concentrations in point source effluents were analyzed using fractionation bioassays. These are summarized in Table 24 and listed for each plant in Appendix D.

It appears that much of the toxicity of municipal plant effluents can be explained by the presence of chlorinated organics, metals, or free available chlorine. Bioaccumulative compounds and high levels of total organic carbon were also detected in the STPs, but most of the organic compounds could not be identified. In comparison, the effluents from industrial and power generating facilities were less likely to have high concentrations of organic and bioaccumulative compounds. However, priority pollutants were detected and many other compounds could not be identified.

TABLE 21.
CHLORINE USE AT CHESAPEAKE BAY POWER PLANTS

Plant	Chlorine lbs/day	hrs/day	Discharge Limit
Maryland			
Wagner	1750	24	0.20 mg L^{-1}
Brandon Shores	200	24	0.20 mg L^{-1}
Westport	200	24	0.20 mg L^{-1}
Gould St.	200	24	0.20 mg L^{-1}
Morgantown	4000	24	0.14 mg L^{-1}
Chalk Pt.	4000	24	0.50* mg L^{-1}
Vienna	does not chlorinate		
Calvert Cliffs	does not chlorinate		
C.P. Crane	does not chlorinate, equipment in place		
Riverside	does not chlorinate		
D.C.			
Potomac R.	830	2	
Benning Rd.	32–50	intermittent	
Virginia			
Portsmouth	165	2 or less	0.20; 0.5 max.
Chesterfield	does not chlorinate, equipment in place		
Yorktown	427	2 or less	0.20; 0.5 max.
Surrey	1.7	at sewage treatment plant only	
Possum Pt.	56	at sewage treatment plant only	

* currently under review

TABLE 22.
PURGEABLE ORGANIC COMPOUNDS IN CHESAPEAKE BAY POTWs COMPARED TO EPA'S NATIONAL SURVEY OF 40 POTWs (ug L-1) (WILSON ET AL. 1982, U.S. EPA 1982)

% Times detected at 40 POTWs[1]	Organic compound	Concentrations detected at Chesapeake Bay[2]							
		C150D	C155D	C156D	C161D	C169C	B141S	C164D	C158D
86	Methylene Chloride		*	*	*	*	*		*
82	Chloroform	*	28	21	28	18	17	*	*
79	Tetrachloroethylene	*	*	*	*		*		
53	Toluene		14	*		11	30	*	*
52	1,1,1-Trichloroethane	*	*	16	*		*		
45	Trichloroethylene			*	*		*		
24	Ethylbenzene		*	*	*				
23	Benzene		*	*			17		
13	1,2-trans-dichloroethylene		*	*	*		*		
8	1-1-dichloroethane			*					
6	Carbon tetrachloride			*					
4	Trichlorofluoromethane					*	*	*	*
3	Chlorobenzene					*			
1	Dichlorodifluoromethane						*		

[1]At least 276 samples were analyzed for each parameter (U.S. EPA 1982).
[2]Confidentiality code; all POTWs are in Virginia except B141S (Maryland) (Wilson et al. 1982).
*10 ug L^{-1} is quantitation limit of computerized identification system for samples.

TABLE 23.
TOXICITY OF EFFLUENTS FROM 28 CHESAPEAKE BAY FACILITIES (WILSON ET AL. 1982)

Facility	Total # Tested	# Not Toxic	# Low Toxicity	# Mod. Toxicity	# High Toxicity
POTWs	8		1	3	4
Industries	19	5	1	8	5
Steam Power Plant	1			1	

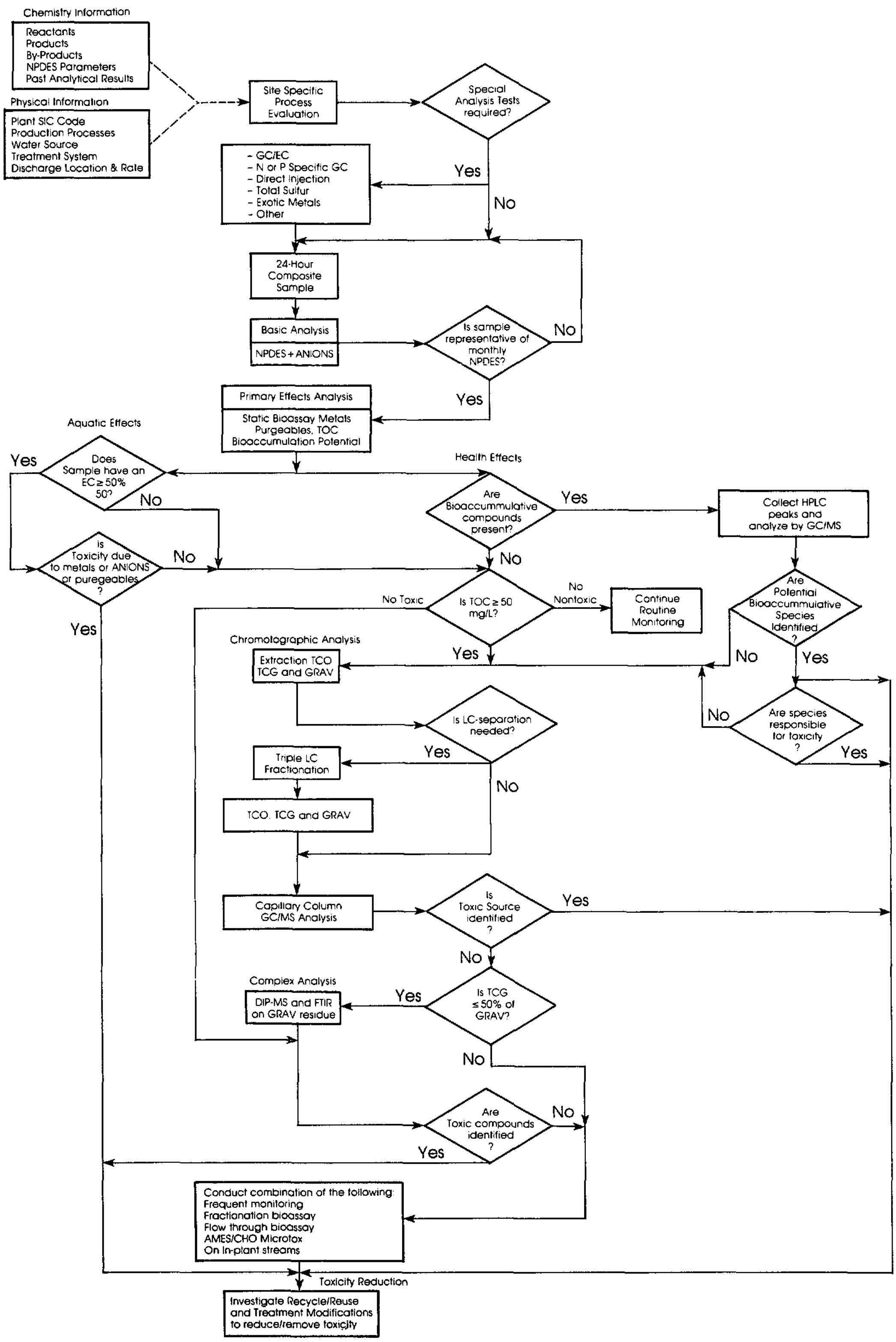


FIGURE 36. Site-specific "decision-tree" for identification and reduction of effluent toxicity.

TABLE 24.
POSSIBLE CAUSES OF TOXICITY AND HIGH ORGANIC AND BIOACCUMULATIVE CONTENT[1]

	POTWs	Industries	Power Plant
Metals	X	X	X
Chlorine	X	X	X
Chlorinated Organics	X	X	
Other Organic Compounds	X	X	
Cyanide		X	
Ammonia	X	X	

[1]Facilities are individually shown in Appendix D.

THE EFFECTIVENESS OF POINT SOURCE CONTROLS

Permit Programs

Progress both nationally and in the Bay area in achieving the first level of pollution control for industry, "Best Practical Technology" (BPT), has been good. The EPA compliance data indicate that, nationally, approximately 90 percent of the industrial facilities were in compliance with BPT at the time of the 1977 deadline. It is estimated that metal and other pollutant loadings discharged by point sources to Chesapeake Bay may have decreased by 33 percent during the 1970's when BPT was installed. The BPT technologies generally remove (or regulate) conventional pollutants, including BOD_5, TSS, pH, and oil and grease. At the same time, treatment for removal of conventional pollutants also achieves some removal of organic chemicals, which appear to volatize or transform in the treatment process, and metals, which adsorb to suspended sediments.

Specifically, metal loads to Baltimore Harbor from Bethlehem Steel and other industrial dischargers decreased significantly after the promulgation of BPT controls. Other significant changes were the construction of the Humphreys Creek industrial waste-treatment plant by Bethlehem Steel in 1971 and large reductions in water use by industries Bay-wide between 1968 and 1977. Reductions of metal loadings to Baltimore Harbor are shown in Figure 37. It is anticipated that further reductions will be achieved when NPDES permits for industrial dischargers are reviewed and upgraded. This will require that either "Best Available Technology" (BAT) toxic limitations be promulgated by the EPA for each industrial category or that the states develop their own limits.

Pretreatment

Two pretreatment programs have been initiated in the Bay area to further reduce point source loadings. The Hampton Roads Sanitation District (HRSD) in the Hampton Roads area has developed a program, and Baltimore City and Baltimore County have started a planning effort this year. The HRSD program, approved by the EPA in 1982, was developed because of the need to protect the District's relatively small facilities, to preserve the quality of their sludge, and to limit hazardous discharges to the James, Elizabeth and York Rivers, Hampton Harbor, Chesapeake Bay, and the Atlantic Ocean. The purpose of the program is to monitor and limit toxic influents from the major industrial facilities. Permits are based on national pretreatment information, the EPA Development Documents, and the District's monitoring and engineering knowledge of the facilities. In 1983, nine treatment plants, ranging from 10 to 36 MGD, will be receiving

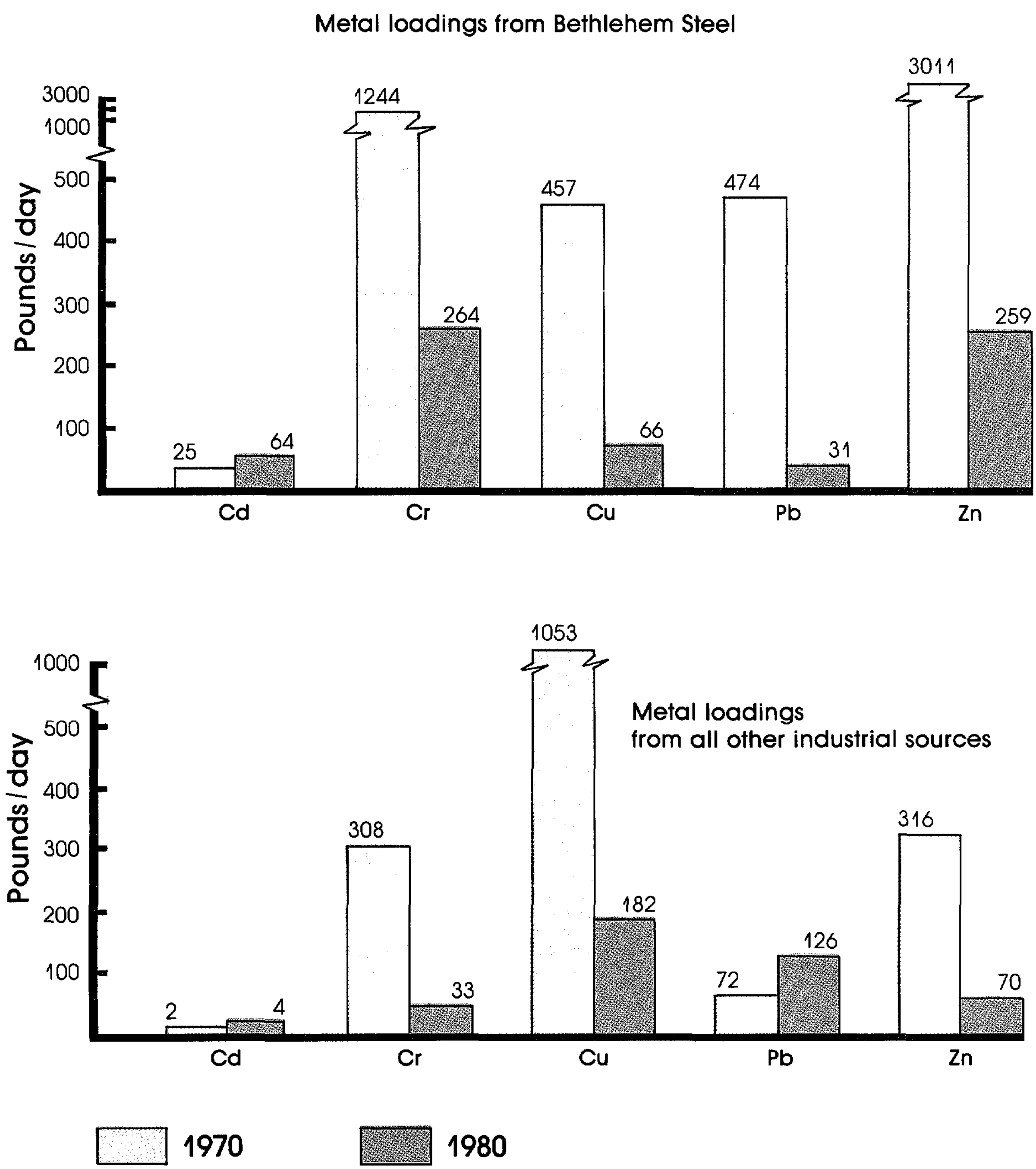


FIGURE 37. Comparison of industrial metal loadings discharged to Baltimore Harbor between 1970 and 1980 (pounds/day).

discharges from 205-permitted facilities. However, most jurisdictions are not developing pretreatment programs because 1) the EPA has not finalized the general pretreatment regulations; 2) there is no construction grant guidance explaining what is and is not eligible for pretreatment program funding; and 3) the EPA's proposals and promulgation of categorical standards for regulated industries have not been completed.

Chlorine

Concern over the use of chlorine has been generated by considerable work in the past 15 years on toxicity and potential environmental effects, chlorine chemistry, and the toxicity of reaction products. In a national survey conducted by the Virginia State Water Control Board, Maryland was identified as one of two states that was doing the most to reduce the use and potential impacts of chlorine. One Maryland program works with POTW operators to improve or modify existing chlorination procedures and reduce the amount of chlorine discharged to spawning areas. Under another program, dechlorination facilities are installed in those sewage treatment plants discharging high residual chlorine concentrations to major fish-spawning areas. Also, many industrial facilities are reducing chlorine discharges. A variety of nonchemical or mechanical techniques, such as abrasive cleaning, are being used in steam electric power plants in the basin. Alternative sterilization techniques are being voluntarily used at 10 percent of the seafood packing houses in Virginia. These programs are discussed in detail in Appendix D.

Summary

Although existing programs are reducing the concentrations of metals, organic compounds, and chlorine being discharged to Bay waters, there are still toxic problems in the Bay. In areas heavily contaminated with metals and organic compounds, such as the Patapsco and Elizabeth Rivers, there are changes in benthic species composition and reduction in organism abundance and diversity relative to similar uncontaminated areas (Reinharz 1981, Schaffner and Diaz 1982). Laboratory studies have shown that these sediments are toxic to benthic organisms (Swartz and DeBen, in prep; Alden et al. 1981). Similarly, levels of toxicants exceeding EPA Water Quality Criteria have been observed in many areas of the Bay, particularly near developed areas. These findings are reason for concern and justify action. Additional information on toxicant/organism relationships is presented in the Environmental Protection Agency's *Chesapeake Bay Program Technical Studies: A Synthesis* (Macalaster et al. 1982) and the Environmental Protection Agency's *Chesapeake Bay: A Profile of Environmental Change* (Flemer et al. 1983). The above findings and the following incidents further suggest that current permitting, monitoring, and enforcement programs do not sufficiently control point source toxic loadings to the Bay.

- In Baltimore Harbor, 6-phenyldodecane, a substituted benzene, was found to be widely distributed (Huggett et al. 1981). Project data from the Monsanto Research Corporation's analysis of industrial discharges were cross-checked, and it was discovered that a number of local industrial dischargers had the compound in their wastewater (Wilson et al. 1982). A review of the NPDES permits revealed that there were no facilities which were allowed or permitted to discharge the compound.
- In the James River, high levels of the pesticide Kepone were discovered in 1975. Apparently, for years the pesticide had been discharged into the James River at Hopewell, Virginia. The amount and extent of Kepone discharged to the water up to 1975 remains unknown.
- In Baltimore, at the Back River Sewage Treatment Plant (BRSTP), discharges of ethyl benzene were detected using GC/MS analysis and, subsequently, a particular industrial plant was identified as the source. The industry, which had discontinued use of the chemical because of production problems, was surprised to learn that ethyl benzene was still being discharged, but now as a result of recombinations during a distillation process. On the basis of that GC/MS analysis at the treatment plant, it

was detected, and once again, removed from the effluent.

In 1983, current monitoring programs would not detect an illegally discharged or dumped bioaccumulative organic compounds which exceeded chronic toxicity levels but did not cause acute effects. It is evident that an ongoing program to monitor effluent, sediments, and resources should be established.

NONPOINT SOURCES AND LOADINGS

Riverine Inputs: Metals

A CBP-funded study by the U.S. Geological Survey estimated loadings of metals at the fall line of the Susquehanna, Potomac, and James Rivers (Table 25).

Thirteen naturally-occurring metals were identified and six—Cd, Cr, Cu, Ni, Pb, and Zn—were found in large enough amounts to indicate that anthropogenic additions by point and nonpoint sources exist above the fall line. The Susquehanna, contributing 50 percent of the freshwater inflow to the Bay, contributes the highest loadings of each metal. The Potomac, contributing one-fifth of the freshwater inflow to Chesapeake Bay, is the second largest riverine source of all metals except Cd. The contribution of acid mine drainage to any of these loads is not well quantified.

A portion of the metals delivered to the fall line may never reach the estuarine two-layered portion of the Bay because they are sorbed to the surface of fine grained sediments which are deposited in the maximum turbidity zones of Chesapeake Bay tributaries. These highly efficient "sediment traps" decrease the riverine metal load to the Bay, although they may reach the main Bay following intense storm events (Bieri et al. 1982a).

Urban Loadings: Metals

The common metal constituents of urban runoff are Fe, Pb, Cr, Cu, and Cd. The major urban sources of these metals are Hampton Roads, Baltimore, and Washington. Hampton Roads is at the mouth of the James River, near one of the most productive oyster regions in the Bay. The other two cities lie along the fall line and drain into important freshwater or brackish fish- and shellfish-spawning grounds. Estimates of metal loadings for the major metropolitan areas are presented in Table 26. The data necessary to calculate these loadings are shown in Appendix D.

It is likely that the loadings of heavy metals and hydrocarbons from urban runoff have a

TABLE 25.
ESTIMATED AVERAGE ANNUAL LOADINGS AT THE FALL LINE FOR SIX METALS FROM THE MAJOR TRIBUTARIES OF CHESAPEAKE BAY FOR THE 1979 TO 1980 PERIOD (VALUES IN POUNDS/DAY) (FROM LANG AND GRASON 1980)

Metal	Susquehanna	Potomac	James	Total
Cd-T*	392	24	36	452
Cr-T	2310	633	380	3323
Cu-T	2352	519	247	3118
Ni-T	1381	657	386	2424
Pb-T	1049	615	187	1851
Zn-T	5047	1942	1719	8708

*T=Total

TABLE 26.
URBAN RUNOFF METAL LOADING FROM THREE MAJOR METROPOLITAN AREAS OF CHESAPEAKE BAY (POUNDS/DAY-1) (BIERI ET AL. 1982)

	Pb	Zn	Cu	Mn	Fe	Cr	Cd	Ni
Baltimore	211	115	18	30	1755	18	30	36
Norfolk/Newport News/Hampton/ Portsmouth	157	90	12	18	1284	24	6	24
Washington, D.C.	302	175	24	42	2852	24	6	60
TOTAL	670	380	54	90	5891	66	42	120

greater influence in local receiving waters, such as the tidal-fresh Potomac River, than on the entire Bay. The local effects of urban runoff may be one of several factors contributing to the significant declines in both the juvenile index and landings that have been observed for both anadromous and semi-anadromous fish in the Potomac. For example, urban runoff contributes 28 percent of the Pb and 15 percent of the Cd to the Potomac River (Table 27). Therefore, although urban runoff has primarily a local impact, areas affected may represent significant or critical habitat for major resources or food chain species.

Research in smaller tributaries of the Potomac indicates that these important spawning areas for alewife, blueback herring, white and yellow perch, and striped bass (as well as forage fish) are more likely to have concentrations of trace metals which exceed EPA water quality criteria (Lippson et al. 1973, Flemer et al. 1983). Seneca Creek, a tributary of the Potomac which drains a mixed-use watershed north of Washington, DC, has been shown to be adversely affected by at least four water quality constituents—trace metals, sediment, bacteria, and pH. Copper, Pb, Zn, and silver (Ag) were among those which chronically exceeded EPA criteria (Schueler and Sullivan 1982). Lead and Cd in urban runoff are associated with automobile exhaust, brakes, tires, and leaded gasoline.

TABLE 27.
HEAVY METAL LOADINGS FROM URBAN RUNOFF

Metal	To Chesapeake Bay Basin	To Tidal-Fresh Potomac
Pb	19 percent	28 percent
Cd	6 percent	15 percent
Zn	2 percent	7 percent
Cr	1 percent	3 percent
Cu	1 percent	3 percent

Urban Loadings: Hydrocarbons

The CBP estimated that the loading of hydrocarbons to Chesapeake Bay [using unit loading rates developed at a Rhode Island site by Hoffman et al. (1982)], from residential, commercial, and industrial land is greater than 100,000 pounds per day (Table 28). This is a conservative estimate because highways and roads, significant hydrocarbon sources, were not differentiated by the LANDSAT analysis of the basin. The results indicate that industrial land-uses have the largest hydrocarbon unit loading rate, followed by highway, commercial, and residential land-uses. At a commercial land-use study site, the primary source of hydrocarbons was found to be automobile crankcase oil.

It should be noted that moderate amounts of hydrocarbons in the water column and the bed sediments have been shown to adversely affect organisms. Declines in zooplankton populations are seen when water column concentrations of No. 2 fuel oil exceed 0.1 ppm. Benthic communities are drastically affected when oiled sediments contain concentrations of 500 ppm of No. 2 fuel oil (Olsen et al. 1982). Management and control of hydrocarbons in the Chesapeake Bay basin should concentrate on:

- Industrial sources—greater care and handling of fuel and crankcase oil;
- Urban runoff from highways and commercial areas—use of crankcase oil disposal facilities and maintenance of automobile gaskets and seals; public education of effects of careless disposal; and
- Combined sewer overflows—new diversion structures and/or better control device maintenance.

Atmospheric Deposition: Metals

The atmospheric deposition of metals to the Bay has been shown to be continuous and significant. The concentrations of metals in the atmosphere are proportional to the total mass of the metals released into the atmosphere from fossil-fuel combustion, manufacturing processes, and many other anthropogenic and natural processes (Bieri et al. 1982a). Metals are deposited as dryfall (dust) and as dissolved constituents of wetfall (rain, snow, hail). Estimates based on wetfall during six storm events are shown in Table 29. As indicated, Zn is the metal deposited in the highest

TABLE 28.
ESTIMATED LOADING OF HYDROCARBONS TO CHESAPEAKE BAY WATERS FROM URBAN LAND

Land Use	Hydrocarbon loading factor ($g/m^2/yr^{-1}$)	Acreage Chesapeake Bay basin[5]	square meters	loading (lbs/day^{-1})
Residential	0.18[1]	683,715	$2{,}775 \times 10^6$	3,017
Commercial	0.6[2]	(289,995)	(1,177 × 106)	4,285
Industrial	14.0[3]	(289,995)	$(1{,}177 \times 10^6)$	96,554
Highways	8.2[4]	unknown	—	—
				103,856

[1,3]Loading rate based on polynomial equation developed by Hoffman et al. 1982.
[2,4]Based on average of factors derived from polynomial and linear equations developed by Hoffman et al. 1982.
[5]Based on LANDSAT (from Hartigan et al. 1983).

concentration by atmospheric wetfall. Almost 5000 pounds per day, 31 percent of the total Zn loadings to the basin, are contributed by deposition on the Bay and its tributaries. Much of the deposition is indirect—either with urban runoff or through leaching of metals by acidic precipitation (Bieri et al. 1982a). Direct impacts of acid precipitation on freshwater tributaries is not known, but is being currently studied in some areas of the Bay.[7]

Some atmospheric deposition to the Bay may have traveled from industrial sources in the midwest United States. However, a climatological atmospheric dispersion and deposition model (NOAA 1981) showed that 30 to 40 percent of the emissions generated within the Chesapeake Bay "cell" are deposited within the 150,259 sq. mile (58,000 km^2) area. Whether this represents a significant percentage of the total contribution from all areas cannot be determined.

Research in the Baltimore region has shown that aerosols and large particulates settle rapidly near the city (Baltimore Regional Planning Council, unpublished data). The wind patterns near Baltimore typically demonstrate west-northwest movement, suggesting that metal emissions from this regional industrial center may be an important source of loadings to Chesapeake Bay.

Research efforts and regional and national coordination of programs must be emphasized. Initial efforts could include:

- Development of a centralized data base containing the results of past and present research and monitoring of air and water in the Chesapeake Bay basin;
- Coordination of effort through a voluntary association of concerned and active researchers;
- Monitoring of local sources and deposition areas;
- Research and regulation of deposition which is potentially harmful to local resources—crops, waters, soils, human health, and ecosystems; and
- Development of regional strategies by interstate councils or associations.

Agricultural Toxicants: Pesticides and Herbicides

Agricultural activities do not contribute significant amounts of metals and petroleum hydrocarbons to Chesapeake Bay. The chief toxic constituents of agricultural runoff are pesticides and herbicides. Because of application rates, cropping patterns, and chemical characteristics, six herbicides are considered of primary importance in the Chesapeake Bay basin: atrazine, alachlor (Lasso), linuron, paraquat, trifloralin, and 2,4-D. More than 200,000 pounds of atrazine, alachlor, and linuron are applied to corn and soybeans annually (Stevenson and Confer 1978). (All loadings are shown in Table 30.) Atrazine and other herbicides were suspected as a cause in the decline of submerged aquatic vegetation in the Bay.

TABLE 29.
ATMOSPHERIC DEPOSITION TO CHESAPEAKE BAY AND ITS TRIBUTARIES

Metal	Pounds per Day	Percent of Total
Zn	4975	31
Fe	525	—
Pb	205	6
Cu	169	4
Ni	151	—
Mn	133	—
Cd	18	3

However, CBP-sponsored research found that ambient atrazine concentrations in the main Bay rarely exceed 1.0 to 5.0 ppb; linuron concentrations were between 2.0 and 3.0 ppb. High concentrations of both pesticides were sometimes found in near-field waters (up to 140 ppb); such levels would have significant impacts on SAV in these areas (Figure 38). With half-lives of 2 to 26 weeks, the levels of herbicides in the main estuary and in sediments remain relatively low (Kemp et al. 1982a).

Commonly-used herbicides and insecticides in the basin are shown in Table 31. The modes of transport are derived from field experiments and estimates of water solubilities of the chemicals. It can be seen that these compounds are both water-soluble and sorb to soil particles. The dissolved fraction is more toxic to fish than the portion adsorbed to sediment, and the fish toxicity values represent concentrations in the water.

The chlorinated hydrocarbons, such as Toxaphene, primarily adsorb to soil. The organic phosphates—Ethoprop, Phorate, Malathion, and Dimethoate—tend to dissolve in water. Therefore, controlling both soil erosion and runoff is necessary for keeping pesticides and herbicides on agricultural fields and preventing environmental degradation of aquatic ecosystems. Results of two pesticide reduction programs—the Virginia Leafspot Advisory Program and the Integrated Pest Management Program in Maryland—are discussed in a later section on the effectiveness of nonpoint strategies.

Pesticides and herbicides can enter the estuary from other sources: widespread spraying of marshes and residential areas for mosquito control; spraying for gypsy moths; herbicide use for weed control along road and powerline right-of-ways; runoff from residential areas; and improper disposal of unwanted pesticides in waterways. It should be noted that a pesticide widely used for mosquito control in marshes—malathion—is very toxic to fish (Table 31).

To keep herbicides and pesticides on agricultural fields, both runoff controls, for highly persistent herbicides dissolved in water, and erosion controls, for those which are adsorbed to organic soil colloids, are necessary. In addition to protecting water quality, control of herbicide and pesticide losses through the soil conservation programs has direct and immediate financial benefits for farmers. Some additional practices which have been shown to significantly reduce loadings, minimize effects, and which have potential in the Bay area are:

- Reduction of pesticide use; increase in the use of integrated pest management (IPM) (now in use, see section on Existing Strategies);
- Timing application periods to avoid rainfall events and subsequent large losses to productive freshwater-spawning areas and

TABLE 30.
LOADINGS AND TRANSPORT OF HERBICIDES TO CHESAPEAKE BAY WATERS (MARYLAND AND VIRGINIA) (STEVENSON AND CONFER 1978, USDA 1975)

Herbicide	Lbs Applied Per Year	Primary Transport Mode
Atrazine	108,000	sed., water
Alachlor (Lasso)	97,000	sed., water
Linuron	31,000	sediment
2,4-D	11,000	sed., water
Trifluralin	11,000	sediment
Paraquat	10,000	sediment
	268,000	

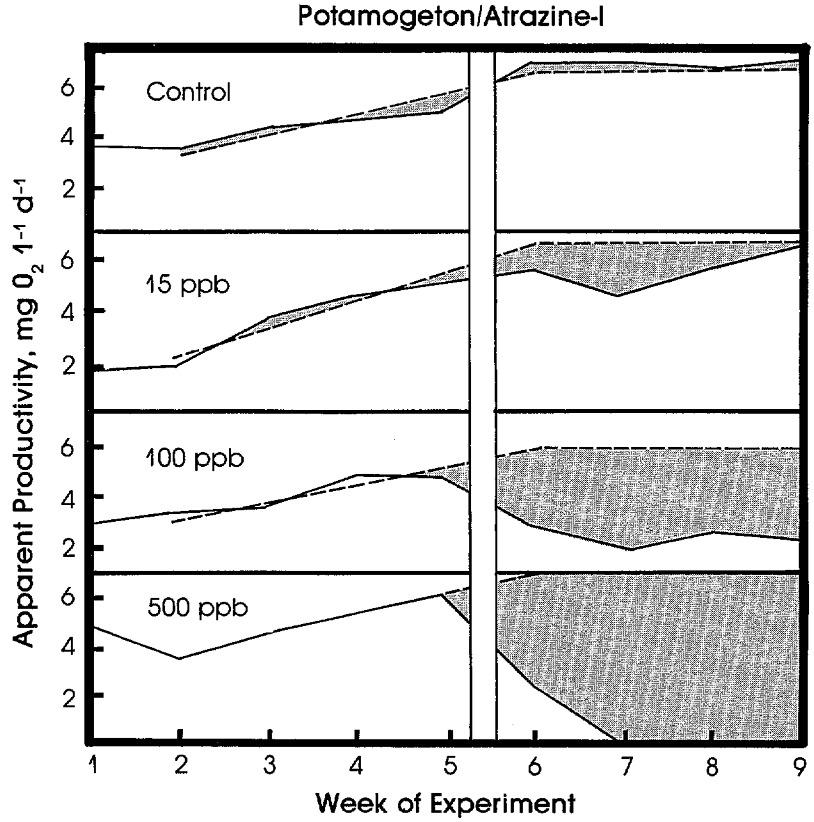


FIGURE 38. Measurements of apparent photosynthesis of Potamogeton perfoliatus treated with varying concentrations of atrazine.

other habitats;

- Use of non-persistent pesticides and herbicides that degrade quickly; use of "biologicals" such as Dipel, BTI; (long-term) development of pesticides that better resist wash-off;
- Reduction or elimination of unnecessary or low priority uses of pesticides, especially near waterways (e.g., spraying of estuarine marshes); replacement with alternatives such as BTI;
- Groundcover planting to reduce weed populations, especially along roadways and powerlines, to reduce herbicide use;
- Roadside or powerline mowing as an alternative to chemical treatments; and
- Use of resistant crop varieties which require fewer treatments (USDA 1975).

The effectiveness and appropriateness of these programs will, of course, vary with region, crop, season, etc.

Marine Activities

Marine activities contribute a variety of organic and inorganic pollutants to Bay waters. Major industrial shipyards, which have NPDES permits, contribute to the point source totals (Appendix D). The discharge or spillage of fuel oil and hazardous materials from ships is also a problem. However, copper and copper compounds, which have been used as antifoulants since the 17th century, may be a major "pollutant" from marine activities.

In 1925, following 20 years of paint research,

TABLE 31.
TOXICITY OF HERBICIDES AND INSECTICIDES USED IN CHESAPEAKE BAY BASIN (USDA 1975).

	Crop	Predominate transport mode mg L^{-1}	Toxicity fish LC_{50} days	Persistence in soil,
Herbicide (trade name)				
Atrazine (AAtrex)	Corn	S, W	12.6	300–500
Alachlor (Lasso)	Corn	S, W	2.3	40–70
Linuron (Lorox)	Soybeans	S	16.0	120
Insecticides				
Carbofuran (Furadan)	Corn, Soybeans	W	0.21	
Ethoprop (Mocap)	Corn	U	1.0	
Phorate (Thiem)	Soybeans	S, W	0.0055	
Malathion	Vegetables Ornamentals Marshes	W	0.019	
Dimethoate (Cygon)	Soybeans	W	9.6	
Carbaryl (Sevin)	Soybeans	S, W	1.0	
Toxaphene*	Corn	S	0.003	

S = sediment, W = water, U = unknown
*Will be phased out by 1986.

cuprous oxide became a primary constituent of the U.S. Navy's standard coal tar-rosin anti-fouling paint (Woods Hole Oceanographic Institute 1952). The minimum acceptable leaching rate for cuprous oxide paints is 10 ug/cm²/day, although leaching rates immediately after application are as high as 1,000 ug/cm²/day. Also of concern are organotin compounds which are currently being developed for use in bottom paints and other applications. They are two or three times more toxic to biota than copper, and leach at a much lower rate of 4 to 10 ug/cm²/day.

Accurate estimates of loadings from anti-fouling paints are extremely difficult to quantify. Maintenance and wear varies considerably among boat types, materials, uses, and locations. Furthermore, the loading from the 273,800 registered boats in Maryland and Virginia are not equally distributed over the Bay throughout the year. Their use is confined primarily to the summer months and more concentrated in near-shore areas of the Bay. As a result, marinas and poorly flushed sub-estuaries may be significant nonpoint sources of Cu to local areas.

Copper loadings were estimated using two methods—one based upon how much paint would be applied to registered boats and another on the basis of the minimum leaching rate necessary to prevent fouling. It was assumed that every registered boat that is not aluminum is painted annually with copper-based paint and that no unregistered boat is ever painted, which is probably a conservative assumption. The range of values shown in Table 32—from 488 to 969 pounds of Cu per day—is too large to make a definitive statement about loadings and effects to

TABLE 32.
COMPARISON OF TWO METHODS FOR ESTIMATING THE LOADINGS OF CUPROUS OXIDE TO THE CHESAPEAKE BAY BASIN[1]

Method	gallons/year	lbs/Cu/day
Total gallons applied to registered boats	76,884	969
Total gallons necessary to maintain 10 ug/cm²/day leaching rate on registered boats	38,690	488

[1]Calculations are shown in Appendix D.

the Bay generally. However, estimated loadings are similar to those from industrial and municipal point sources.

Loadings of bis(tributyltin)oxide (TBTO) and tributyltin floride (TBTF), used on larger ships, are estimated to be from 7 to 16 pounds per day (Table 33). Although large commercial ships, U.S. Navy ships, and smaller leisure craft can be treated with either biocide, there is an increasing use of organotins over Cu-based paints. The organotins last longer, are available in a variety of colors, provide more consistent protection, and kill a broader spectrum of biological foulers.

Marinas and other areas with high concentrations of boats may be significant nonpoint sources of Cu, TBTF, and TBTO to local areas. In Maryland waters, there are 268 public marinas and hundreds of private ones. In Anne Arundel County, Maryland, there are a total of 313 public and private facilities. There are 180 commercial marinas in Virginia with a storage capacity for approximately 10 percent of the registered boats.

The speciation of Cu and Sn in the estuarine system is extremely complex and current scientific knowledge does not allow us to fully estimate the effects on the ecosystem. Laboratory studies under

TABLE 33.
TOTAL ORGANOTIN COMPOUND NECESSARY TO MAINTAIN 4 TO 10 ug/cm²/DAY LEACHING RATE AND PREVENT FOULING

Number of ships entering Baltimore Harbor per day	avg/ft²/ship	leaching rate lbs/ft²/day	Total lbs/day
10.2[1]	80,000[2]	8×10^{-6}[3]	7
10.2[1]	80,000[2]	8×10^{-5}[4]	16

[1]3,733 ships at Baltimore Harbor in 1981 (Maryland Port Administration, 1982)
[2]Personal Communication "Application Rate of Antifouling Paints," Chandler, Bethlehem Steel Shipyard, 1983.
[3]Equivalent to 4 ug/cm²/day
[4]Equivalent to 10 ug/cm²/day

controlled conditions provide the most accurate assessment available on the toxicity of metals. To ensure the protection of aquatic life, the EPA Water Quality Criteria for Cu are 23 ug L^{-1} (acute) and 4 ug L^{-1} (chronic) in salt water. Comparable criteria have not been developed for Sn or organotin but research on the levels and effects has demonstrated their toxicity. Some concentrations of Sn in Bay-waters (152 ug L^{-1} in a water sample taken below a sewage treatment outfall) and sediments (239,633 ug kg^{-1} in Baltimore Harbor) exceed levels shown to be toxic to fish, algae, barnacles, shrimp, and tubeworms (Hallas and Cooney 1981).

Dredging and Disposal

Sedimentation and dredging of navigational channels and ports is a continuing process in the Chesapeake Bay estuary. Research conducted by the Bay Program found that there were several documented or probable environmental effects from dredging and disposal activities. This information emphasizes the importance of thoroughly evaluating future sites.

Major channels and disposal sites – The two major dredging projects in the Maryland portion of the Bay are centered around Baltimore Harbor and the Chesapeake and Delaware (C & D) Canal. Since 1870, 82 million cubic yards of material have been dredged from the Baltimore Harbor. The approach and connecting channels have had approximately 95 million cubic yards of material removed. Dredging the C & D Canal area required the movement of 100 million cubic yards of material from the canal itself and 55 million cubic yards from the canal's approach channel (Schubel and Wise 1979).

In the past, most material was dumped into open-water sites in the main Bay or diked nearby dredging sites. A dike is presently being constructed on Hart and Miller Islands for disposal of contaminated spoils from Baltimore Harbor and from the Chesapeake's main channel which leads into the Harbor. Future Federal dredging projects include deepening and maintaining the Baltimore Harbor, the Harbor approaches, the C & D Canal connection, and maintaining the C & D Canal.

The major dredging projects in the Virginia portion of the Bay are centered around Hampton Roads and Norfolk. Maintaining the port of Hampton Roads requires 3.8 million cubic yards to be dredged annually. This would increase by 1.2 million cubic yards if proposals for deepening the shipping channels to 55 feet are approved. Almost 70 percent of the sediments dredged in the Norfolk District from 1970 to 1980 were placed in the Craney Island disposal area because of their potential contamination by toxicants.

Environmental considerations – The major environmental effects from dredging and spoil disposal operations have been well-documented by the U.S. Army Corps of Engineers National Dredged Materials Research Program. In addition, several studies have been conducted locally (Cronin et al. 1970, also see Table 34). All of these studies suggest that, in selecting a disposal site, the following objectives should be considered:

- The material dumped should be no more toxic than the existing bed sediments to prevent environmental degradation;
- The receiving area should be one of active, continuous deposition to prevent movement of the spoils;
- The receiving area should be continuously below the wave base to prevent resuspension; and
- To prevent ecological impacts, the receiving area should not contain important benthic organisms, or be near critical habitat areas for other organisms.

Several sources of information have been developed by CBP researchers to help Bay managers meet these objectives (Figure 39). They are as follows:

- The Contamination Index (CI), a measure of the relative enrichment of sediments above natural levels by six metals (Chapter 2 – State of the Bay);
- Historic shoaling data for the Virginia (Byrne et al. 1982) and Maryland (Kerhin et al. 1982) portions of the main Bay *(Chesapeake Bay: A Profile of Environmental Change)*;
- Bottom-wind wave orbital velocities developed by Dean and Biggs, 1981; and
- The location of commercially important shellfish bars *(Chesapeake Bay: A Profile of*

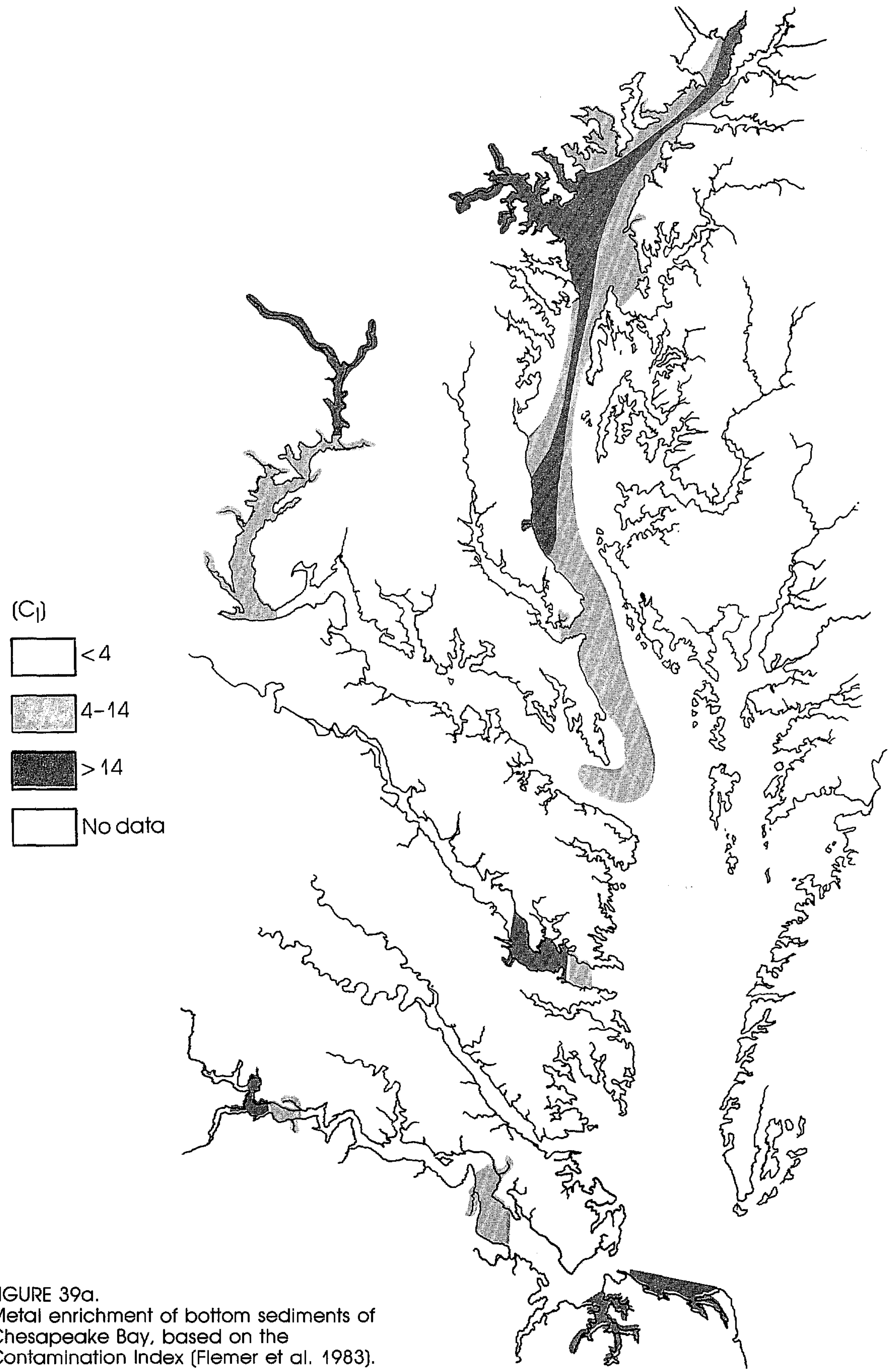


FIGURE 39a.
Metal enrichment of bottom sediments of Chesapeake Bay, based on the Contamination Index (Flemer et al. 1983).

FIGURE 39b.
Major shoaling areas in Virginia (Byrne et al. 1982) and Maryland (Kerhin et al. 1982).

TABLE 34.
DOCUMENTED OR LIKELY ENVIRONMENTAL IMPACTS FROM DREDGING AND DISPOSAL (AURAND AND MAMANTOV 1982)

• Physical—	topographical changes, increased suspended sediment, altered sediment type
• Chemical—	disposal of hazardous substances, release of sediment-bound contaminants
• Biological—	nutrient release, oxygen depletion, elevated levels of turbidity

Environmental Change), major fish-spawning areas, and SAV beds.

Furthermore, another potential strategy involving the disposal of clean (i.e., noncontaminated) dredge spoil might involve overboard disposal of this spoil in areas where bed sediments are heavily contaminated with toxic materials. This would serve to cover and isolate toxic bottom sediments. Other criteria (i.e., receiving area being one of active deposition and below wave base) would have to be met. These sources of information will provide some guidance in locating potential disposal sites. However, site-specific studies on a particular location must be conducted prior to any final disposal decision.

THE EFFECTIVENESS OF NONPOINT SOURCE CONTROLS

Local planning agencies, in cooperation with state agencies and the EPA, are responsible for the development of local programs and management alternatives for controlling nonpoint sources of pollution. This planning and regulatory program was created by section 208 of the Clean Water Act. All nonpoint sources of pollution within the planning area (i.e., agricultural and mining activities, construction, land disposal, and irrigation) must be identified and be evaluated for control measures and land-use requirements. The EPA's recommended planning strategy involves five steps: 1) identification and assessment of water quality problems and nonpoint sources of pollution, 2) identification and assessment of alternative management practices, 3) best management practice selection and alternative control program formulation, 4) evaluation and testing of alternative control programs, and 5) selection of control program(s) for implementation.

Urban Activities

Water quality sampling conducted during the 208 program showed very high concentrations of particulate and organic materials from urban activities in the Baltimore region. In the Baltimore region, which includes Anne Arundel, Baltimore, Carroll, Harford, and Howard Counties, and Baltimore City, there are a variety of best management practices used, including solid-waste management and reduction, street cleaning and runoff storage, and collection system controls (RPC 1980). Water quality sampling data have been limited; therefore, the effectiveness of these controls is uncertain. In Virginia, the Hampton Roads Water Quality Agency (HRWQA) has been evaluating water quality in the lower James River basin. Evaluations are being conducted on the effectiveness of existing urban runoff controls in the region and the effectiveness of selected BMPs in the Lynnhaven River basin, an urban watershed.

Preliminary results from the EPA's Nationwide Urban Runoff Program indicates that heavy metals, especially Pb, Sn, and Cu are frequently present in concentrations which are considered to be threatening to beneficial uses (U.S. EPA 1982c). Organic priority pollutants are found in certain urban runoff discharges; monitoring is recommended in those areas where potable water supplies are in close proximity to urban runoff (U.S. EPA 1982c). A survey of the effectiveness of urban control programs found that some detention basins are extremely effective—with pollutant reductions of 90 percent or more, including high removal of metals—while others are "consistently poor performers." Preliminary results also indicate that recharge basins offer promise because of their effectiveness and relatively low cost (U.S. EPA 1982c).

Many of the preliminary findings from the NURP projects are applicable (where needed) to Baltimore, MD; Richmond, VA; Hampton Roads, VA; Washington, D.C.; and Harrisburg, PA, the major urban areas in the Chesapeake Bay basin. Researchers determined that source controls, such as urban housekeeping and solid-waste disposal, were the most effective strategies in the older urban core areas. In the fringe urban areas with lower development densities, structural controls, such as wet detention ponds, grassed infiltration strips, and recharge basins, reduced the levels of toxicants in receiving waters. Conventional street-sweeping was only effective in areas with long periods of dry weather.[8]

Generally, the effectiveness of many of the reduction strategies is limited by technological restraints, costs, and local site conditions. In some cases, very high degrees of removal may be necessary because of the toxic potential to humans and organisms. Reduced loadings, especially over an entire urban area, are prohibitively expensive in some cases and must be limited to those areas which can be improved most conveniently. Control programs in central urban areas, which could provide significant reductions in large loadings of pollutants, are limited because of density and space restrictions (U.S. EPA 1982c).

Pesticides and Herbicides

The Federal Insecticide, Fungicide, and Rodenticide Act of 1972 required that farmers and others who apply pesticides commercially obtain a pesticide applicator's license by 1977. It is estimated that by early 1978, almost every commercial pest control operator and 85 percent of the farmers in the Washington Metropolitan Area were certified (WashCOG 1978). The licensing procedure, designed to educate farmers on the use, handling, and care of pesticides is considered to be more effective and less expensive than removing pesticides using conventional or advanced water treatment processes (WashCOG 1978).

Conservation plans, designed to reduce the losses of soil and pesticides from erosion and protect water resources, are developed and implemented by local soil conservation districts with assistance from the U.S. Soil Conservation Service. According to the Baltimore Regional Planning Council, "limitations on staffing and on the funds available to help farmers implement these plans keeps this program from achieving its full potential" (RPC 1978). These pesticide reduction strategies must be supplemented by increased enforcement of pesticide controls, additional technical assistance to farmers, and support for research on farm management practices which reduce reliance on chemical pesticides (WashCOG 1978).

The use of alternative pesticides, particularly bacterial diseases, has become more common, particularly for large-scale spraying. The bacterium *Bacillus thuringiensis* (BT), marketed under the name Dipel or Thuricide, has been used extensively in the Maryland and Virginia areas for control of the gypsy moth. Pilot programs to evaluate the effectiveness of a related pesticide, *B. thuringiensis israeliensis* (BTI), for the control of mosquitoes in marshes have begun in Maine and in the New York/New Jersey area. Two local efforts to reduce pesticide use (as well as costs and energy expenditures) are described below: one (Virginia) is a timing strategy, the other (Maryland) involves integrated pest management (IPM).

Case Study: Reduction and Timing of Herbicide Applications: The Virginia Leafspot Advisory Program—

A pilot project in southeast Virginia, which monitors temperature and humidity conditions and recommends fungicide application information, is saving money and energy for local peanut farmers. Early Leafspot and Late Leafspot are caused by fungi that require high relative humidity (95 percent or above) and warm temperatures as a stimulus to grow and infect peanut leaves (Phipps 1981). The project has established stations at Blackstone and Suffolk, Virginia, which monitor environmental conditions and recommend spraying after two consecutive days of adverse conditions. Growers can call a toll-free Virginia number, contact county agents, or listen for advisories on radio and television programs.

Spraying less frequently than under a traditional six-day schedule, farmers have been able to reduce applications, control leafspot, maintain yields, and save approximately 8 to 10 dollars per acre each time they do not spray. Results for one test farm are shown in Table 35. It can be seen that in every case, the yields are higher under the advisory schedule than the standard scheule. In 1982, only two fungicide sprays were recommended, four less than usual. Because each spray on Virginia's 94,000 acres of peanuts costs approximately 906,000 dollars, there was a potential savings of 3.6 million dollars state-wide.

Case Study: Integrated Pest Management: Maryland's Soybean Program –

The Mexican bean beetle is a destructive pest to soybeans in several mid-Atlantic states, including Maryland. An effective IPM program, run by the Maryland Department of Agriculture and the USDA, uses a parasitic wasp to suppress the Mexican bean beetle population and reduce the need for chemical controls. Monitoring and evaluation are conducted to ensure that the crop is sufficiently protected. Although unusually large beetle populations may require an application of insecticide, the quantity needed is below that required without the IPM program.

Marine Activities

Recreational boating and commercial shipping have been recognized as a source of estuarine water pollution, most significant in areas of the Bay with large numbers of boats and maritime traffic. In Anne Arundel County, Maryland, some facilities which are used for painting and cleaning boats use local water and subsequently return it untreated. Baltimore and Harford Counties are also major recreational boating areas, have considerable commercial traffic, and are subject to pollution from marine activities. Impacts commonly noted in the Baltimore region include shore erosion, dumping of sewage and wastes, and oil

TABLE 35.
EVALUATION OF FUNGICIDES AND SPRAY PROGRAMS FOR CONTROL OF CERCOSPORA LEAFSPOT OF PEANUTS IN VIRGINIA* (PHIPPS 1981)

Total no. Treatment	% leafspot Schedule	Yield sprays	at harvest	(lbs/ac)
Benlate/Super 6	Standard	6	26	4345
Benlate/Super 6	Advisory	2	48	4380
Duter/Super 6	Standard	6	11	4231
Duter/Super 6	Advisory	2	49	4412
Bravo 500	Standard	6	4	4027
Bravo 500	Advisory	2	21	4390
Kocide 404S	Standard	6	38	4198
Kocide 404S	Advisory	2	61	4300
Unsprayed Check			97	3381

*Savage Farm Rt., Suffolk, 1982

spillage. The RPC's report on marine activities in Baltimore County concludes, "it seems likely that water pollution problems are associated with some of the marina activities, but no water quality data are available to substantiate this belief" (RPC 1980).

Dredging

The Chesapeake Bay contains two major commercial ports, Baltimore and Norfolk, which together load approximately 90 percent of the domestic coal exports, excluding the Great Lakes. However, because of the Bay's importance as a commercial fishery and recreational area, the environmental and economic effects of both private and public dredging projects are major issues within the Chesapeake Bay region. To ensure that the quality of the Bay does not deteriorate in the future, the U.S. Corps of Engineers' Baltimore and Norfolk district offices and the States of Maryland and Virginia set performance standards and issue permits for both new starts and maintenance dredging projects.

Maintenance dredging, private dredging, and harbor expansion projects are known to cause increased turbidity. Along with the disposal of dredge materials, which are sometimes contaminated by toxicants, these activities are viewed by fishermen and environmentalists as being detrimental to fisheries. Generally, it appears that current operations do not produce major consequences on the ecology of the Bay (Aurand and Mamantov 1982). However, local effects may be more pronounced.

SUMMARY

Nonpoint control programs have not been successful enough in reducing the harmful loadings of metals and organic compounds. Many NPS provisions have been voluntary, some have not been enforced adequately, and some represent only preliminary stages of planning and control. Also, impacts of some nonpoint sources are not fully known. All four states have reported that nonpoint source pollution will likely be a major reason for failing to meet the fishable/swimmable goals of the Clean Water Act in the near future.

The previous sections discussed the sources, fate, and potential effects of toxicants in Chesapeake Bay. It is apparent that toxic materials enter the estuary from a variety of sources, some not well understood; that the identity or impacts of many substances is now known; and that many toxicants accumulate in Bay sediments or in the tissues of organisms. Furthermore, in many cases, current permitting, monitoring, or enforcement programs fail to detect or control toxic inputs. The following recommendations are the result of the CBP studies, and are designed to strengthen existing programs and to help initiate other efforts to control toxicants in Chesapeake Bay.

The overall strategy is to determine and monitor sources of toxicants, to identify toxic discharges, to assess potential impacts on receiving waters and important resources species, and to initiate, strengthen, or coordinate programs to control both point and nonpoint inputs of toxic materials. The eventual goal is to reduce loadings and concentrations of toxicants to ranges which will not limit healthy populations of finfish, shellfish, SAV, etc. as well as the food chains on which they depend, and also to prevent accumulations of toxicants in tissue of food organisms which could represent potential threats to human health.

One recognized difficulty in dealing with toxicants is the almost overwhelming variety of materials—particularly synthetic organic compounds—which have been identified in discharges to the Bay by the CBP researchers; many of these are known to be toxic at some concentration. However, demonstrating clear impacts in the naturally variable estuarine environment is difficult in many cases. Nevertheless, in light of the analyses and research summarized in Chapter 2, it would be inadvisable to discount impacts of at least some of the more prevalent toxicants. It is further recognized that ongoing and proposed research and monitoring programs will supply needed information for control of other toxicants. This information can be incorporated into management programs as an ongoing part of the toxicant control strategy.

The Bay-wide point and nonpoint source toxicant strategies presented below are intended to be implemented simultaneously. Initial focus is designed to be on 1) areas known to be heavily impacted by toxic inputs; 2) critical resource habitat areas; and 3) materials identified as highly toxic and widespread in the Chesapeake Bay environment. Results of the initial programs can be coupled with monitoring and research inputs to guide toxicant control efforts elsewhere in the Bay and to refine or modify programs already in place.

BAY-WIDE TOXICANT RECOMMENDATIONS

OBJECTIVE:

CONTROL AND MONITOR POINT AND NONPOINT SOURCES OF TOXIC MATERIALS TO MITIGATE THE POTENTIAL OR DEMONSTRATED IMPACT OF TOXICANTS ON THE LIVING RESOURCES OF THE BAY.

General Recommendations

1. *The states*[9] *and the EPA, through the Management Committee, should utilize the existing water quality management process to develop a basin-wide plan, that includes implementation schedules, to control toxicants from point and nonpoint sources by July 1, 1984.*

Point Source Recommendations

2. *The states, through the NPDES permit program, should use biological and chemical analyses of industrial and municipal effluents to identify and control toxic discharges to the Bay and its tributaries.*

Biomonitoring and chemical analyses (GC/MS "fingerprint") of effluents can be used to identify toxic discharges and to assess potential impacts on receiving waters. Initial focus should be on all major discharges, facilities known or thought to be releasing priority pollutants, and POTWs receiving industrial wastes. In developing this protocol, the states should follow the EPA's policy and recommendations (Appendix D). Priority areas for implementation should be the Patapsco, Elizabeth, and James Rivers, to be expanded to other areas as appropriate. All effluent biological and chemical data will be stored in the EPA's Permit Compliance System (PCS), as well as in the CBP data base. Monitoring of effluents should be coordinated with the Bay-wide monitoring plan outlined in Appendix F; this includes analysis of toxicant levels in sediments, water column, and in tissues of finfish and shellfish.

3. *The states and the EPA, through the Management Committee, should utilize the Chesapeake Bay Program findings in developing or revising water quality criteria and standards for toxicants.*

Initial priority should be given to pollutants identified as highly toxic and prevalent in the Bay, specifically chlorine, cadmium, copper, zinc, nickel, chromium, lead and, in tributaries, atrazine and linuron. Numerical criteria should be developed when needed and incorporated into state water quality standards as soon as feasible. Site-specific criteria that are developed should be based on biological and chemical characteristics of individual receiving waters according to the EPA guidelines.

4. *The states should base NPDES permits on the EPA effluent guidelines or revised state water quality standards, whichever are more stringent. Furthermore, the states should enforce all toxicant limitations in NPDES permits.*

The EPA should maintain its current schedule for promulgating BAT effluent guidelines. To facilitate writing of permits, the EPA should continue to transfer knowledge and expertise developed during the effluent guideline process to the states. The states should also consider increasing the number of training programs for permit writers.

5. *Pretreatment control programs should be strengthened where needed to reduce the discharge of hazardous and toxic materials.*

The pretreatment program in various basins has contributed to reductions of toxicants in some municipal discharges, but the CBP has found that, as a group, treatment plants continue to be major contributors of heavy metals, organic compounds, and other toxicants including chlorine. Current EPA regulations require pretreatment programs to be developed by July 1, 1983.

Municipal dischargers who have not submitted their program should do so as soon as possible. The EPA and the states should enforce these programs.

6. *Chlorine control strategies should be implemented (or continued, where now in place) in areas of critical resource importance. Strategies should focus on the reduction or elimination of chlorination, use of alternative biocides, and the reduction of the impact of effluents.*

Major areas of emphasis would include fresh or brackish fish spawning and nursery areas, and shellfish spawning areas. Maryland and Virginia have already begun to reduce chlorine residuals, evaluate site-specific effects of chlorine, and consider environmental effects in siting and permitting of dischargers. Specific programs and strategies for chlorine are described in Appendix D.

Nonpoint Source Recommendations

7. *The EPA, the U.S. Army Corps of Engineers, and the states should utilize the CBP program findings and other new information in developing permit conditions for dredge-and-fill and 404 permits.*

Information developed (or assembled) by the Chesapeake Bay Program includes: a measure of the relative enrichment of sediments by six metals, concentrations of organic materials in surface sediments, shoaling and erosion patterns, distribution of sediment types, location of submerged aquatic vegetation beds, shellfish beds, fish spawning and nursery areas, as well as relationships between habitat quality and living resources.

8. *A Bay-wide effort should be made to ensure proper handling and application techniques of pesticides and herbicides, particularly in light of the potential increase in use of these materials in low-till farming practices.*

Innovative strategies, such as integrated pest management (IPM) and reduction and timing of application have proven to be successful in the Bay area. The states should encourage the use of these reduction strategies, support runoff and erosion control programs, demonstration projects, and monitor the fate and effect of those substances on the Bay's aquatic environment.

9. *Research, monitoring programs, and control strategies to reduce urban runoff should be continued and strengthened by the localities which are most directly affected.*

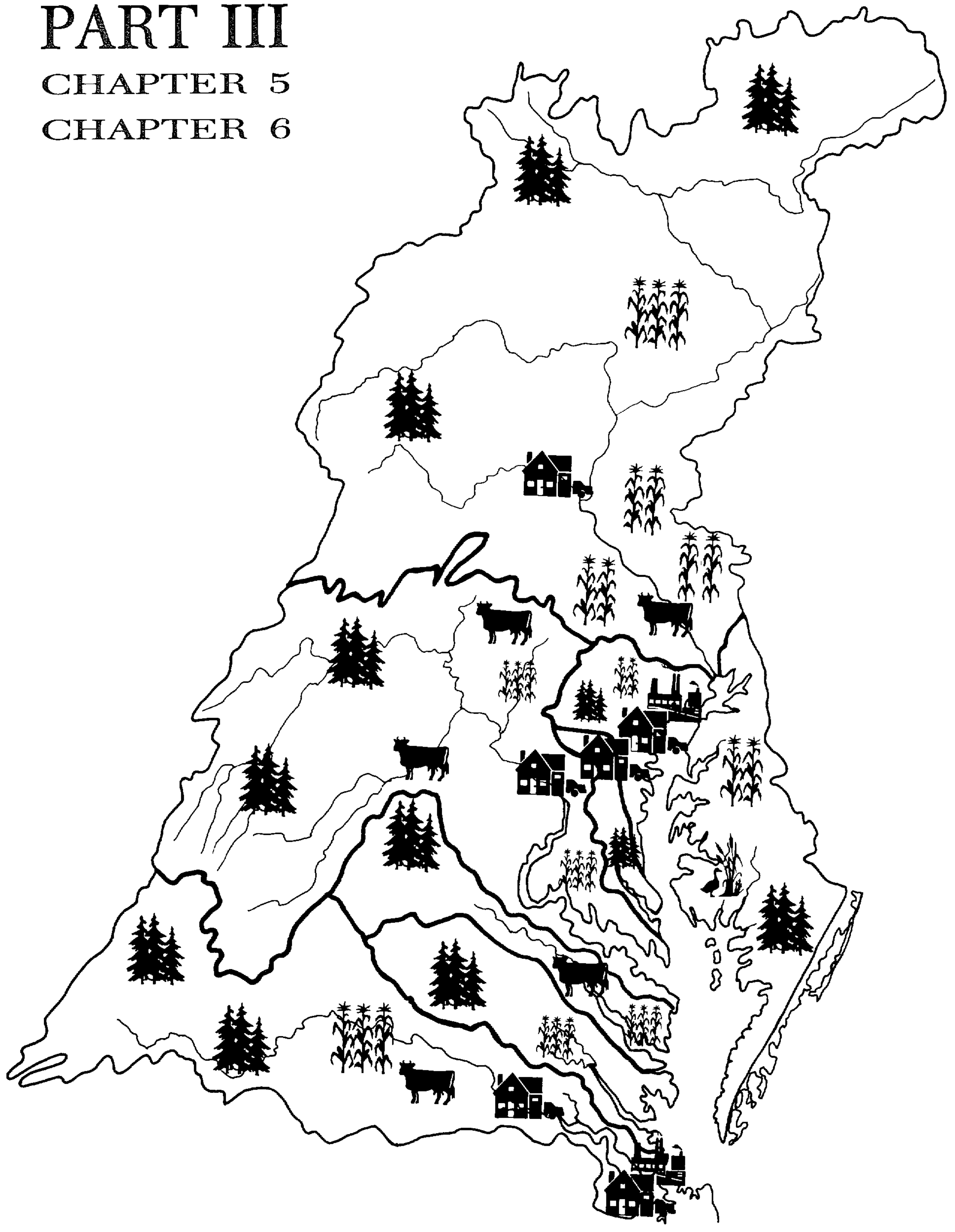
The states and urban areas should develop and implement plans which identify urban management strategies to protect water quality in those areas where urban runoff controls provide the most effective results.

10. *The states and the EPA should evaluate the magnitude and effects of other sources of toxicants, including atmospheric deposition, acid precipitation, contaminated groundwater, acid mine drainage, hazardous waste disposal and storage sites, accidental spills, and antifouling paints.*

As information becomes available, it should be factored into control and permit processes, etc. For example, models indicate that 30 to 40 percent of atmospheric emissions generated within the Bay area are deposited there. The CBP has estimated potentially significant inputs of metals from acid mine drainage and antifouling paints, particularly in tributaries. Many of these toxicant sources are currently being investigated by Federal and state agencies.

PART III

CHAPTER 5
CHAPTER 6



CHAPTER 5
BASIN PROFILES

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INTRODUCTION

What is the cost to clean the Bay? What do we have to do to re-establish Bay grasses or to increase striped bass harvests? Chesapeake Bay is too diverse an ecological system to allow a single answer to these questions. In addition, the various salinity, depth, and energy regimes the Bay provides for living resources at different times throughout their life cycles are influenced by a great number of factors. Certainly, nutrient and toxic substances present in runoff from cropland and urban areas, as well as in effluent discharged from municipal and industrial point sources are primary factors. However, the relative magnitude of each of these factors may vary in intensity and importance throughout the year and within each of the eight major drainage areas discharging to the Chesapeake Bay estuary. Furthermore, certain environmental conditions, such as circulation patterns or substrate, may be more favorable to particular resources in one basin than in another.

This chapter recognizes the unique nature of each basin discharging to the Chesapeake Bay and summarizes information on area, population (1950, 1980, 2000), land use (1980), and sources of toxic (total metal) and nutrient loads within the basin. (A more detailed fact sheet is provided in Appendix B.) In addition, a general description of the basin's resource and water quality conditions and trends is included followed by a summary of major existing policies and programs to address these issues. Lastly, the effectiveness of management strategies in reducing existing (1980) and future (2000) nutrient loads is presented as are specific recommmendations to mitigate or prevent water quality problems within the basin.

The effectiveness of the management strategies in reducing existing (1980) and future (2000) nutrient loads within each basin is illustrated in the form of bar charts in Figures 42 through 49. The effectiveness of the management strategies (P ban, Level 2, and TP = 2) in reducing existing (1980) nutrient loadings has been extrapolated to provide an estimate of their effectiveness in reducing future (2000) loadings. Corresponding percent reductions in nutrient loads and estimates of present-value implementation costs for management strategies are included with each bar graph. To allow comparison of present-value costs and percent reductions in nutrient loads, the present-value cost to remove one pound of nutrient has been calculated and is included on the bar graphs. This allows comparison of strategies on a uniform basis, and identification of the least-cost alternative. (Although the TP = 1, TN = 6 and Future TP = 1, TN = 6 strategies limit both phosphorus and nitrogen effluent concentrations, implementation costs are presented in terms of phosphorus or nitrogen control alone.) More detailed information regarding costs may be found in Appendix B.

UPPER CHESAPEAKE BAY (THE SUSQUEHANNA RIVER BASIN)

The upper Bay represents the estuarine portion of the Susquehanna River and extends from the Susquehanna Flats to the Patuxent River basin on the western shore and to the Choptank River on the Eastern Shore, including all tributaries in between. The area draining to the upper Chesapeake Bay encompasses over 30,000 square miles (77,700 km^2), almost half of the Bay's 64,000 square mile (165,760 km^2) drainage area. It can be divided into three areas: the Susquehanna River basin, the western Chesapeake, and the upper Eastern Shore. The Susquehanna basin, stretching from the Adirondocks in New York to the Coastal Plain in Maryland, provides more than 90 percent of the freshwater discharged to the upper-Bay and is the major source of nutrients to the upper-Bay.

Resources and Water Quality

The upper Bay in the vicinity of the Susquehanna Flats is a major freshwater-fish spawning area. However, in recent years the success of these species has declined greatly, particularly for shad and river herring, white and yellow perch, and striped bass. The once-abundant beds of submerged vegetation have been reduced or eliminated except in a few areas; most remaining beds consist of the introduced species *Eurasian watermilfoil*. The harvest of soft crabs has been particularly impacted by the loss of SAV. Prior to 1970, the area at the mouth of the Chester River was a good oyster recruitment and harvest area. However, spat set has been reduced to near-zero since 1971, and present harvest depends on the planting of seed from other areas. The upper Bay area has been experiencing oyster mortalities in summer, probably due to disease and/or low dissolved oxygen levels. Soft clam populations were decimated by Tropical Storm Agnes in 1972, and recovery has been slow, with numerous summer mortalities of unknown cause. Recently, however, clam numbers (and harvest) have been good in the vicinity of the Annapolis Bay Bridge and south. The upper Bay was once a major waterfowl wintering area; however, because of the loss of SAV, waterfowl populations have shifted down-Bay or even to other states.

SUSQUEHANNA BASIN FACT SHEET

AREA: 27,100 square miles; 17,344,000 acres

POPULATION (1000's):	1950	1980	2000
	3096.7	3693.5	4080.6

LAND USE (1980):	Percent of Total
Cropland (total)	18.3
Conventional tillage	2.2
Conservation tillage	16.2
Pasture	17.5
Forest	61.8
Urban and other uses	2.4

TOXIC SUBSTANCES: Fall line metal loads of 12,531 lbs/day indicate additions from municipal and industrial point sources are occurring. No discharges below the fall line.

NUTRIENTS: Total Load (lbs, March-October)

	Phosphorus 2,900,000		Nitrogen 58,200,000	
Source	Above Fall line	Below Fall line	Above Fall line	Below Fall line
Industrial*	7	0	1	0
Municipal*	16	0	9	0
Cropland	60	0	85	0
Other nonpoint sources	17	0	5	0
Total	100	0	100	0

*Number of dischargers
Industrial 15, Municipal 118

Analysis of main-Bay sediment samples indicates that organic compounds and metals are abundant in upper-Bay sediments. Depth-averaged mean concentrations for total nitrogen indicate that the waters are presently over-enriched with respect to total nitrogen. Trend analysis indicates that both annual and seasonal chlorophyll a concentrations and annual total phosphorus and nitrate/nitrite concentrations are increasing in upper-Bay waters. The increase in nutrient concentrations appears to be contributing to the temporal and spatial increase in low dissolved oxygen levels observed in the main channel bottom waters.

The relative sources of nutrients and toxic materials to the upper Bay vary by sub-basin. For example, intensive agricultural land-use in the Susquehanna basin generates significant nutrient loadings; industrial and urban complexes in the West Chesapeake basin contribute large amounts of toxic materials. In terms of general water quality, however, nutrient enrichment appears to be critical. During an average rainfall year, the upper Chesapeake Bay receives more than 5 million pounds of phosphorus, almost 40 percent of the total phosphorus load delivered to the Bay, and 76 million pounds of nitrogen, approximately 52 percent of the total nitrogen load delivered to the Bay. Figure 40 illustrates the nutrient contribution from the Susquehanna, West Chesapeake, and upper Eastern Shore to the upper Bay during average year rainfall conditions, 1980 land uses, and 1980 point source loadings. The Susquehanna is the dominant source of phosphorus, contributing 53 percent of the total phosphorus load to the upper Bay. The West Chesapeake is second, contributing 44 percent of the total load, and the upper Eastern Shore is the smallest, contributing 3 percent of the total phosphorus load reaching the upper Bay. The Susquehanna is also the dominant source of nitrogen, contributing 77 percent of the nitrogen delivered to the upper Bay. The West Chesapeake and upper Eastern Shore areas contribute 21 percent and 2 percent, respectively.

It is important to recognize not only the magnitude of the nutrient contribution from each of the three areas discharging to the upper Bay, but the relative contribution from nonpoint and point sources within each basin. The Susquehanna and upper Eastern Shore are dominated by non-point sources which account for 76 and 60 percent, respectively, of the phosphorus and 90 percent of the nitrogen loads from within each basin. The West Chesapeake is dominated by point sources which account for 85 percent of the phosphorus and 72 percent of the nitrogen load. Due to the different sources of nutrient loadings within each basin, it can be anticipated that different strategies will be more effective in reducing nutrient loads within each basin. For this reason, the effectiveness of the management strategies will be determined separately for each of the three areas discharging to the upper Bay. The most effective strategies within individual basins can then be combined to provide the best mix of management strategies to reduce nutrient loads to the upper Bay. Because the Susquehanna is the dominant factor in determining water quality in the upper Bay, it alone will be discussed in detail in this section. Nutrient loads from the West Chesapeake and that part of the Eastern Shore discharging to the upper-Bay have been summarized here and will be discussed in detail in their respective Basin Profiles.

The Susquehanna River basin is the largest drainage area in the Bay catchment area. A high percentage of the nitrogen (85 percent) and phosphorus (60 percent) loadings delivered by the Susquehanna are attributable to runoff from cropland. Moreover, Chesapeake Bay watershed modeling studies (Hartigan 1983) determined that 41 percent of the Susquehanna's nonpoint source load comes from the intensively-farmed area in the lower basin below Sunbury. Soil loss from untreated cropland within this sub-basin may be as high as 17.7 tons/acre/year as compared to average soil losses of around 7.4 tons/acre/year (SCS 1983b). Large concentrations of livestock within the lower Susquehanna drainage area have resulted in excessive manure applications (Appendix C and Pennsylvania DER 1983). For example, in the upper Conestoga River area, the plant nutrients being applied through manure and commercial fertilizer exceed the per acre crop needs for nitrogen by 203 pounds, for phosphorus by 81 pounds, and for potassium by 15 pounds (Robinson et al. 1983). Currently, the chief crop in the lower Susquehanna drainage area is corn, upon which nitrogen and phosphorus are applied at an average rate of 130 pounds and 140 pounds per

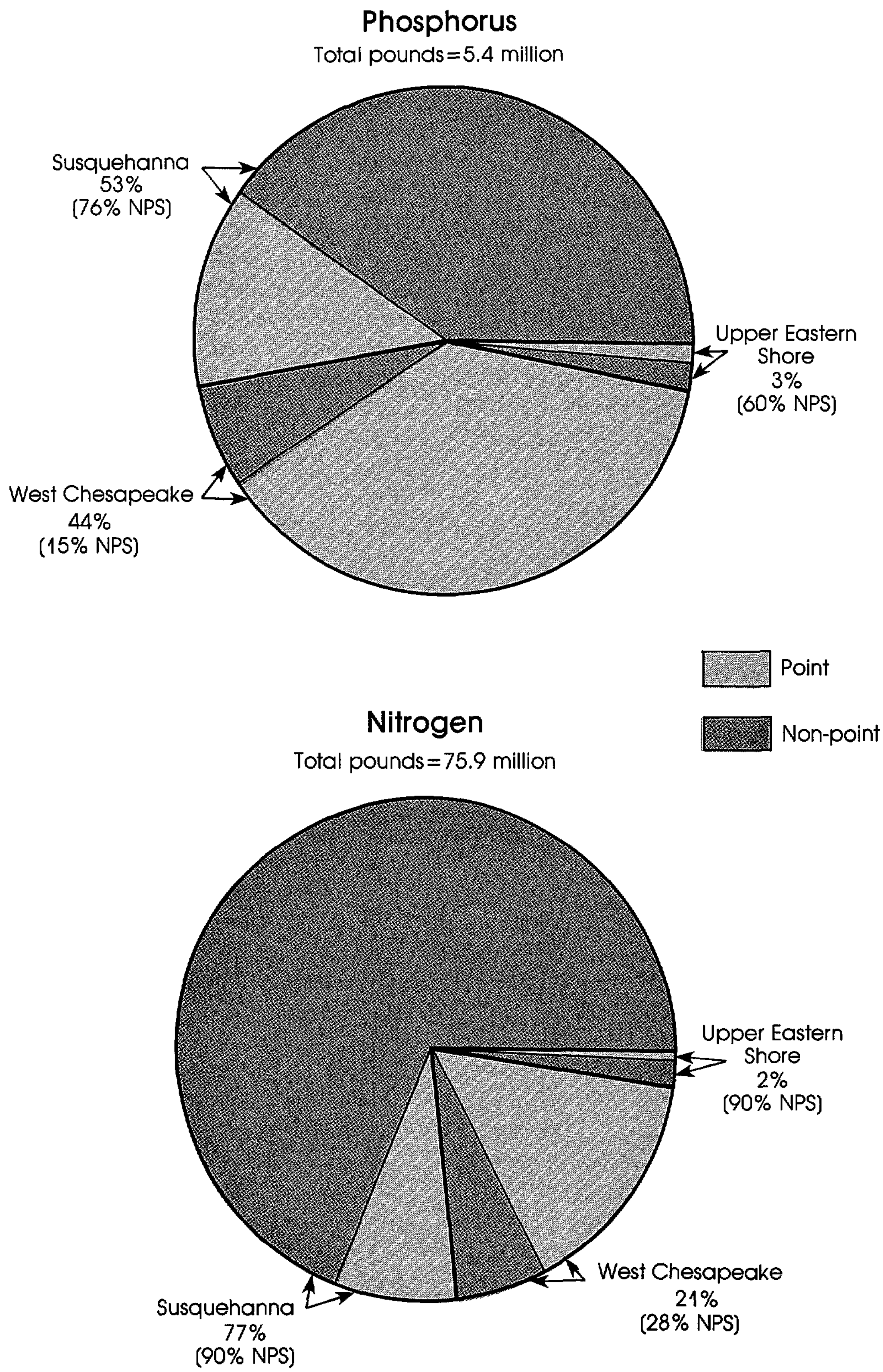


FIGURE 40. Percent of existing (1980) nutrient loads to upper Chesapeake Bay from Susquehanna, upper Eastern Shore, and West Chesapeake drainage areas under average rainfall conditions.

acre, respectively (Appendix C.) Improved fertilizer management in many cases would not only reduce nutrient loads to the upper Bay, but would save farmers money, as discussed in Chapter 3.

Furthermore, the lower Susquehanna subbasin has the highest percentage of conventional-tillage cropland and the lowest percentage of forest land within the basin (Appendix B.) This is significant because nutrient loadings from conventional-tillage cropland are potentially the highest for all land uses while those from forest land are the smallest (Hartigan 1983). In addition, of the entire river basin, nutrients from the lower Susquehanna River have the shortest travel time to the Bay and, based on modeling results, 99 percent of the nonpoint nitrogen load and 82 percent of the nonpoint phosphorus load generated within the lower Susquehanna are delivered to the fall line (Appendix B).

Existing Policies and Planning

Mason-Dixon Erosion Control Project — The Maryland and Pennsylvania State offices of the USDA/SCS have included the lower Susquehanna drainage area and parts of the Potomac, Patuxent, Eastern Shore, and West Chesapeake drainage areas in the Mason-Dixon Erosion Control Area (SCS 1983b). They have proposed that the area receive targetted technical assistance. The primary objective of the proposal is the protection of the soil resource-base and improvement of the productive capability through a significant reduction in annual soil loss in the 22-county area in Maryland and Pennsylvania (Figure 41). The SCS has included 700,000 dollars in its current budget to provide technical assistance by way of soil conservation technicians and engineers required to identify appropriate BMPs and to formulate a strategy for sediment, erosion, and animal-waste control. The estimated cost to install resource management systems (a combination of needed BMPs) in the Mason-Dixon Erosion Control Project, which also includes land draining to the Delaware Bay, is 21 million dollars per year for 10 years. This represents a 9.1 million dollar increase in present funding. For the portion of this area within the Chesapeake Bay basin, the cost is estimated to be about 15.7 million dollars per year for 10 years (9.6 million dollars in Pennsylvania and 6.1 million dollars in Maryland); parts of the lower Susquehanna, Eastern Shore, West Chesapeake, and Potomac River basins would be included.

It is not known what effect the sediment, erosion, and animal-waste control BMPs advocated by the Mason-Dixon Project will have on nutrient loadings. However, Chesapeake watershed modeling results indicate that applying a Level 3 agricultural conservation practice, contour plowing, in concert with a Level 2 practice, such as conservation-tillage, reduces direct-stream loadings of phosphorus and nitrogen from nonpoint sources in the lower Susquehanna River by 30 percent and 13 percent, respectively.

An Assessment of Agricultural Nonpoint Source Pollution in Selected High Priority Watersheds in Pennsylvania — The Pennsylvania DER (June 1983) proposes a number of recommendations based on detailed studies. The complete recommendations may be found in Appendix C. In general, the report recommends that soil conservation districts establish realistic time frames in which to accomplish the goals they originate. In addition, they should seek the assistance of their cooperating agencies and/or private agricultural organizations to accomplish these goals.

Connestoga Headwaters Rural Clean Water Program — This Federal nonpoint source control program provides 1.9 million dollars for the control of fecal coliforms, nitrate, dissolved solids, sediment, and pesticides from nonpoint sources of pollution. The BMPs instituted on agricultural and urban land in the Connestoga River and tributaries include animal-waste controls, terraces, waterways, and grazing land.

Upper Chesapeake Bay Phosphorus Limitation Policy — In the Susquehanna, the Upper Chesapeake Bay Phosphorus Limitation Policy (UCBP) requires 80 percent removal (approximately equal to 2.0 mg L^{-1} effluent) of phosphorus for all new or modified wastewater treatment facilities with flows greater than or equal to 0.5 MGD and discharging to tributaries and the main stem of the Susquehanna River below its confluence with the Juniata River. The Pennsylvania Department of Environmental Resources (PA DER) has a similar regulation for phosphorus removal but without the 0.5 MGD

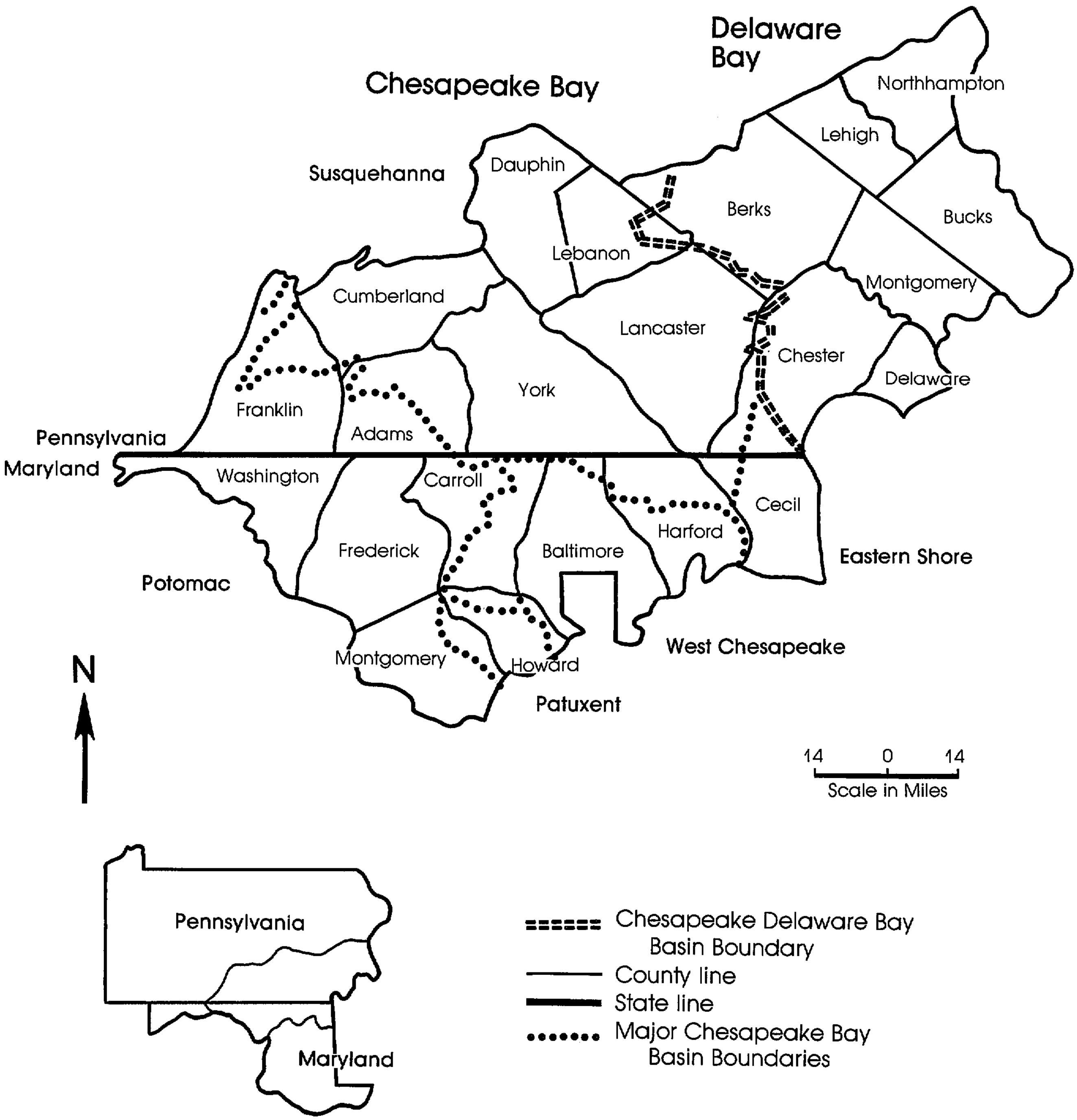


FIGURE 41. The 22 county Mason-Dixon Erosion Control Area indcludes land draining to the Susquehanna, Potomac, Patuxent, West Chesapeake, and Eastern Shore basins of Chesapeake Bay. The northeast portion of the control area drains to the Delaware Bay.

limitation. The Pennsylvania DER estimates that 40 percent of the POTWs in the lower Susquehanna providing phosphorus removal and subject to the policy are not in compliance with the 2.0 mg L^{-1} limitation; noncompliance is greatest among smaller plants. Failure to meet the limitation is most often attributable to operation and design problems, and to inadequate sludge-handling capabilities.

Comparison of Strategies

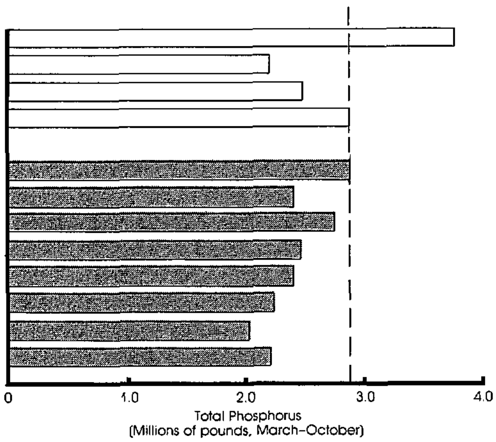
Figure 42 illustrates the effectiveness of management strategies in reducing existing (1980) and future (2000) nutrient loads within the Susquehanna River basin. In addition, it quantifies the percent change in nutrient loadings and summarizes estimated implementation costs for the different management strategies. According to Figure 42, the least-cost alternative for reducing existing loads from the Susquehanna to the upper Bay is implementation of the Level 2 strategy, conservation-tillage. This strategy provides a 16 percent reduction in the phosphorus load and a one percent reduction in the nitrogen load with present-value costs of 0.34 and 0.26 dollars per pound removed, respectively. The largest reduction in the existing (1980) phosphorus load is achieved by combining the Level 2 option, conservation-tillage, with a 2 mg L^{-1} phosphorus effluent limitation (TP = 2 + Level 2). This strategy reduces the Susquehanna phosphorus load 29 percent and increases the nitrogen load 18 percent. A policy to limit the content of phosphorus in detergents (phosphorus ban) would reduce the total phosphorus load 4 percent with the highest present-value cost to remove one pound of phosphorus, 29.47 dollars. Based on pollutant delivery ratios (Appendix B), it is calculated that the simultaneous implementation of Level 2 BMP basin-wide and Level 3 BMP in the lower Susquehanna would reduce existing (1980) total phosphorus and nitrogen loads from the Susquehanna 22 and 5 percent, respectively. This indicates that significant basin-wide reductions in nutrient loadings, including nitrogen, can be achieved with implementation of appropriate BMPs in the lower Susquehanna drainage area.

The UCBP policy which focuses on the POTWs in the lower Susquehanna drainage area is projected to reduce the year 2000 total phosphorus load from the Susquehanna by 32 percent. This reduction equals the projected increase and, as a result, existing (1980) conditions would be maintained. The wisdom of this policy is that it applies to point source dischargers (POTWs) in an area that directly impacts the upper Bay. Modeling studies (Hartigan 1983) indicate that 59 percent of the phosphorus load discharged by point sources in the lower Susquehanna reach the fall line. In contrast, only 16 percent of the point source load discharged in the Juniata, 11 percent in the North Branch, and 11 percent in the West Branch make it to the fall line (Appendix B).

As evidenced in the previous discussion of management strategies, watershed modeling production runs that reduce phosphorus loadings to tidal-fresh areas may increase nitrogen loadings (Figure 42, Nitrogen). The explanation for this phenomenon lies in the utilization of nutrients by phytoplankton. During photosynthesis, phytoplankton consume phosphorus and nitrogen in specific ratios. When less phosphorus is available because of decreased loadings, less nitrogen is consumed and a greater load is made available to be passed downstream. This phenomenon is best exemplified in the Susquehanna basin, all of which is considered freshwater. In light of this phenomena, it is important that nonpoint source control strategies that decrease nitrogen loads, such as the Level 2 BMP and the Level 2 and Level 3 combination of BMPs, be implemented in conjunction with phosphorus-reducing point source strategies to control nitrogen loads.

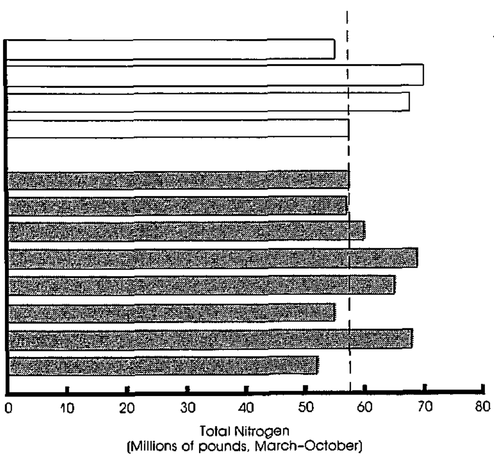
Recommendations — Susquehanna River Basin

To maintain current conditions, future total basin loads must not exceed 2,900,000 pounds total phosphorus and 58,200,000 pounds total nitrogen (existing 1980 load). To improve conditions, future total basin loads must be reduced below these levels. It is anticipated that the following recommendations will best meet the goal of maintaining current conditions into the year 2000 and allow for improvements in these conditions



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+32	–	–
Future TP=2+Level 2	-23	273.3	5.77
Future TP=1, TN=6	-13	286.9	7.40
Future UCBP Policy	0	55.7	2.07
Existing	0	–	–
Level 2	-16	4.65	0.34
P Ban	-4	105.4/33.2*	29.47
TP=2	-14	188.7	15.44
TP=1, TN=6	-17	201.4	14.07
Level 2 + Level 3**	-22	?	?
TP=2+Level 2	-29	191.8	7.66
Total NPS	-23	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.
**Calculated from delivery ratios—Level 2 basin-wide and Level 3 in lower Susquehanna.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	-4	–	–
Future TP=2+Level 2	+22	273.3	N increases
Future TP=1, TN=6	+18	1194.8	N increases
Future UCBP Policy	0	55.7	–
Existing	0	–	–
Level 2	-1	4.65	0.26
P Ban	+4	105.4/33.2*	N increases
TP=2	+19	188.7	N increases
TP=1, TN=6	+12	779.1	N increases
Level 2 + Level 3**	-5	?	?
TP=2+Level 2	+18	191.8	N increases
Total NPS	-10	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.
**Calculated from delivery ratios—Level 2 basin-wide and Level 3 in lower Susquehanna.

FIGURE 42. Existing (1980) and future (2000) estimates of nutrient loads and present value costs for different management strategies in the Susquehanna River drainage basin under average rainfall conditions.

if nonpoint source controls are successfully implemented.

1. The Piedmont region of the lower Susquehanna basin should be targetted by the proposed Comprehensive Implementation Program to reduce agricultural nonpoint source pollution. Funding for the Mason-Dixon Erosion Control Project and similar projects in critical sub-basins should be strongly supported and expanded to provide for immediate installation of Best Management Practices that focus on commercial fertilizer management, animal waste application management, animal waste control, erosion control, and sediment control. Recommendations outlined in the Pennsylvania DER report, *An Assessment of Agricultural Nonpoint Source*

Pollution in Selected High Priority Watersheds in Pennsylvania (June 1983) should be implemented. The recommendations are listed in their entirety in Appendix C. In general, they call for soil conservation districts to establish goals and realistic schedules for accomplishing the specified goals.

—Cost Estimate—

Present-value cost—109 million dollars

Annual O & M cost—10.4 million dollars

2. Pennsylvania should continue to implement its regulation similar to the UCBP Policy which requires 80 percent removal of phosphorus at all new or modified point source discharges.

—Cost Estimate—

Present-value cost—55.7 million dollars

Capital cost—19.8 million dollars

Annual O & M cost—3.46 million dollars

(Assumes secondary treatment capability is in place and does not include costs to maintain secondary treatment or to control industrial dischargers.)

THE WEST CHESAPEAKE DRAINAGE AREA

The West Chesapeake drainage basin extends from the mouth of the Susquehanna to the Patuxent River basin. Most of the northern catchment area lies in the Piedmont Province while the west and southern portions lie in the Atlantic Coastal Plain. Slicing through the West Chesapeake basin is the steadily expanding corridor of urban and suburban development that stretches northeastward from Washington, D.C., through Baltimore, and on to Wilmington, DE. The Patapsco River is the largest of the numerous western shore tributaries located within the basin, and includes the Baltimore Metropolitan Region which has developed into one of the nation's largest urban centers. Much of this growth has been encouraged by marine, commercial, and industrial activities made possible by the development of the Port of Baltimore.

WEST CHESAPEAKE BASIN FACT SHEET

AREA: 2,058 square miles; 1,317,420 acres

POPULATION (1000's):	1950	1980	2000
	1365.6	1874.9	1993.9

LAND USE (1980):	Percent of Total
Cropland (total)	23.0
Conventional tillage	2.4
Conservation tillage	20.6
Pasture	19.3
Forest	45.2
Urban and other uses	12.5

TOXIC SUBSTANCES:	total metal load (lbs/day)
Industrial dischargers (43)	1352.1
Municipal dischargers (28)	743.1

NUTRIENTS: Total Load (lbs, March-October)

	Phosphorus 2,391,000		Nitrogen 15,984,000	
Source	Above Fall line	Below Fall line	Above Fall line	Below Fall line
Industrial*	0	2	0	11
Municipal*	0	83	0	61
Cropland	0	8	0	20
Other nonpoint sources	0	7	0	8
Total	0	100	0	100

*Number of dischargers - Industrial 15, Municipal 28

Resources and Water Quality

Most of the small western shore tributaries of the West Chesapeake support (or supported) runs of anadromous and semi-anadromous fish, particularly alewife, white and yellow perch, and some striped bass. However, many of the tributary streams in this area have physical structures which adversely impact migratory species of finfish and prevent full utilization of habitat. Loss of submerged vegetation in all but a few areas has also affected habitat for fish and other organisms. Only the southern-most rivers provide potential oyster habitat area, and spat set is poor to nonexistent. Harvests from these bars depend on seed planting, and have generally been low for the past decade or more. Soft clam populations have recovered in many areas, supporting good harvests at this time. Landings of crabs have been relatively stable, although the loss of submerged vegetation has affected the availability of soft crabs in some areas. Some of these tributaries support moderate populations of waterfowl, particularly where food is abundant (i.e., SAV, benthic organisms). Two very impacted tributaries, the Back and the Patapsco Rivers, show the greatest loss of living resources, including alterations of benthic community structure.

The economic growth and development of the West Chesapeake has not been without environmental cost. Sediments in the Baltimore Harbor are among the most toxic found in the Bay (Flemer et al. 1983). Concentrations of organics in bed sediment found in the tidal-fresh portion of the Patapsco River were among the highest in the Bay. The sum of all organic compounds detected exceeded 100 ppm at several locations. Concentrations of polynuclear aromatic hydrocarbons ranged from 1 to 90 ppm, and levels of PCBs were as high as 8,000 ppb. It is apparent that these unusually high levels are due to industrial activities in Baltimore Harbor. This is further substantiated by sediment core analyses which show correlations between the variation in both the concentrations of phthalate esters and polynuclear aromatics and historical rates of coal production (Flemer et al. 1983). In addition, the entire Baltimore region poses potential stormwater runoff problems which increase with intensified suburban development. Also, maintenance of the shipping channel to Baltimore Harbor generates large amounts of spoil which need to be disposed of in an environmentally sound manner. Depth averaged mean concentrations for total nitrogen and total phosphorus indicate that the Patapsco and the Back Rivers are presently over-enriched with respect to total nitrogen, and the Back River is over-enriched with respect to total phosphorus (Flemer et al. 1983). Trend analysis shows that total nitrogen is decreasing from historically higher levels in the Patapsco River.

Existing Policies and Planning

UCBP Policy—In the West Chesapeake drainage area, the UCBP policy requires all point sources with flows greater than or equal to 0.5 MGD discharging into the Maryland portion of the Bay north of and including Gunpowder River, (Zone I), or point sources with flows greater than or equal to 10.0 MGD between Gunpowder River and the southern edge of the Choptank (Zone II), to meet a 2.0 mg L^{-1} effluent limitation.

Jones Falls Watershed Urban Stormwater Runoff Project—The Jones Falls Watershed Urban Stormwater Runoff Project examined the problems associated with urban stormwater runoff in a densely populated section of Baltimore. The project also evaluated the feasibility of implementing structural and non-structural BMPs in the area. Major findings and conclusions from the study include:

- Urban runoff contributed significant amounts of Cu, Pb, and Zn to stream loadings.
- Implementation of structural BMPs was found to be prohibitively expensive due to the extensive infrastructure changes required.
- Non-structural BMPs such as manual and mechanical street sweepers were judged to be of variable effectiveness.
- Implementation of non-structural BMPs such as removal of animal waste by dog owners was highly dependent on the population's level of awareness regarding the relationship between animal waste removal and water quality.

Based on these latter findings, the investigators concluded that education, particularly of urban dwellers, is a prerequisite for the adoption and success of nonstructural BMPs.

The Back River Wastewater Treatment Plant (WWTP) – The 181 MGD Back River WWTP serving Baltimore City, Baltimore County, and other bordering municipalities is the largest POTW located in the West Chesapeake drainage area and the second largest in the Chesapeake basin. At present, the Maryland Office of Environmental Programs (MD OEP) is evaluating three distinct treatment alternatives for the Back River WWTP to satisfy water quality objectives in Back River (Whitman, Requardt and Associates 1982). Phosphorus concentrations associated with the different levels of advanced treatment considered are 0.2, 1.0, and 2.0 mg L^{-1}. The present-value costs of the alternatives under consideration range from 221 to 323 million dollars. These costs reflect an almost total rebuilding of the existing secondary treatment system which became operational in 1909 and is currently unable to consistently meet NPDES permit limits. Cost estimates generated by the CBP to upgrade POTWs in the West Chesapeake do not include costs to rebuild the Back River plant. The CBP cost estimates assume an existing secondary treatment plant is in existence and include only costs to upgrade for nutrient removal.

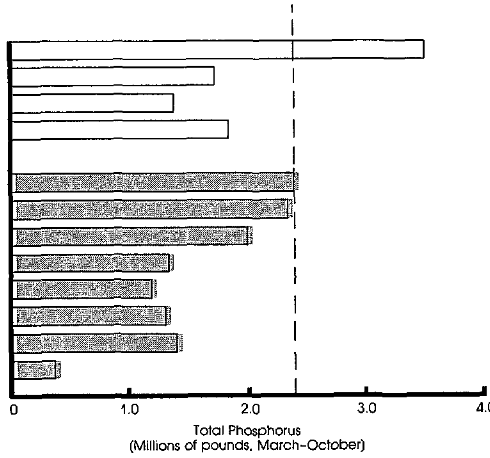
A pretreatment program to control the discharge of toxic substances from industrial sources to the Back River Plant is near completion. Metal loads from certain industries have already been substantially reduced as part of the program and a permit-compliance schedule for all dischargers to the plant is to be completed by July 1, 1984. The program developed for the Back River plant may serve as a model for the Patapsco and other POTWs in the West Chesapeake basin receiving and treating industrial wastes. Industries that discharge directly to surface waters are regulated through the NPDES and subject to effluent limitations promulgated by the EPA.

By agreement with the City of Baltimore, the Bethlehem Steel Corporation purchases and discharges at least 100 MGD of Back River effluent which it uses as industrial process water at its Sparrows Point plant. Almost 2,000 pounds of phosphorus are removed from this wastewater by Bethlehem Steel before its final discharge. Through another agreement, Back River accepts iron-rich waste pickle liquor (WPL) from Bethlehem Steel and uses it as a reagent to precipitate phosphorus from its wastewater. As a result, the Bethlehem Steel Corporation is able to minimize disposal problems and the Back River treatment plant realizes significant operating cost savings by using WPL rather than other treatment chemicals (the Blue Plains treatment plant also receives WPL, free of charge, from Bethlehem Steel). This cooperation serves as an example of innovative utilization of waste products to protect water quality. Similar opportunities to be explored include the use of industrial wastes such as corn silage derivative, yeast, whey, and agent sulfite liquor as sources of organic carbon in the denitrification treatment at POTWs (Skrind and Surinder 1982).

Double Pipe Creek Rural Clean Water Project – This Federal nonpoint source control program provides 3.6 million dollars to control bacteria and sediment from agricultural lands and septic tanks in the Double Pipe Creek and Monocacy River. The BMPs implemented include animal-waste control, diversions, grazing land, and waterways.

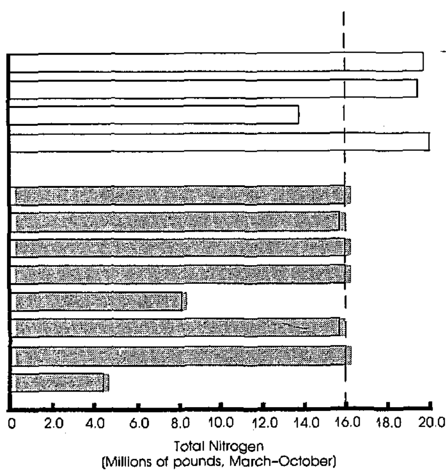
Comparison of Strategies

Figure 43 illustrates the effectiveness of management strategies in reducing existing (1980) and future (2000) nutrient loads within the West Chesapeake basin. The Level 2 nonpoint strategy, conservation-tillage, reduces the existing (1980) phosphorus and nitrogen loads each 2 percent. It also has the lowest present-value cost per pound of phosphorus removed. The largest percent reduction in the phosphorus load is achieved with the TP = 1 strategy. It reduces the existing phosphorus load 51 percent at a present-value cost of 4.90 dollars per pound of phosphorus removed. Combining the TP = 2 strategy with the Level 2 option reduces the phosphorus load 45 percent at a present-value cost of 4.78 dollars per pound of phosphorus removed. The phosphorus ban is estimated to reduce the existing load 19 percent at a present-value cost of 3.85 dollars per pound of phosphorus removed. If the ban were implemented in concert with a basin-wide



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+46	–	–
Future TP=2+Level 2	-28	247.4	4.63
Future TP=1, TN=6	-42	254.1	3.98
Future UCBP Policy	-23	237.0	4.75
Existing	–	–	–
Level 2	-2	0.38	0.23
P Ban	-19	53.0/19.7*	3.85
TP=2	-43	152.9	4.96
TP=1, TN=6	-51	177.8	4.90
TP=2+Level 2	-45	153.3	4.78
UCBP Policy	-41	149.6	5.04
Total NPS	-85	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+23	–	–
Future TP=2+Level 2	+22	247.4	–
Future TP=1, TN=6	-14	718.9	4.04
Future UCBP Policy	+24	237.0	–
Existing	0	–	–
Level 2	-2	0.38	0.05
P Ban	0	53.0/19.7*	–
TP=2	0	152.9	–
TP=1, TN=6	-49	524.4	2.23
TP=2+Level 2	-2	153.3	18.54
UCBP Policy	0	149.6	–
Total NPS	-72	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.

FIGURE 43. Existing (1980) and future (2000) estimates of nutrient loads and present value costs for different management strategies in the West Chesapeake drainage basin under average rainfall conditions.

phosphorus effluent requirement, POTWs subject to the limitation would realize a 1.9 million dollars annual reduction in O & M costs.

According to Figure 42, future (2000) phosphorus loadings are projected to increase 46 percent. This increase, based on 1980 levels of treatment and year 2000 municipal flows, does not reflect improved phosphorus removal at the 181 MGD Back River treatment plant or projected improvements at the 30 MGD Patapsco plant. These improvements should be viewed as progress toward the implementation of management strategies and would reduce estimated implementation costs. Year 2000 nitrogen loads are projected to increase 23 percent. All three future management strategies (Future TP = 1, TN = 6, Future TP = 2 and Level 2, and Future UCBP Policy) reduce the projected phosphorus loadings to levels below existing (1980) loads. The Future TP = 1, TN = 6 nitrogen effluent limitation reduces future (2000) nitrogen loadings to a level 14 percent below existing (1980) level. It is evident that municipal point source strategies are effective in reducing nutrient loadings in the West Chesapeake.

A sediment and water quality analysis indicates that toxic materials are being discharged by point sources in the West Chesapeake drainage area. The possible causes of toxicity in municipal and industrial effluents, as well as the source of the effluents, can be determined through the biomonitoring and fingerprinting programs developed by the CBP and described in Appendix D. Pretreatment programs can control the discharge of toxic substances to POTWs and the NPDES permit can control the discharge of toxic substances from industrial dischargers to surface waters.

Recommendations — West Chesapeake Drainage Area

To maintain current nutrient conditions, future total basin loads must not exceed 2,391,000 pounds total phosphorus and 15,984,000 pounds total nitrogen (existing — 1980 load). To improve conditions and prevent deterioration, both nutrient and toxic substances must be reduced. Based on a desired goal of improving conditions in the West Chesapeake, the following recommendations are proposed.

1. Expand the UCBP to include all new or modified plants less than 10.0 MGD but greater than 1.0 MGD in Zone II. Existing plants that are less than 10 MGD and greater than 1 MGD located near the boundary between Zone I and II should consider phosphorus removal. Implement UCPB Policy.

   — Cost Estimate —

   Present-value cost — 237.0 million dollars
   Capital cost — 74.8 million dollars
   Annual O & M cost — 15.6 million dollars

   (Assumes secondary treatment capability is in place and does not include costs to maintain secondary treatment or to control industrial dischargers.)

2. The State of Maryland, through the NPDES program, should establish a pilot biomonitoring and chemical fingerprinting program for identification and control of toxic discharges to the Patapsco River.

   — Cost Estimate —

   Present-value cost — 4.2 to 8.3 million dollars
   Annual O & M cost — 0.4 to 0.8 million dollars

   (Monitoring program costs only. Does not include cost to set up lab or to provide removal of toxic substances).

3. Implement storm water control recommendations proposed as a result of the Jones Falls Nationwide Urban Runoff Project (NURP). Counties in the West Chesapeake should implement and enforce 1983 state regulations for urban stormwater management. In addition, the findings from the Jones Falls Project should be considered in their planning and implementation process.
4. All counties in the West Chesapeake basin should be targetted by the proposed Comprehensive Implementation Program to reduce agricultural nonpoint source pollution. Implement an accelerated nonpoint source control program in Harford, Baltimore, Anne Arundel, and Carroll counties to reduce nutrients, sediment, and animal waste from agricultural operations.
5. The State of Maryland and the counties should consider, as one of several control alternatives, a policy to limit the content of phosphorus in detergents in light of immediate significant reductions achievable in phosphorus loads. This policy could impact the level of removal required in the UCBP Policy and could also impact O & M costs at treatment plants with phosphorus removal. Evaluation of this policy should be completed by July 1, 1984 and, if deemed appropriate, implemented by July 1, 1986.

   — Cost Estimate (to consumers) —

   Present-value cost — 53.0 million dollars
   Annual O & M cost — 5.1 million dollars

—Cost Savings Estimate (to POTWs)—

Present-value cost—19.7 million dollars
Annual O & M cost—1.9 million dollars

6. All dredging and disposal permit decisions in this area should reflect Chesapeake Bay Program findings.

THE EASTERN SHORE DRAINAGE AREA

The Eastern Shore lies wholly within the Atlantic Coastal Plain. Elevations of over 100 ft (31 m) above sea level occur in the upper portion of the Eastern Shore but are seldom greater than 20 ft (6 m) south of the Choptank River. The land, mostly level, is well suited to large, mechanized farming operations and of all Chesapeake Bay drainage areas, the Eastern Shore has the highest percentage of cropland (40.8 percent). Woodlands, game and wildlife, and recreation areas are plentiful. Rivers are numerous and the water table is close to the surface.

Resources and Water Quality

The Eastern Shore contains a number of small to moderate-sized rivers and embayments which are rather diverse biologically and in their present water quality. A number of the northern-most tributaries and the upstream regions of the larger rivers are important finfish-spawning and nursery areas, supporting runs of alewife, blueback herring, shad, striped bass, white and yellow perch, as well as the young of marine spawners such as spot and menhaden. Abundance of some species, especially herring and white perch, has declined in these rivers. Striped bass are doing moderately well in the Nanticoke and Choptank Rivers, although numbers of young fish do not equal peak years of 1970 and before. Many of the smaller tributaries of these rivers have dams or other structures which block the migration of fish to spawning grounds.

Major spat set areas occur in small tributaries of the lower Choptank, the Little Choptank, the Miles, and the Honga Rivers. Although the Chester lost its spat set after 1971, the Eastern Shore sustains better spat set overall than do other areas. Oyster harvests reflect a similar pattern. The upper reaches of tributaries in the Eastern Shore (Elk, Bohemia, Sassafras, Chester) have lost most of their submerged aquatic vegetation, and there have also been declines in the upper and

EASTERN SHORE FACT SHEET

AREA: 3,821 square miles; 2,445,550 acres

POPULATION (1000's):	1950	1980	2000
	282.7	415.5	485.9

LAND USE (1980):	Percent of Total
Cropland (total)	40.8
Conventional tillage	4.8
Conservation tillage	36.0
Pasture	7.5
Forest	50.2
Urban and other uses	1.5

TOXIC SUBSTANCES:	total metal load (lbs/day)
Industrial dischargers (6)	30.2
Municipal dischargers (29)	40.7

NUTRIENTS: Total Load (lbs, March-October)

Source	Phosphorus 833,000 Above Fall line	Phosphorus 833,000 Below Fall line	Nitrogen 8,741,000 Above Fall line	Nitrogen 8,741,000 Below Fall line
Industrial*	0	9	0	2
Municipal*	0	31	0	8
Cropland	0	50	0	83
Other nonpoint sources	0	10	0	7
Total	0	100	0	100

*Number of dischargers - Industrial 9, Municipal 29

mid-Choptank as well as the Honga, Nanticoke, Wicomico, Monokin, Annamessex, and Pocomoke Rivers. Eastern Bay, the lower Choptank River, and the Tangier Sound area still retain relatively healthy beds of SAV. These areas are major blue crab harvest areas, especially for soft crabs. Soft clams are found in many of these rivers, more abundantly in the mid-Bay. Lower rivers and Tangier Sound support populations of the hard clam which depend on higher-salinity water for successful recruitment. A major waterfowl wintering area exists in the Eastern Shore rivers and embayments, but the loss of SAV has caused some species to forage in agricultural fields. Overall, the Eastern Shore maintains the best resource quality compared to other Bay areas, but declines are occurring.

Although concentrations of pesticides and herbicides may reach elevated levels in the upper reaches of Eastern Shore tributaries for short periods of time immediately after storm events, toxic substances are not a problem. Examination of nutrient trends shows increases in concentrations of nitrogen in the Elk, Chester, Nanticoke, and Wicomico Rivers and increases in concentrations of phosphorus in Tangier Sound. Currently, the Elk and Choptank Rivers are enriched with respect to total nitrogen and the Chester River is enriched with respect to total phosphorus. None of the Eastern Shore embayments are enriched with nutrients (Flemer et al. 1983).

The increasing enrichment of its waters from nonpoint source runoff is the major problem facing the Eastern Shore. Runoff from cropland accounts for 50 percent of the total phosphorus and 83 percent of the total nitrogen load from the Eastern Shore. It is estimated that 20 percent of the nutrient load from the Eastern Shore is discharged to the upper Bay.

Existing Policies and Planning

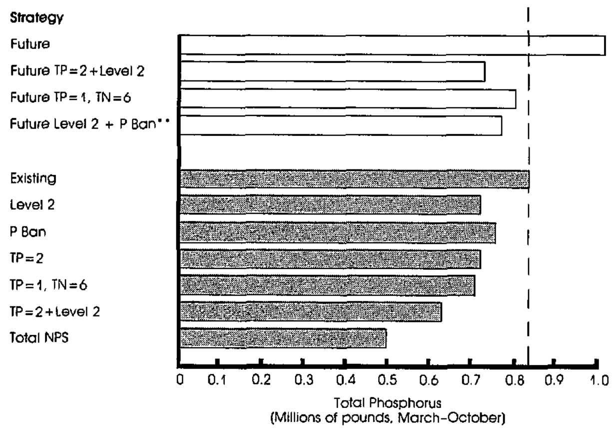
Maryland Small Watershed Program (Public Law 83-566) — Currently, the Maryland SCS is proposing the ditching of more than 90 miles (128.8 km) of small waterways along the upper Chester River. The objective of the project is to drain water from lands along the river for increased farm production. The CBP findings indicate that submerged aquatic vegetation has suffered a precipitous decline since the early 1970's (Flemer et al. 1983). The unprecedented loss of this vital resource is attributable to decreases in the availability of light, resulting from increased turbidity and epiphytic growth on plant surfaces. It is estimated that without proper conservation measures, such as soil erosion and sediment control measures, the sediment and nutrient load to the Bay from the Chester River watershed will likely increase as a result of this project and precious existing SAV beds in the Chester estuary may be endangered. In addition, tidal wetlands which act as nutrient and sediment sinks may be lost unless adequate precautions are taken.

Comparison of Basin Strategies

Figure 44 illustrates the effectiveness of management strategies in reducing existing (1980) and future (2000) nutrient loads from the Eastern Shore drainage area. The least-cost strategy for reducing nutrient loads from the Eastern Shore is the Level 2 strategy, conservation-tillage. Model results indicate that the existing phosphorus load could be reduced 14 percent and the nitrogen load 7 percent with this strategy. The present-value dollars per pound cost to remove one pound of phosphorus is 0.41 dollars and 0.08 dollars for nitrogen. The TP = 1 strategy reduces the existing load about the same as the Level 2 option (15 percent versus 14 percent) but at a much higher present-value cost per pound removed (4.97 dollars versus 0.41 dollars). A phosphorus ban would reduce the existing phosphorus load 9 percent.

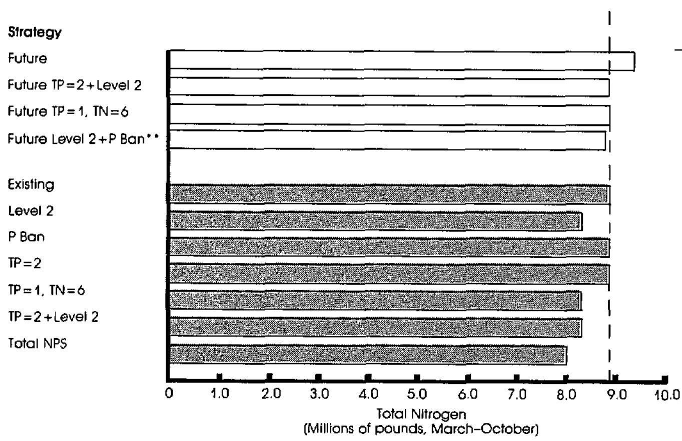
Future phosphorus loads are projected to increase 22 percent and future nitrogen loads 6 percent over the existing (1980) load. Both the Future TP = 1, TN = 6, and Future TP = 2 and Level 2 strategies reduce projected phosphorus loads to a level below existing (1980) loads. The Future TP = 2 and Level 2 combined strategy provides a 13 percent reduction in existing loads and at the lowest present-value cost per pound of phosphorus removed (3.49 dollars).

The effectiveness of the Level 2 strategy can be extrapolated to determine its effectiveness on future (2000) nutrient loads. The projected 22 per-



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+22	–	–
Future TP=2+Level 2	-13	29.9	3.49
Future TP=1, TN=6	-4	31.4	4.93
Future Level 2 + P Ban**	-8	15.3	2.07
Existing	–	–	–
Level 2	-14	1.44	0.41
P Ban	-9	11.8/1.8*	5.26
TP=2	-14	15.6	5.85
TP=1, TN=6	-15	17.9	4.97
TP=2+Level 2	-25	17.0	2.73
Total NPS	-40	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.
**Extrapolated from effectiveness on existing (1980) loads.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+6	–	–
Future TP=2+Level 2	0	29.9	1.79
Future TP=1, TN=6	0	66.6	4.38
Future Level 2+P Ban**	-1	15.3	0.82
Existing	–	–	–
Level 2	-7	1.44	0.08
P Ban	0	11.8/1.8*	–
TP=2	0	15.6	–
TP=1, TN=6	-7	36.9	2.02
TP=2+Level 2	-7	17.0	0.98
Total NPS	-10	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.
**Extrapolated from effectiveness on existing (1980) loads.

FIGURE 44. Existing (1980) and future (2000) estimates of nutrient loads and present value costs for different management strategies in the Eastern Shore drainage basin under average rainfall conditions.

cent increase in phosphorus and 6 percent increase in nitrogen loads are due to increases in the volume of municipal wastewater discharged. The Level 2 nonpoint strategy has no effect on municipal point sources and a decrease in the effectiveness of this strategy is expected when applied to future (2000) loads. The 14 percent reduction in phosphorus and 7 percent reduction in nitrogen loadings achieved by the Level 2 strategy reduces the existing (1980) phosphorus load 0.116 million pounds (833,000 pounds × 0.14) and the existing (1980) nitrogen load 0.612 million pounds (8,741,000 × 0.07). When these reductions are extrapolated to future loads, the projected phosphorus load is reduced to a level 8 percent greater than the existing (1980) phosphorus load and 1 percent less than the existing (1980) nitrogen loads. A phosphorus ban is calculated to reduce future (2000) loadings 0.13 million pounds. When this reduction is combined with the reduction achieved by the Level 2 nonpoint strategy and extrapolated to projected phosphorus loads, future (2000) loads are reduced to a level 8 percent below existing levels. If Level 3 BMPs and animal-waste controls were implemented in concert with a Level 2 BMP, it is anticipated that additional phosphorus and nitrogen reductions could be achieved.

Recommendations — Eastern Shore Drainage Area

To maintain current conditions, future total basin loads must not exceed 833,000 pounds of total phosphorus and 8,741,000 pounds of total nitrogen (existing 1980 load). To improve conditions, future total basin loads must be reduced below these levels. Based on the desired goal of maintaining existing conditions and protecting the valuable marine resources of the Eastern Shore, the following recommendations are proposed.

1. Accelerate implementation of current nonpoint source programs in the Eastern Shore. The upper Eastern Shore should be targetted by the proposed Comprehensive Implementation Program to reduce nutrients, sediment, and animal waste from agricultural activities.
2. If the accelerated nonpoint source control program does not reduce future phosphorus loadings below existing levels, then Eastern Shore counties should consider, as one of several control alternatives, a policy to limit phosphorus in detergents. Evaluation of the policy should proceed concurrently with the accelerated nonpoint source control program and be completed by July 1, 1984. The decision to implement the phosphorus limitation policy should be made as soon as the effectiveness of the nonpoint source control is known.

   — Cost Estimate (to consumers) —

   Present-value cost — 11.8 million dollars
   Annual O & M cost — 1.13 million dollars

   — Cost Savings Estimate (to POTWs) —

   Present-value cost — 1.8 million dollars
   Annual O & M cost — 0.17 million dollars
3. All Federal and state permits for drainage and construction projects affecting tidal wetlands should consider Chesapeake Bay Program findings regarding the value of wetlands as nutrient and sediment buffers and as habitat for living resources.

   — Cost Estimate —

   Present-value cost — 0.55 million dollars
   Annual O & M cost — 0.053 million dollars

   (Includes coordination of 404 permit and EIS review and 404 permit enforcement. Does not include EIS preparation or state costs.)
4. The States of Maryland and Virginia should require nutrient and BOD5 controls for industrial dischargers in the Eastern Shore where appropriate.

THE PATUXENT RIVER BASIN

This long, slender watershed lies entirely within Maryland's boundaries and occupies one-tenth of the state's land area. It is the smallest drainage basin in the Bay catchment area. The upper third of the river's main-stem and two of its three major tributaries, the Middle and Little Patuxent, are entirely in the Peidmont Province. The lower two-thirds of the river drains the Atlantic Coastal Plain. The rapid population growth and replacement of agricultural and forest lands by urban development within the Patuxent River basin is attributed to the basin's location near the "urban corridor" stretching north-eastward from Washington, D.C. to Delaware. Bay-wide, the highest percentage of urban and other land-use is within the Patuxent basin (5.6 percent).

Resources and Water Quality

The Patuxent River has experienced changes in major living resources during the past 20 years. The river supports (or once supported) runs of American and hickory shad, alewife, blueback herring, white and yellow perch, and striped bass. In addition, many marine spawners, including spot, croaker, menhaden, and bluefish use the estuarine portion as a nursery area. Because the river is not monitored annually for juvenile finfish, information on trends is spotty. However, the loss of community diversity was noted as early as 1971. Submerged vegetation is virtually absent from the Patuxent, after a relatively abrupt decline in the late 1960's. Oyster spat set is now low, except at an area near the river mouth. Harvests have remained relatively stable only because of management practices such as seed planting. Harvests of crabs have increased since 1960. Moderate numbers of ducks use the Patuxent as a wintering area; these feed mostly on benthic animals because of the lack of SAV.

PATUXENT BASIN FACT SHEET

AREA: 884 square miles; 565,750 acres

POPULATION (1000's):	1950	1980	2000
	195.2	678.1	851.1

LAND USE (1980):	Percent of Total
Cropland (total)	20.6
Conventional tillage	1.1
Conservation tillage	19.5
Pasture	20.7
Forest	53.1
Urban and other uses	5.6

TOXIC SUBSTANCES:	total metal load (lbs/day)
Industrial dischargers (1)	.3
Municipal dischargers (31)	26.9

NUTRIENTS: Total Load (lbs, March-October)

	Phosphorus 478,000		Nitrogen 2,493,000	
Source	Above Fall line	Below Fall line	Above Fall line	Below Fall line
Industrial*	3	1	1	1
Municipal*	59	20	28	19
Cropland	5	6	13	30
Other nonpoint sources	2	4	3	5
Total	69	31	45	55

*Number of dischargers - Industrial 4, Municipal 10

Chesapeake Bay Program research has shown that the reduced abundance of finfish and shellfish in the Patuxent is related, in part, to the low dissolved oxygen levels in the deeper waters, depressed by increased nutrient levels. The high levels of nutrients are also believed to be responsible for the decline of SAV in the Patuxent. When compared to other basins, the highest nutrient concentrations have been found in the Patuxent and, when compared to similar segments, the highest chlorophyll *a* concentrations are also within the river. Land-use changes and population growth have caused the water quality problems observed in the Patuxent. For example, the volume of wastewater discharged from POTWs has increased 360 percent since 1950 and currently (1980), municipal treatment plants account for 79 percent of the total phosphorus and 47 percent of the total nitrogen load within the estuary.

Existing Policies and Planning

Hydroqual Modeling Results—In 1980, Hydroqual, Inc. conducted a study to determine the relationship between point and nonpoint source nutrient loads to the Patuxent estuary, water quality problems defined as high algal levels (chlorophyll *a*) in the upper portion of the tidal Patuxent, and low dissolved oxygen concentrations in the bottom waters of the lower estuary. This was accomplished through a review of historical water quality data, an analysis of nutrient inputs to the Patuxent, and the development and application of a two-layer, steady-state eutrophication model of the Patuxent estuary. The use of the validated model to project water quality conditions in the Patuxent estuary for various treatment alternatives under consideration produced the following results:

- Nonpoint source nutrient loads alone could support a background summer phytoplankton level comparable to historical levels observed in the early 1960's.
- Neither nitrogen nor phosphorus currently limit algal growth in the upper Patuxent estuary. Light and detention time are primarily the controlling factors. In the lower estuary, nitrogen appears to be the limiting nutrient under existing conditions, although the evidence is certainly not conclusive.
- Upstream point source and background loads have little direct impact on lower estuary chlorophyll a and DO levels. Lower estuary chlorophyll *a* levels and low bottom layer DO levels are due primarily to the release of nutrients from the sediment, sediment oxygen demand, and exchange with Chesapeake Bay water. There is, however, an indirect link between upstream loads and lower estuary water quality. This linkage is based on the hypothesis that reduced chlorophyll *a* levels upstream will reduce both sediment nutrient releases and sediment oxygen demand in the lower estuary.
- Upper estuary chlorophyll *a* levels are due primarily to nutrient inputs from point and upstream nonpoint sources. As a result, either nitrogen or phosphorus control can reduce upper estuary chlorophyll *a* concentrations.
- Dissolved oxygen levels in the bottom layer of the lower Patuxent estuary are most sensitive to the degree of stratification, which worsens the effect of sediment oxygen demand and algal respiration.

Patuxent River Policy Plan—The Patuxent River Policy Plan (Patuxent River Commission 1983) is a land-management plan that has both a broad foundation of basin-wide goals as well as specific, focused actions to carry-out the goals. Unlike previous plans for the river, the policy plan cuts across all levels of government: state, local, as well as provisions for Federal cooperation. The Policy Plan is based on goals set during an intensive three-day workshop known as the Patuxent Charette that was convened in December, 1981. At the Charette, approximately 40 Federal, state, and county officials, watermen, and concerned citizens developed a series of agreements designed to restore water quality to 1950 levels in the Patuxent basin. These agreements included recommendations to Maryland's Department of Health and Mental Hygiene, the Maryland Department of Natural Resources, the seven river basin counties adjacent to the river, and the Patuxent River Commission for the establishment of water quality goals, nutrient limits, nonpoint source controls, monitoring and research, and proposals for water conservation and increasing finfish and shellfish populations.

The Patuxent River Commission was charged to develop a comprehensive plan for nonpoint source pollution control. The central concept of the plan, developed by the Commission and incorporated into the policy plan, is to establish policies applicable throughout the watershed and to focus attention on lands closest to the river and its tributary streams. The latter approach recognizes the particular significance of the resources adjacent to those water bodies, and the great potential for these lands to degrade water quality if improperly managed. The watershed-wide policy developed by the Commission consists of two parts: the first part calls for establishing primary management areas and accomplishing specific actions within these areas; the second part calls for the application of development and management guidelines through out the watershed via adjustments to state programs and local comprehensive plans, zoning, and other regulatory and guidance activities. Thirty-four percent of the 5 million dollars in Maryland's Agricultural Cost-Sharing Program (ACP) is to be directed toward controlling nonpoint sources of pollution in the Patuxent. The ACP is described in Chapter 3.

Nutrient Control Strategy for the Patuxent River Basin—Adapted by the Maryland Office of Environmental Programs (MD OEP) in January 1982, the Nutrient Control Strategy (NCS) provides the foundation for the 208 Water Quality Management Plan (Maryland Department of Health 1982)for the Patuxent River basin. Like the Patuxent River Policy Plan, the NCS is based on the Charette held in the fall of 1981. The NCS calls for point sources to provide nutrient removal to meet a total daily phosphorus limit of 420 pounds and a total daily nitrogen limit of 3,900 pounds. These limits or goals are to be achieved by the year 1987. However, to receive construction grant funding for nutrient removal, the EPA's Draft Advanced Treatment Review Policy requires that the proposed project must be shown to result in significant water quality and public health improvements. Such projects must be scientifically supported by an adequate data base and technical studies which demonstrate the relationships between waste load and water quality or public health. In the case of the Patuxent River, it is the EPA's opinion that the information and studies performed to date do not provide an adequate technical basis to support nitrogen control in addition to phosphorus control. In view of the EPA's reluctance to fund nitrogen control, Governor Hughes of Maryland has pledged to provide an additional 18 million dollars to the 29 million dollars already earmarked for upgrading POTWs in the Patuxent River basin to specifically implement the Patuxent NCS.

Patuxent River Studies—The Academy of Natural Sciences has recently completed a study analyzing the effects of zooplankton grazing on phytoplankton in the Patuxent River system. Findings of the study will be used to further define nutrient dynamics in the Hydroqual Water Quality Model. Another study, conducted by the USGS and the Maryland Department of Health and Mental Hygiene is aimed at determining sediment oxygen demand and benthic nutrient fluxes in the Patuxent estuary. This three-year study is in its second year. In addition, a microcosm study to investigate the effects of nutrient loading on algal productivity, to identify nutrient limitations, and to evaluate the nutrient and organic matter transport and exchange mechanisms in the water column and benthic sediments has been proposed.

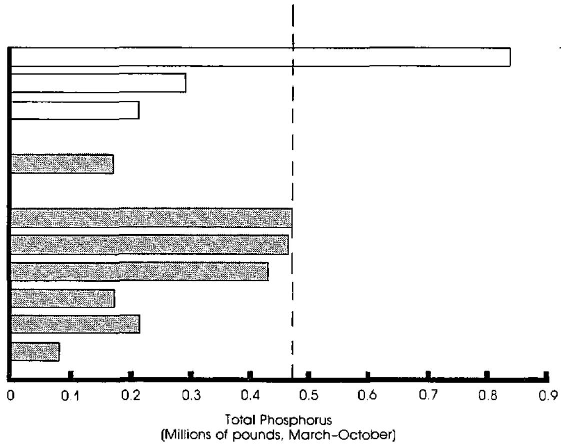
Comparison of Strategies

Figure 45 illustrates the effectiveness of management strategies in reducing existing (1980) and future (2000) nutrient loads within the Patuxent drainage area. The Level 2 nonpoint source strategy, conservation-tillage, has the lowest present-value cost per pound of nutrient removed of all strategies examined. However, the magnitude of the reduction achieved is so small (1 percent phosphorus and 1 percent nitrogen) that it cannot be expected to improve water quality substantially. The phosphorus ban strategy reduces the existing phosphorus load 10 percent with present-value consumer costs estimated at 19.3 million dollars. Present-value O & M savings at treatment plants required to meet a phosphorus effluent limitation are estimated to be 4.0 million dollars (0.39 million dollars annually). The TP = 1, TN = 6 strategy reduces the 1980 phosphorus load 64 percent and the nitrogen load 30 percent. The present-value cost of this strategy is calculated to be 135.2 million dollars.

Future (2000) phosphorus loads are projected to increase 77 percent and future (2000) nitrogen loads are projected to increase 34 percent over existing (1980) loads. Implementation of a Future TP = 1, TN = 6 strategy reduces projected phosphorus loads 54 percent and nitrogen loads 19 percent below existing (1980) loads. The Future TP = 2 and Level 2 strategy reduces projected phosphorus loads to a level 37 percent below existing (1980) loads. Either strategy can be modified and applied to selected POTWs to maintain existing loadings. The Patuxent NCS reduces existing (1980) phosphorus loadings 63 percent and existing (1980) nitrogen loadings 57 percent. The Patuxent NCS strategy removes phosphorus at approximately the same cost as the TP = 1, TN = 6 strategy. However, it removes nitrogen at about a 25 percent lower present-value cost per pound than the TP = 1, TN = 6 strategy, largely because it takes advantage of economies of scale by controlling nitrogen at larger plants. The Patuxent NCS and Patuxent River Policy Plan enjoy wide support and provide an opportunity to assess water quality benefits resulting from comprehensive point and nonpoint source controls of nutrients.

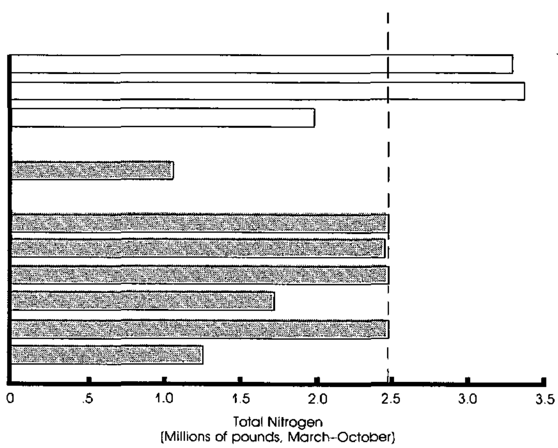
Recommendations—Patuxent River Basin

To maintain current conditions, future total basin loads must not exceed 478,000 pounds total phosphorus and 2,493,000 pounds total nitrogen (existing 1980 load). To improve conditions, future



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+77	—	—
Future TP=2+Level 2	-37	67.0	4.09
Future TP=1, TN=6	-54	73.2	3.91
Patuxent NCS (1987)	-63	135.2*	4.64
Existing	—	—	—
Level 2	-1	0.07	0.46
P Ban	-10	19.3/4.0**	14.08
TP=1, TN=6	-64	41.9	4.58
TP=2+Level 2	-55	38.8	4.92
Total NPS	-83	?	?

*Includes costs for nitrogen removal
**O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+34	—	—
Future TP=2+Level 2	+36	67.0	N increases
Future TP=1, TN=6	-19	176.6	4.49
Patuxent NCS (1987)	-57	135.2*	3.22
Existing	—	—	—
Level 2	-1	0.07	0.14
P Ban	0	19.3/ 4.0**	—
TP=1, TN=6	-30	93.8	4.21
TP=2+Level 2	0	38.8	—
Total NPS	-49	?	?

*Includes costs for phosphorus removal.
**O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.

FIGURE 45. Existing (1980) and future (2000) estimates of nutrient loads and present value costs for different management strategies in the Patuxent River drainage basin under average rainfall conditions.

total basin loads must be reduced below these levels. Based on the desired goal of restoring water quality to 1950 levels in the Patuxent River, the following recommendations are proposed.

1. The State of Maryland should be encouraged to implement the Patuxent River Policy Plan and Nutrient Control Strategy which recognize the significance of non-point source pollutants and the role of nitrogen as a potential limiting nutrient in estuarine waters. If the Patuxent Policy Plan and Nutrient Control Strategy result in significant improvements to the condition of the Patuxent, the States of Maryland and Virginia should consider implementing a similar approach in other river basins.

—Cost Estimate—

Present-value cost—135.2 million dollars

Capital cost—36.2 million dollars
Annual O & M cost—9.2 million dollars

(Does not include costs to maintain existing secondary treatment capability or to implement policy plan.)

2. Maryland research projects on sediment oxygen demand, bottom and main Bay nutrient fluxes, and microcosm studies within the Patuxent should be continued and used to determine water quality benefits arising from the Patuxent Policy Plan and Nutrient Control strategy.

—Cost Estimate—

Total Project costs—0.74 million dollars

3. Water quality models should be further developed for use in the Patuxent to assess the impact of management strategies on water quality in the upper and lower Patuxent estuary.

THE POTOMAC RIVER BASIN

The Potomac River basin drains 14,134 square miles (36,748 km[2]), and is the second largest in the Bay catchment area. It stretches from West Virginia across the Appalacian Ridge and Valley, Blue Ridge, Piedmont, and Atlantic Coastal Plain Provinces to Point Lookout, Maryland and Smith Point, Virginia. About 3 million people live within the metropolitan Washington area that surrounds the Nation's Capital and marks the southern terminus of the "urban corridor."

Resources and Water Quality

The Potomac River is a major spawning area for anadromous and semi-anadromous fish, including American and (rarer) hickory shad, alewife, blueback herring, white and yellow perch, and striped bass. Marine spawners (spot, croaker, seatrout, menhaden, bluefish) use the lower and middle river as a nursery area. Declines in the spawning success of some freshwater spawners occurred during the 1970's, but alewife, blueback herring, and white and yellow perch

POTOMAC BASIN FACT SHEET

AREA: 14,134 square miles; 9,045,550 acres

POPULATION (1000's):	1950	1980	2000
	2106.8	3659.6	4390.8

LAND USE (1980):	Percent of Total
Cropland (total)	16.1
Conventional tillage	1.9
Conservation tillage	14.2
Pasture	18.2
Forest	61.6
Urban and other uses	4.2

TOXIC SUBSTANCES:	total metal load (lbs/day)
Industrial dischargers (6)	19.2
Municipal dischargers (99)	934.0

In addition to these discharges below the fall line, fall line metal loads of 4,390 lbs/day indicate significant additions from point sources above the fall line.

NUTRIENTS: Total Load (lbs, March-October)

	Phosphorus 2,866,000		Nitrogen 35,077,000	
Source	Above Fall line	Below Fall line	Above Fall line	Below Fall line
Industrial*	1	0	1	1
Municipal*	3	55	3	39
Cropland	16	7	39	9
Other nonpoint sources	10	8	4	4
Total	30	70	47	53

*Number of dischargers - Industrial 15, Municipal 99

have been relatively stable or have even increased in recent years. The Potomac lost the abundant SAV of the upper tidal-fresh river in about 1930, while that of the lower estuary disappeared in the late 1960's. However, relatively healthy populations of submerged vegetation exist in the riverine-estuarine transition zone. There has been some slight recovery of SAV in the upper river near Washington in the last few years.

Wintering waterfowl, especially diving ducks, use the Potomac shoreline where suitable food is available, particularly in smaller tributaries of the river where submerged vegetation still occurs. Oyster spat set has declined to near zero in the upper portion of the species' range in the Potomac due to sedimentation, reduction in water quality, and the impact of Tropical Storm Agnes. Spat set in the lower river, particularly at the mouth, remains good. Oyster harvest has declined significantly in the decade since 1971, as compared to the previous decade, due in part to the loss of upstream productivity. Crab harvests have also declined in the Potomac, compared to the decade before 1971. Whether this reflects economic (i.e., fishery) changes or the loss of crab habitat (SAV) is not known. Soft clam populations have again reached harvestable densities in the lower river, after a decade of lower populations.

In the 1960's the Potomac was often characterized by massive blue-green algae blooms and low dissolved oxygen levels associated with high levels of nutrients. It was described as an open sewer and a national disgrace. Fortunately, efforts were made to halt the river's degradation by upgrading the treatment capabilities of POTWs discharging to the river. This policy, costing about 1 billion dollars, seems to have worked. Today there is a decrease in the total phosphorus concentration in the water column of the upper segment and a decrease in total nitrogen levels in the lower portion of the estuary (Flemer et al. 1983). In addition, there has been moderate recovery in some resources, particularly finfish.

Municipal point sources account for 58 percent of the phosphorus and 42 percent of the nitrogen load in the Potomac River basin and, as stated earlier, the river's cleanup is the result of actions taken to upgrade municipal treatment. Specifically, Virginia, Maryland, and the District of Columbia require phosphorus removal at treatment plants discharging to the Virginia embayments and upper Potomac estuary. For example, the 317 MGD Blue Plains treatment plant, the largest POTW in the Chesapeake drainage area, employed advanced waste-water treatment in 1980 to produce an effluent with a total phosphorus concentration of 1.2 mg L^{-1}. As of 1983, the level of treatment has been improved to produce an effluent in the 0.5 to 1.0 mg L^{-1} range. In addition, the Alexandria (27 MGD), Arlington (22 MGD), Lower Potomac (22 MGD), Mooney (6 MGD), Aquia (1 MGD), and Piscataway WWTPs (15 MGD) each have phosphorus removal technology in place to meet effluent limits.

Although the District of Columbia and other jurisdictions in the Washington metropolitan area have actively pursued the goal of clean water through the expansion and upgrading of area wastewater treatment plants, a significant volume of sanitary sewage can escape treatment and be discharged to contaminate area waters. This untreated discharge results from wet weather overflows from the sewers in that part of the city where the sanitary sewers and storm drains are connected together as a single combined sewer system. Overflows from these systems significantly contribute to dissolved oxygen-demanding materials in the bottom sediments.

Existing Policies and Planning

Blue Plains Feasibility Study—The Blue Plains Feasibility Study (Greeley and Hansen 1983) includes consideration of the effects on the Potomac estuary of variations in the quality of treated waste-water effluents from current NPDES permit levels. Effluent limits based on combined phosphorus and nitrogen removal, and on individual nutrient removal are evaluated.

The Potomac Strategy—In April 1979, the EPA Region III developed the Potomac Strategy, which coordinates local, state, and EPA water quality planning efforts into a comprehensive program aimed at addressing the most significant water quality issues of the Potomac River. The primary focus of the first phase of the strategy, which is scheduled for completion in early 1984, is to address the eutrophication and dissolved oxygen issues for the upper 50 miles (81 km) of the tidal Potomac River (Chain Bridge to approximately Maryland Point). The ultimate objective of the first phase effort is the development of recommendations for a control strategy which, upon approval by the States of Maryland and Virginia, the District of Columbia, and the EPA, will lead to the establishment of updated total maximum daily loads (TMDLs) and NPDES permits.

To accomplish first-phase objectives of the strategy, two main-stem Potomac River models (short-term and long-term) were developed to project the water quality response of the Potomac estuary to various pollution control alternatives, including phosphorus and nitrogen control. These are under evaluation in the Blue Plains Feasibility Study. Although the modeling effort is not due for completion until early 1984, preliminary results indicate the following:

- The improvements in water quality observed since the late 1960's in the upper 50 miles (81 km) of the Potomac estuary are principally attributed to the current point source control program.
- Phosphorus removal alone, at or below effluent limits of 1 mg L^{-1}, will begin to limit algal growth under low flow (1977) conditions in the upper 35 miles (56 km) of the estuary.
- Nitrogen removal alone at a total nitrogen effluent limit of 2 mg L^{-1} will limit algal growth under low flow (1977) conditions in the upper 50 miles (81 km) of the estuary but will be considerably less effective at higher river flows, and generally no better than phosphorus-only removal programs in reducing peak chlorophyll a levels in the upper estuary.
- Reductions in lower estuary (between mile 35 and 50) algal levels can only be achieved through some reduction in nitrogen loadings. The major algal problem, however, occurs above mile 35.
- Nitrification alone at the POTW will increase summer average DO levels by 2 mg L^{-1} under 1977 low flow conditions.

Another element of the Potomac Strategy for the clean-up of the upper Potomac's surface water resource is the Combined Sewer Overflow Abatement Program (O'Brien and Gere 1983).

Combined Sewer Overflow Abatement Program — The Combined Sewer Overflow Abatement Program defined water quality problems attributable to combined sewer overflows (CSOs) and developed a two-segment program for control and abatement. The first segment of the CSO control program principally consists of minimal modifications of the existing sewerage system to maximize containment of wet-weather flows for treatment at the existing central treatment facility, and the implementation of a major end-of-pipe treatment facility to mitigate water quality problems in the Anacostia River. The second segment of the CSO abatement program is to be based on a mid-course reassessment of environmental conditions following completion of the Segment I program to assure the most effective expenditure of resources. Probable elements in the Segment II program would include two additional swirl treatment facilities along the Anacostia River, and construction of an 885 MGD capacity screening facility on the Piney Branch overflow, the largest CSO along Rock Creek.

Metropolitan Washington Council of Governments Nationwide Urban Runoff Pollution Project — The Metropolitan Washington Council of Governments' Nationwide Urban Runoff Pollution (NURP) project investigated control measures in developing areas. During the four-year study, the efficacy and cost-effectiveness of twelve types of BMPs (including wet ponds, dry ponds, porous pavements, etc.) were studied at several suburban sites in Virginia and Maryland. The investigators concluded the following:

- Wet ponds are among the most effective means of controlling urban runoff. However, the initial costs for constructing these structures is significantly higher than for dry ponds; these initial outlays tend to be offset by increased property values which wet ponds tend to generate.
- Porous pavement is an effective BMP for reducing the rate of stormwater runoff and pollutant loads.
- Grassy swales, long favored by developers, were found to be no more effective than the curb and gutter systems that they were designed to replace.

In their recommendations, the coordinators of the Washington area NURP plan call for the strengthening of existing stormwater regulations to make them an instrument for improving water quality and reducing stream-bank erosion. The program also advocates the promulgation of regulations requiring the government and developers to absorb implementation and O & M costs, rather than leaving this responsibility to homeowners' associations, which have fewer resources.

Comparison of Strategies

Figure 46 illustrates the effectiveness of management strategies in reducing existing (1980) and future (2000) nutrient loads within the Potomac River drainage area. The Level 2 nonpoint source option, conservation-tillage, provides a 4 percent reduction in the total phosporus load and at the lowest present-value cost per pound removed. In addition, the strategy reduces the nitrogen load 1 percent. The next least-cost alternative is the combination of the Level 2 nonpoint source control with a phosphorus effluent limitation of 2.0 mg L^{-1}. This strategy reduces the phosphorus load 17 percent and increases the nitrogen load 2 percent.

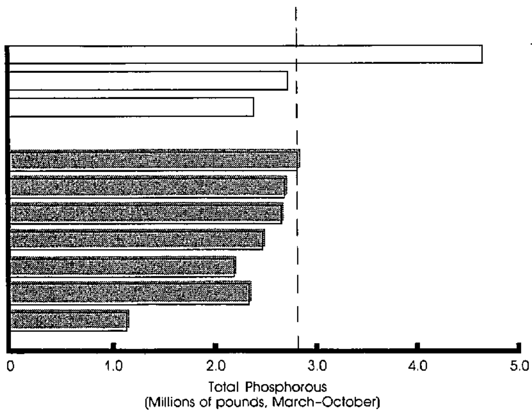
The TP = 1, TN = 6 effluent limitation reduces the phosphorus load 10 percent more than the TP = 2 effluent limitation (22 percent to 12 percent) and at a slightly lower present-value cost per pound removed (6.02 versus 6.30 dollars). The cost to remove a pound of phosphorus through a phosphorus ban (24.24 dollars) is very large when compared to costs for other strategies in the Potomac and other basins. There are two reasons for this: first, many POTWs in the Potomac already employ phosphorus removal technology so reductions in phosphorus loading associated with the ban will be small; second, there is a large population in the Potomac area which would bear increased consumer costs. However, a phosphorus ban would reduce POTW O & M costs for chemicals and sludge disposal and result in annual savings of 4.8 million dollars basin-wide with 3.5 million dollars in savings for the Blue Plains POTW. Because Blue Plains meets some of its chemical needs with waste-pickle liquor supplied free by Bethlehem Steel, the actual savings may be less. A 21 percent reduction in total nitrogen loadings can be achieved by the TN = 6 strategy. The present-value cost of the strategy is 1.2 billion dollars.

Future (2000) phosphorus loads are projected to increase 65 percent and future (2000) nitrogen loads are projected to increase 5 percent over existing (1980) loads. As stated earlier, significant improvements in phosphorus removal have taken place at the Blue Plains treatment plant since 1980. These improvements should be viewed as progress toward the implementation of management strategies and would reduce estimated implementation costs. Implementation of the Future TP = 1, TN = 6 strategy reduces projected phosphorus loads 14 percent and nitrogen loads 18 percent below existing (1980) loads. The Future TP = 2 strategy combined with the Level 2 strategy reduces projected phosphorus loads to a level 3 percent below existing (1980) loads. The present-value cost per pound of nutrient removed is slightly less with the Future TP = 1, TN = 6 strategy than with the Future TP = 2 plus Level 2 strategy (2.08 versus 2.26 dollars). Application of either strategy to maintain existing (1980) loads, however, should be preceeded by an accurate assessment of current loads based on improved nutrient removal at Blue Plains and other treatment plants discharging to the upper Potomac.

Recommendations — Potomac River

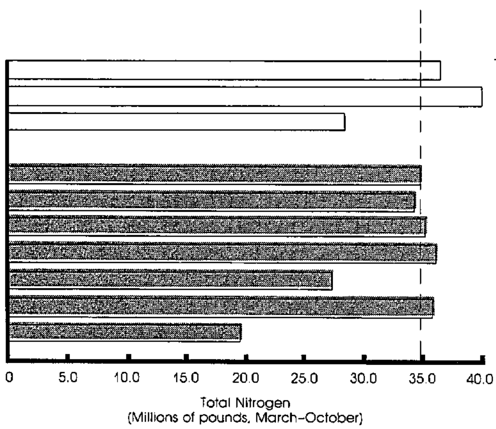
To maintain current conditions, future total basin loads must not exceed 2,866,000 pounds total phosphorus and 35,077,000 pounds total nitrogen (existing 1980 load). To improve conditions, future total basin loads must be reduced below these levels. Based on the desired goal of maintaining existing conditions in the Potomac River, the following recommendations are proposed.

1. The governments of the metropolitan Washington area should continue to develop and implement the Potomac Strategy to achieve optimum nutrient reduction from point and nonpoint sources. Water quality models for the Potomac should be expanded to simulate water quality impacts in the lower Potomac.
2. All counties in the Potomac basin should be targetted by the proposed Comprehensive Implementation Program to reduce



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+65	—	—
Future TP=2+Level 2	-3	130.2	2.26
Future TP=1, TN=6	-14	140.3	2.08
Existing	—	—	—
Level 2	-4	2.13	0.57
P Ban	-5	103.3/49.9*	24.24
TP=2	-12	66.5	6.30
TP=1, TN=6	-22	115.2	6.02
TP=2+Level 2	-17	68.5	4.79
Total NPS	-59	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+5	—	—
Future TP=2+Level 2	+15	130.2	N increases
Future TP=1, TN=6	-18	1,581.0	6.49
Existing	—	—	—
Level 2	-1	2.13	0.15
P Ban	+1	103.3/49.9*	N increases
TP=2	+3	66.5	N increases
TP=1, TN=6	-21	1,272.4	5.81
TP=2+Level 2	+2	68.5	N increases
Total NPS	-44	?	?

*O&M savings realized by POTWs if required to meet a nitrogen effluent limitation.

FIGURE 46. Existing (1980) and future (2000) estimates of nutrient loads and present value costs for different management strategies in the Potomac River drainage basin under average rainfall conditions.

agricultural nonpoint source pollution. Implement an accelerated nonpoint source control program in Frederick and Carroll counties to reduce nutrients, sediment, and animal waste from agricultural operations.

3. The District of Columbia should implement the two-segment program for abatement of pollution from combined sever overflows developed as part of the Potomac Strategy.

—Cost Estimate—

Present-value cost—72.6 million dollars
Capital cost—70.6 million dollars
Annual O & M cost—0.191 million dollars

4. The states and the District of Columbia should consider, as one of several control alternatives, a policy to limit phosphorus in detergents in the metropolitan Washington area. Sludge disposal is a major problem facing Blue Plains and other POTWs removing phosphorus in the Potomac basin. A phosphorus limitation on detergents would reduce the amount of

sludge generated and result in reductions in O&M costs. Evaluation of the policy should be completed by July 1, 1984 and, if deemed appropriate, implemented by July 1, 1986.

—Cost Estimate (to consumers)—

Present-value cost—103.3 million dollars
Annual O & M cost—9.94 million dollars

—Cost Estimate (to POTWs)—

Present-value cost—49.9 million dollars
Annual O & M cost—4.8 million dollars

5. The District of Columbia and surrounding counties should implement the Metropolitan Washington Council of Governments Nationwide Urban Runoff Program (NURP) recommendations to reduce nutrient and toxicant loadings to the Bay. In addition, Prince Georges and Montgomery counties should implement and enforce new state 1983 regulations for stormwater management. Northern Virginia counties should continue to implement and enforce their nonpoint source control program.

RAPPAHANNOCK BASIN FACT SHEET

AREA: 2,631 square miles; 1,683,880 acres

POPULATION (1000's):	1950	1980	2000
	96	150	209

LAND USE (1980):	Percent of Total
Cropland (total)	15.5
Conventional tillage	
Conservation tillage	
Pasture	19.6
Forest	64.3
Urban and other uses	0.6

TOXIC SUBSTANCES:	total metal load (lbs/day)
Industrial dischargers (0)	0
Municipal dischargers (8)	7.4

NUTRIENTS: Total Load (lbs, March-October)

	Phosphorus 278,000		Nitrogen 2,945,000	
Source	Above Fall line	Below Fall line	Above Fall line	Below Fall line
Industrial*	0.5	15	0	1
Municipal*	0.5	23	5	7
Cropland	21.0	17	40	33
Other nonpoint sources	15.0	8	10	4
Total	37	63	55	45

*Number of dischargers - Industrial 2, Municipal 8

THE RAPPAHANNOCK RIVER BASIN

The Rappahannock River basin is located entirely in the northeastern section of Virginia. The drainage area is quite narrow below Fredericksburg, only 10 miles wide (16 km) at one point, but fans out to a maximum width of about 50 miles (80 km) in its headwaters in the Peidmont Province. The basin is largely rural with less than 0.6 percent in urban use. The Rappahannock drains 2,631 square miles (6,841 km^2) and discharges less than 2 percent of the average year total phosphorus load and 2 percent of the total nitrogen load delivered to the Bay system. While these loadings may be minor in terms of Bay-wide loadings, they have an important influence on local water quality and resources.

Resources and Water Quality

The Rappahannock is considered one of the least-impacted western tributaries of the Bay. Nevertheless, negative trends in some living resources have been recorded. The river supports runs of hickory and American shad, alewife, blueback herring, white and yellow perch, and striped bass. There is only scattered information on trends in freshwater-fish spawning success, but significant declines in the landings of these species probably indicate at least some reduction in stocks. The Rappahannock also lost its beds of submerged vegetation between 1970 and 1975. Declines in oyster spat set have been reflected in significant declines in oyster harvest since 1971. Spat set has also declined in the Piankatank, a small river included in the lower Rappahannock estuary. Crab landings have been reduced significantly since 1971. Parts of the Rappahannock have supported commercial densities of soft clams in the past, but populations are variable. Hard clams occur occasionally in the lower Piankatank. The Rappahannock is an important wintering area for waterfowl in Virginia, especially for geese and diving ducks.

Although concentrations of phosphorus in the mid- and lower reaches of the river are currently low, trend analysis indicates that concentrations of inorganic phosphorus have been increasing (Flemer et al. 1983). Nutrient loadings in the Rappahannock drainage system are chiefly from nonpoint sources. Industrial activities generate more than one-third of the total point source phosphorus load. Small areas of the lower Rappahannock are moderately enriched with cadmium from natural sources, but over all, toxic substances are not a problem in the river.

Existing Policies and Planning

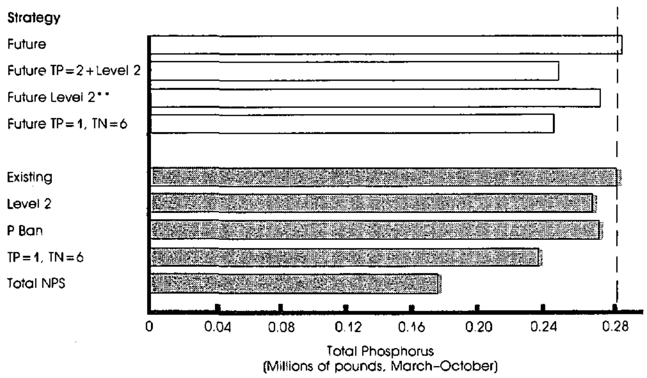
From 1969 to 1970, the Federal Water Pollution Control Administration (FWPCA), precursor to the Environmental Protection Agency, participated with local, state, and other Federal agencies in a joint water resources study of the Rappahannock River. At the time, a need was found for a mathematical model of the river to be used as a planning tool for predicting the water quality responses of the river to various combinations of waste loads, flows, and so forth. An intratidal single-stage biochemical oxygen demand and dissolved oxygen model was developed by the FWPCA to meet this need. Subsequently, in an effort to better represent the complex processes which determine the DO levels of the river, additional significant parameters such as nitrogenous BOD were modeled and a more extensive data base was used. In addition, the Virginia Institute of Marine Science developed mathematical models for the prediction of salinity and dissolved oxygen in the Rappahannock River.

The City of Fredericksburg and Spotsylvania County are planning to renovate the abandoned FMC Corporation industrial site to provide additional waste-water treatment capacity (initial phase -2.6 MGD) to attract light industry and to accomodate future population growth.

Comparison of Strategies

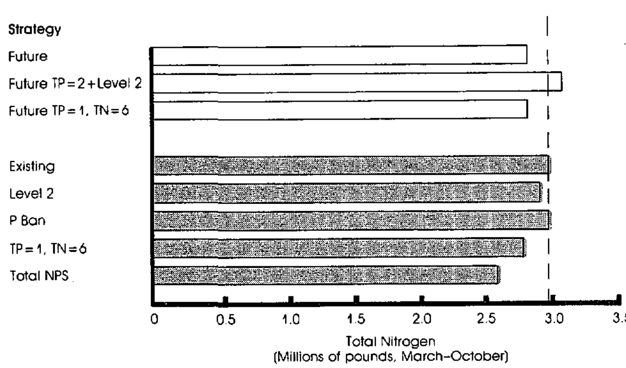
Figure 47 illustrates the effectiveness of management strategies in reducing existing (1980) and future (2000) nutrient loads within the Rappahannock drainage area. The Level 2 nonpoint source strategy, conservation tillage, reduces the existing phosphorus load 5 percent and the existing nitrogen load 2 percent with the lowest present-value cost per pound removed (phosphorus 0.82 dollars and nitrogen 0.21 dollars). A phosphorus ban reduces the existing phosphorus load 4 percent. The present-value cost to remove a pound of phosphorus with the ban is greater than with the TP = 1, TN = 6 strategy. This indicates that phosphorus removal in the Rappahannock is more cost effective at POTWs than through a phosphorus detergent ban. A phosphorus ban would, however, provide annual O & M savings to POTWs subject to a phosphorus effluent limitation of 0.07 million dollars. The TN = 6 strategy would reduce the existing nitrogen load 6 percent at a present-value cost of 3.32 dollars per pound removed.

Future (2000) phosphorus loads are projected to increase 1 percent and future (2000) nitrogen loads are projected to decrease 5 percent relative to existing (1980) loads. The Future TP = 1, TN = 6 strategy and Future TP = 2 plus Level 2 strategy reduce projected phosphorus loads to levels 13 percent and 12 percent below existing (1980) loads. The Level 2 nonpoint strategy reduced existing (1980) phosphorus loadings 5 percent and did so at a present-value cost per pound removed lower than the effluent limitations or phosphorus ban strategies. The effectiveness of the



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+1	—	—
Future TP=2+Level 2	-12	11.2	10.03
Future Level 2**	-4	0.35	0.82
Future TP=1, TN=6	-13	11.7	10.26
Existing	—	—	—
Level 2	-5	0.35	0.82
P Ban	-4	4.2/0.7*	13.94
TP=1, TN=6	-17	8.3	5.83
Total NPS	-39	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.
**Extrapolated from effectiveness on existing (1980) loads.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	-5	—	—
Future TP=2+Level 2	+4	11.2	N increases
Future TP=1, TN=6	-5	24.3	5.51
Existing	—	—	—
Level 2	-2	0.35	0.21
P Ban	0	4.2/0.7*	—
TP=1, TN=6	-6	16.3	3.28
Total NPS	-13	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.

FIGURE 47. Existing (1980) and future (2000) estimates of nutrient loads and present value costs for different management strategies in the Rappahannock River drainage basin under average rainfall conditions.

Level 2 strategy can be extrapolated to determine its effectiveness on future (2000) nutrient loads in the Rappahannock. The projected 1 percent increase in year 2000 phosphorus loads is due to increases in the volume of municipal waste-water discharged. The Level 2 nonpoint strategy has no effect on municipal discharges, so there is a decrease in the effectiveness of this strategy when extrapolated to future (2000) phosphorus loads. The 5 percent reduction in phosphorus achieved by the Level 2 strategy reduced the existing (1980) phosphorus load 0.0139 million pounds (278,000 $\times 0.05$). When this reduction in existing (1980) loads is applied to future (2000) phosphorus loads, they are reduced to a level 4 percent less than the existing (1980) phosphorus load.

Recommendations—Rappahannock River

To maintain current conditions, future total basin loads must not exceed 278,000 pounds total phosphorus and 2,945,000 pounds total nitrogen (existing 1980 load). To improve conditions, future total basin loads must be reduced below these levels. Based on the desired goal of maintaining existing conditions and protecting the valuable marine resources of the Rappahannnock River, the following recommendations are proposed.

1. Federal, state, and county agencies should encourage the implementation of needed BMPs in critical sub-basins.
2. All new or modified wastewater treatment plants should consider providing nutrient removal. This would ensure that population growth does not increase existing (1980) loads.
3. The State of Virginia should require nutrient and BOD_5 control for industrial dischargers in the Rappahannock River, where appropriate.

THE YORK RIVER BASIN

The York River basin, the third smallest in the Bay drainage area, is largely rural and has the smallest percentage of urban and other land uses. More than 70 percent of this basin is forested. The upper reaches of the Pamunkey and Mataponi, tributaries to the York, extend into the Peidmont Province, while the York River itself lies wholly in the Atlantic Coastal Plain Province.

Resources and Water Quality

The York is another relatively unimpacted western shore tributary, but it has also lost some resource quality in the past decade or so. The York supports runs of American and hickory shad, alewife, blueback herring, white and yellow perch, and striped bass. Landings of alosids (shad, herring) have declined drastically during the 1970's. The spawning success of white perch and striped bass has shown some improvement in 1980 and 1981, although present harvests are low. In fact, overall landings of freshwater-spawning finfish have declined throughout the basin. The York also supports juvenile marine spawners, particularly sciaenids such as spot and croaker. Juvenile abundance of these finfish has been good in the last few years; subsequent harvests are affected greatly by winter survival, however. The

YORK BASIN FACT SHEET

AREA: 2,986 square miles; 1,911,310 acres

POPULATION (1000's):	1950	1980	2000
	98	180	258

LAND USE (1980):	Percent of Total
Cropland (total)	16.6
Conventional tillage	
Conservation tillage	
Pasture	13.1
Forest	70.6
Urban and other uses	0.2

TOXIC SUBSTANCES:	total metal load (lbs/day)
Industrial dischargers (2)	16.4
Municipal dischargers (11)	2.7

NUTRIENTS: Total Load (lbs, March-October)

	Phosphorus 221,000		Nitrogen 2,329,000	
Source	Above Fall line	Below Fall line	Above Fall line	Below Fall line
Industrial*	0	23	0	0
Municipal*	2	10	3	2
Cropland	26	26	2	49
Other nonpoint sources	7	6	4	6
Total	35	65	35	65

*Number of dischargers - Industrial 2, Municipal 11

York river lost most of its submerged vegetation in the period from 1971 to 1975; good populations remain in Mobjack Bay and at the river's mouth.

The York River does not contain much oyster bottom; spat set is low to moderate, and has shown little change in the past 20 years. Mobjack Bay, although it has low oyster acreage, has good spat set and is a potential seed area. Oyster harvest has declined significantly in these two areas since 1960 because of the impact of MSX, a protozoan parasite. Blue crab landings have been relatively stable during this period. Soft clams are not found in commercial quantities, although harvestable populations of hard clams are sometimes found. The upper York is an important wintering area for geese and puddle ducks; diving ducks use the lower river and Mobjack Bay.

The tidal-fresh portion of the York is moderately enriched with respect to phosphorus, and trend analysis indicates that nitrogen concentrations are increasing in the Pamunkey and Mataponi Rivers, tributaries to the York (Flemer et al. 1983). Overall, toxic substances do not present any water quality problems. Nonpoint sources are the major source of nutrients, contributing 65 percent of the phosphorus and 87 percent of the nitrogen load. Industrial discharges are significant, and account for more than 23 percent of the basin's total phosphorus load and 8 percent of its nitrogen load. The largest POTW in the York River basin has a discharge of 0.75 MGD and was not subject to any POTW effluent limitation strategies. Some POTWs provide only primary treatment (Appendix B).

Existing Policies and Planning

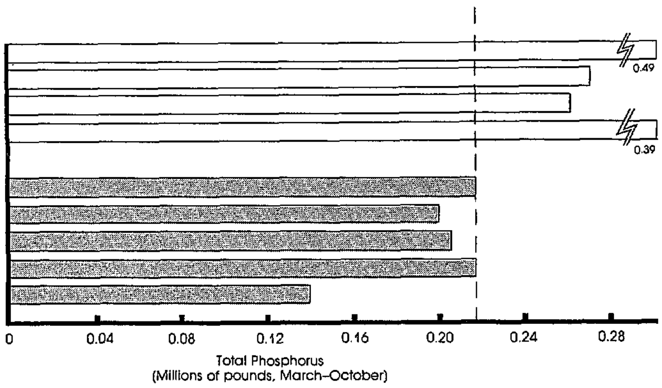
As part of the 208 Planning Process, a water quality model was developed for the study of environmental questions in the York River basin. Model projections show that water quality conditions are not at desired levels and will not change significantly in the future. Dissolved oxygen levels in the upper layer of the river will normally be above 5 mg L^{-1} but levels of dissolved oxygen in the bottom layer will virtually always be below the 4 mg L^{-1} standard (Hampton Roads Water Quality Agency 1978).

The York Wastewater Treatment Plant (15 MGD design) is scheduled to begin operation in the fall of 1983. The plant will be administered by the Hampton Roads Sanitation District (HRSD), and will discharge to the lower York estuary. The plant will treat wastewater from York County that is currently treated at the James River wastewater treatment plant. The plant will increase the capacity for treatment of the HRSD and will provide wastewater treatment for the anticipated population growth in the lower James-York River area.

Comparison of Strategies

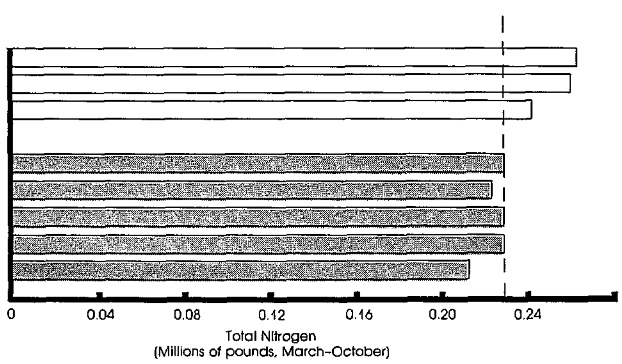
Figure 48 illustrates the effectiveness of management strategies in reducing existing (1980) and future (2000) nutrient loads within the York River drainage area. The Level 2 option, conservation tillage, reduces the existing (1980) phosphorus load 8 percent and the existing (1980) nitrogen load 3 percent. A phosphorus ban reduces the existing (1980) phosphorus load 6 percent. The present-value cost per pound phosphorus removed is 0.40 dollars with the Level 2 strategy, as compared to 14.11 dollars with the phosphorus ban. There are no POTWs with 1980 operational flows greater than 1 MGD in the York basin, and no POTW effluent strategies were simulated.

Future (2000) phosphorus loads are projected to increase 122 percent and future (2000) nitrogen loads are projected to increase 26 percent over existing (1980) loads. Three treatment plants, including the 15 MGD York Wastewater Treatment Plant, are projected to have flows greater than 1 MGD in the year 2000 and POTW effluent strategies were applied to these plants (Appendix B). Implementation of the Future TP = 1, TN = 6 municipal point source strategy does not reduce projected phosphorus and nitrogen loads to levels below existing (1980) conditions. This indicates that municipal point source controls alone cannot maintain existing (1980) loadings in the York. The Level 2 nonpoint source strategy reduced existing (1980) phosphorus loads 8 percent and the phosphorus ban reduced them 6 percent. Extrapolating the combined effectiveness of the two strategies, future (2000) phosphorus loads, which are projected to increase 122 percent, are reduced to a level 77 percent greater than existing (1980) levels.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+122	—	—
Future TP=2+Level 2	+25	16.0	2.51
Future TP=1, TN=6	+18	17.5	2.57
Future Level 2+P Ban**	+77	7.88	2.65
Existing	—	—	—
Level 2	-8	0.51	0.40
P Ban	-6	5.2/0*	14.11
TP=1, TN=6	0	0	—
Total NPS	-35	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.
**Extrapolated from effectiveness on existing (1980) loads.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound (dollars)
Future	+26	—	—
Future TP=2+Level 2	+24	16.0	10.73
Future TP=1, TN=6	+8	44.0	3.66
Existing	—		
Level 2	-3	0.51	
P Ban	0	5.2/0*	14.11
TP=1, TN=6	0	0	—
Total NPS	-13	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.

FIGURE 48. Existing (1980) and future (2000) estimates of nutrient loads and present value costs for different management strategies in the York River drainage basin under average rainfall conditions.

Recommendations—York River

To maintain current conditions, future total basin loads must not exceed 221,000 pounds of total phosphorus and 2,329,000 pounds of total nitrogen (existing 1980 load). To improve conditions, future total basin loads must be reduced below these levels. Based on the desired goal of maintaining existing conditions and protecting the valuable marine resources of the York River, the following recommendations are proposed.

1. Federal, state, and county agencies should encourage the implementation of needed best management practices in critical subbasins.
2. The State of Virginia should require nutrient and BOD_5 control for industrial dischargers in the York, where appropriate.
3. Complete upgrading of all primary treatment plants to secondary treatment plants. All new or modified treatment plants should consider providing nutrient

removal. This would ensure that population growth does not increase existing (1980) loads.

— Cost Estimate —

Present-value cost — 53.3 million dollars
Capital cost — 15.9 million dollars
Annual O & M cost — 3.6 million dollars

(Provides for nitrogen and phosphorus control at York POTW and upgrades from primary to secondary treatment. Does not maintain existing secondary treatment.)

4. Local planning agencies should work with the counties to encourage implementation of urban runoff stormwater management programs in the lower York River basin.

THE JAMES RIVER BASIN

Draining roughly one quarter of Virginia's total area, the James River basin is the largest in the state and the third largest in the Bay catchment area. The James River winds 434 miles (694 km) through the basin from its headwaters along the Virginia-West Virginia state line across the Appalachian Ridge and Valley, Blue Ridge, Piedmont, and Coastal Plain Provinces to its mouth at Hampton Roads. The James basin has the greatest percentage of forested land (72.6 percent) and the smallest percentage of cropland (10.5 percent). The James is different than other basins in that it contains several areas where population and industrial activity are concentrated below the fall line (Richmond, Hopewell, and Williamsburg) and it is the only basin that has major nutrient and toxic dischargers located in its lower estuary (Greater Hampton Roads area). Furthermore, the lower James River estuary is located near the mouth of the Chesapeake Bay where strong tidal flushing from the Atlantic Ocean takes place.

JAMES BASIN FACT SHEET

AREA: 10,195 square miles; 6,524,900 acres

POPULATION (1000's):	1950	1980	2000
	1206.2	2001.0	2287.6

LAND USE (1980):	Percent of Total
Cropland (total)	10.5
Conventional tillage	1.3
Conservation tillage	9.2
Pasture	13.7
Forest	72.6
Urban and other uses	3.2

TOXIC SUBSTANCES:	total metal load (lbs/day)
Industrial dischargers (28)	152.2
Municipal dischargers (31)	398.6

In addition to these discharges below the fall line, fall line metal loads of 2,955 lbs/day indicate significant additions from point sources above the fall line.

NUTRIENTS: Total Load (lbs, March-October)

	Phosphorus 3,791,000		Nitrogen 20,505,000	
Source	Above Fall line	Below Fall line	Above Fall line	Below Fall line
Industrial*	1	12	1	16
Municipal*	6	62	2	43
Cropland	9	3	18	11
Other nonpoint sources	4	4	4	5
Total	20	80	25	75

*Number of dischargers - Industrial 22, Municipal 31

Resources and Water Quality

The James River shows environmental degradation and the consequent loss of biological resources. Historically, the James supported runs of shad, alewife, blueback herring, white and yellow perch, and stiped bass. There is relatively little information available on the recent spawning success of these species. However, landings of all freshwater spawners declined in the early 1970's before the Kepone-induced ban on fishing was in place (1975). The James has had no SAV in the upper and middle portions of the river as far back as the earliest surveys; this has been related to the turbidity of the river. The few vegetation beds in the lower estuary were lost in the mid-1970's.

The James River once supported the major oyster-seed area for the entire Chesapeake Bay; however, in 1959 to 1960, a large drop in spat set occurred, particularly on the upstream bars. Although still relatively productive, these bars no longer produce the millions of bushels of spat annually as in the past. Adult oysters are subject to MSX in this river, and harvests have dropped significantly since 1960. There has been a reduction in crab harvests as well; these have been affected by the Kepone ban. Only scattered populations of soft and hard clams occur in this river. Major waterfowl users of the James are Canada geese (mostly on refuges), Bay ducks (lower river), puddle ducks (upper river), and sea ducks (lower river). Diving ducks feed primarily on benthic organisms in the James River.

Most of the James' total toxic and nutrient load is generated below the fall line by industrial and municipal point sources. Research by Bieri et al. (1983a) indicates that toxic organic compounds in Bay waters are most often associated with point and nonpoint sources located in industrial areas; the highest concentrations of organic substances in bed sediment were found in the Elizabeth River. Concentrations of polynuclear aromatic hydrocarbons ranged from 1 to over 100 ppm in Elizabeth River sediments. The degree of metal contamination in the sediment is very high in the Elizabeth and upper James Rivers. Because of the high levels of Kepone, much of the James River was closed to fishing in 1975. The Contamination Index, a useful indicator of potential problem areas in the Bay, identified the industrialized section of the James, such as in the Norfolk and Hampton Road areas as the most contaminated sections of the Bay.

High levels of both phosphorus and nitrogen are found in the upper- and mid-reaches of the river (Flemer et al. 1983). However, trend analysis indicates that both phosphorus and nitrogen concentrations are declining throughout most of the estuary. Municipal point sources below the fall line account for 62 percent of the phosphorus and 43 percent of the nitrogen load in the James River. Some POTWs provide only primary treatment (Appendix B). Industrial discharges are significant sources of toxic substances and nutrients.

Existing Policies and Planning

208 Planning—As part of the 208 Planning process, a water quality model was developed for the study of environmental questions in the James River basin. The model includes the portion of the river from Richmond to Old Point Comfort, and the Appomattox, Chickahominy, Nansemond, and Elizabeth Rivers. Studies which have been conducted in the James include channel modifications, point sources, and thermal plumes. The original study for which the model was constructed was the proposed dredging of the navigation channel from the James River Bridge to the Richmond Deepwater Terminal.

Modeling results indicate that elevated coliform levels at the mouth of the Elizabeth River or immediately adjacent to Craney Island are due to conditions in the Elizabeth River and not due to runoff or discharges to the James (Hampton Roads Water Quality Agency 1978). Chlorophyll *a* projections are around 10 ug L^{-1}, levels that should not result in environmental stress. Nutrient levels are projected to remain reasonably high. Although no readily observable impacts are noted, nutrient enrichment should be watched closely. Stormwater runoff increases BOD levels; as a result, dissolved oxygen concentrations drop below 5 mg L^{-1} for a small number of stations. However, the minimum level predicted for dissolved oxygen is 4.87 mg L^{-1}. This concentration does not represent a severe impact or a critical problem.

Richmond-Crater Interim Water Quality Management Plan—In 1980, the Virginia State Water Control Board was designated by the Governor to complete the area-wide 208 management plan which would control the Richmond-Crater study area's point and nonpoint sources of water pollution and residual wastes to maintain existing water quality standards in the upper James River (The Richmond Regional and Crater Planning District 1982). Adopted by the board in

February 1983, the plan calls for Richmond-area localities to spend nearly 400 million dollars to upgrade sewage treatment facilities and to build a new 30 MGD secondary treatment plant in Henrico County. Under the plan, the City of Richmond and the County of Chesterfield are required to have additional outfalls located downstream to prevent unacceptable stress on the dissolved oxygen demand in the upper portions of the estuary. This would be accomplished by constructing a common pipeline to transport treated effluent from the Richmond, Proctor's Creek, and Falling Creek sewage treatment plants to a regional outfall upstream of Hopewell. The plan provides for continuing monitoring of the river's quality by a regional advisory committee and establishes waste-land allocations for industrial and municipal dischargers to the river. It also calls for a voluntary control to limit pollution of the James by runnoff from agricultural lands and city streets. Despite the improvements in wastewater treatment called for by the plan, higher levels of treatment may be required to maintain existing water quality in the Hopewell and Prince Georges areas of the James River.

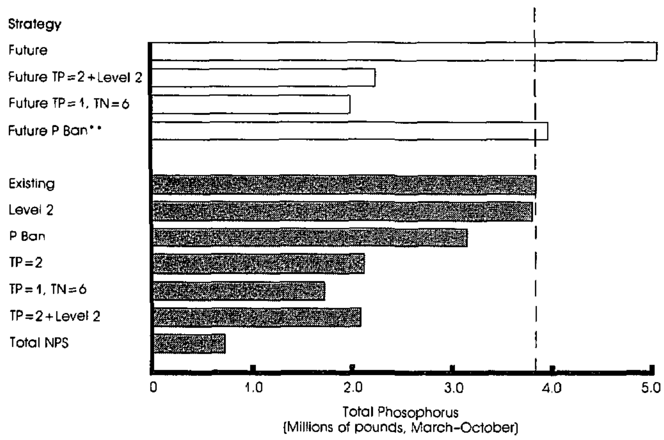
Combined Sewer Overflow Monitoring Sampling Program — Approximately 50 percent of the area of the City of Richmond (11,803 acres) is served by combined sewers which transport both urban stormwater runoff and municipal wastewater (Proceedings 1977). Increased wet-weather flows due to rainfall during storm events causes these sewers to overflow and to discharge treated and untreated municipal and industrial waste, surface water, street wash, and other wash waters directly to the upper James River. A detention basin is under construction and currently projected to go into operation in early 1984 to control combined sewer overflows in the largest of the 46 combined sewer basins in the Richmond area, the 7,300 acre Shockoe basin. The objectives of the Combined Sewer Overflow Monitoring Sampling Program (CSO) are to determine water quality improvements that result from the installation of the Shockoe detention basin, the relative impact of the remaining CSOs in the Richmond area, and the extent of upgrading necessary for the Richmond sewage treatment plant. However, the Shockoe detention basin was originally scheduled to be in operation as early as January 1983, and the postponement may place the operations phase of the detention basin beyond existing monitoring fiscal resources and prevent realization of these objectives.

Pretreatment — Approved by the EPA in 1982, the Hampton Roads Sanitation District (HRSD) has developed a pretreatment program for the nine POTWs within its jurisdiction, each of which receives significant volumes of industrial wastewater for treatment. The objective of the program is to remove, prior to treatment, those industrial wastes which might create problems in sewers (fire, corrosion, explosion) inhibit municipal sewage treatment processes; or pass untreated into waterways or sludge, rendering it unfit for beneficial use or disposal.

Nansemond-Chuckatuck Rural Clean Water Program — This Federal nonpoint source control program provides 1.8 million dollars for the implementation of BMPs to control runoff of fecal coliforms, nutrients, and sediments from agricultural land. The BMPs investigated included animal-waste controls, conservation tillage, vegetative buffers, and diversions.

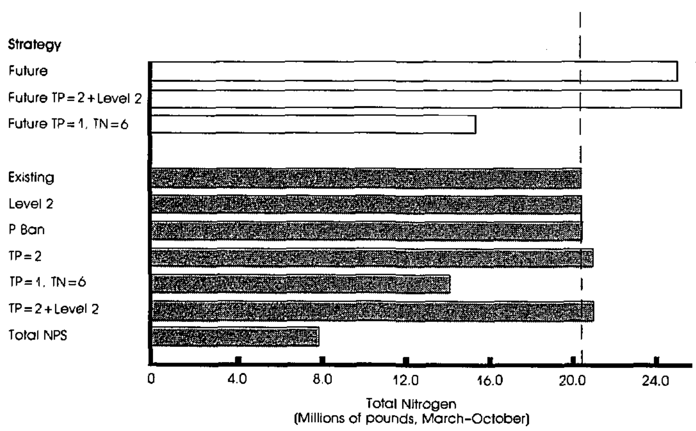
Comparison of Strategies

Figure 49 illustrates the effectiveness of management strategies in reducing existing and future nutrient loads within the James River drainage area. The phosphorus ban reduces the existing (1980) phosphorus load 18 percent. The TP = 2 and TP = 1, TN = 6 strategies reduce the existing (1980) phosphorus load 44 and 55 percent, respectively. The present-value cost to remove 1 pound of phosphorus with the phosphorus ban is 2.82 dollars. The present-value costs to remove 1 pound of phosphorus with the 2 or 1 mg L^{-1} effluent limitation are 4.13 dollars and 3.88 dollars, respectively. This indicates that although a smaller reduction in the total phosphorus load is achievable on a cost per pound removed basis, phosphorus can be removed more economically with a phosphorus ban than with an effluent limitation at POTWs. The Level 2 nonpoint option, conservation-tillage, is not very effective in the point-source-dominated James, reducing the phosphorus load 1 percent and the nitrogen load even less. The TP = 1, TN = 6 strategy reduces the



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: cost to remove 1 pound (dollars)
Future	+32	–	–
Future TP=2+Level 2	-41	290.3	3.34
Future TP=1, TN=6	-49	339.2	3.68
Future P Ban**	+4	62.9	2.00
Existing	–	–	–
Level 2	-1	1.0	1.06
P Ban	-18	56.9/23.8*	2.82
TP=2	-44	207.1	4.13
TP=1, TN=6	-55	242.2	3.88
TP=2+Level 2	-45	208.2	4.09
Total NPS	-81	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.
**Extrapolated from effectiveness on existing (1980) loads.



Strategy	Percent change (relative to existing)	Present Value: Total value (millions of 1982 dollars)	Present Value: Cost to remove 1 pound of Nutrient (dollars)
Future	+22	–	–
Future TP=2+Level 2	+23	309.0	N increases
Future TP=1, TN=6	-24	847.7	2.97
Existing	–	–	–
Level 2	0	1.0	1.13
P Ban	+0.1	56.9/23.8*	N increases
TP=2	+2	207.1	N increases
TP=1, TN=6	-30	589.7	3.22
TP=2+Level 2	+2	208.2	N increases
Total NPS	-62	?	?

*O&M savings realized by POTWs if required to meet a phosphorous effluent limitation.

FIGURE 49. Existing (1980) and future (2000) estimates of nutrient loads and present value costs for different management strategies in the James River drainage basin under average rainfall conditions.

nitrogen load 30 percent with a present-value cost of 589.7 million dollars. The water quality benefits to be realized from nitrogen removal should be fully investigated before initiating a nitrogen removal strategy in the James River.

Future (2000) phosphorus loads are projected to increase 32 percent and future (2000) nitrogen loads are projected to increase 22 percent over existing (1980) loads. Implementation of the Future TP = 1, TN = 6 strategy reduces projected phosphorus loads to a level 49 percent below existing loads and nitrogen loads to a level 24 percent below existing levels. The Future TP = 2 combined with the Level 2 strategy reduces projected phosphorus loads to a level 41 percent below existing loads. Either effluent strategy can be modified and applied to selected POTWs based on size to maintain existing (1980) loadings. The effectiveness of a phosphorus ban in reducing existing (1980) phosphorus loads can be extrapolated on future (2000) loadings. The 32 percent projected increase in projected phosphorus loadings is due to increases in the volume of municipal wastewater treated and discharged. A phosphorus ban reduces the municipal effluent phosphorus concentration 30 percent. A phosphorus ban would reduce the projected increase in phosphorus loadings 0.36 million pounds (future load – existing load × 0.30). Combining the reduction achieved by the phosphorus ban with existing (1980) loadings (3,791,000 × 0.18 = 0.682 millions pounds), and the calculated reduction in the increase in existing (1980) loadings (0.364 million pounds), it is estimated that future phorphorus loadings can be reduced 1.04 million pounds by a phosphorus ban.

The significant number of municipal and industrial dischargers in the James River represents a potential toxic threat to water quality and living resources. The possible causes of toxicity in municipal and industrial effluents as well as the source of the effluents can be determined through the biomonitoring and fingerprinting programs developed by the CBP (described in Appendix D). The NPDES permit can be used to control the discharge of toxic substances from industrial dischargers to surface waters and the pretreatment program developed by the HRSD can be used to control the discharge of toxic substances from industrial dischargers to municipal treatment plants.

Recommendations – James River

To maintain current conditions, future total basin loads must not exceed 3,791,000 pounds total phosphorus and 20,505,000 pounds total nitrogen (existing 1980 load). To improve conditions and prevent deterioration, both nutrient and toxic substance loads must be reduced. Based on the desired goal of improving conditions in the James, the following recommendations are proposed.

1. Complete upgrading of all primary treatment plants to secondary.

   – Cost Estimates –

   Present-value cost – 33.1 million dollars
   Capital cost – 33.1 million dollars

   (Does not include cost of maintaining upgraded secondary treatment plants.)

2. The State of Virginia should establish a pilot biomonitoring and chemical fingerprinting program for identification and control of toxic discharges in the Elizabeth and James Rivers.

   – Cost Estimates –

   Present-value cost – 4.2-8.3 million dollars
   Annual O & M cost – 0.4-0.8 million dollars

   (Monitoring program costs only. Does not include cost to set up lab or to provide removal of toxic substances.)

3. The State of Virginia, through the NPDES program, should continue to evaluate the impact of sewer overflows on water quality in the greater Hampton Roads and Richmond areas.

   – Costs Estimates –

   Annual Costs – 0.15 million dollars

   (Monitoring cost only. Does not include cost to control combined sewer overflows.)

4. The State of Virginia and the political jurisdictions in the upper James River basin should consider, as one of several control alternatives, a policy to limit the content of phosphorus in detergents in light of immediate significant reductions achievable in phosphorus loads. Evaluation of the policy should be completed by July 1, 1984 and, if deemed appropriate, implemented by July 1, 1986.

   – Cost Estimates (to consumers) –

   Present-value cost – 56.9 million dollars
   Annual O & M cost – 5.48 million dollars

   – Cost Savings Estimates (to POTWs) –

   Present-value cost – 23.8 million dollars
   Annual O & M cost – 2.29 million dollars

5. Federal, state, and local agencies should utilize results from the Nansemond-Chuckatuck Rural Clean Water Program to implement needed BMPs in other agricultural subbasins.

6. The State of Virginia should evaluate the effectiveness of nutrient removal at POTWs in improving water quality in the tidal-fresh upper James estuary.

SUMMARY

Table 36 summarizes the present-value implementation and effectiveness of management strategies in reducing existing (1980) nutrient loads from the major drainage basins discharging to the Chesapeake Bay. The largest reduction in phosphorus and nitrogen loads is achieved with the TP = 1, TN = 6 strategy. On a present-value dollar per pound removal cost basis, the Level 2 strategy is the most cost effective of those tested. Basin-wide, this nonpoint-source strategy removes one pound of phosphorus at an average present-value cost of 0.43 dollars as compared to 5.61 and 5.83 dollars, respectively, with the TP = 1 and TP = 2 municipal point source controls. As discussed earlier, reductions in freshwater phosphorus loads may lead to increases in nitrogen loads. This phenomena is exemplified in the Susquehanna and Potomac basins. The Level 2 nonpoint source strategy is the only strategy that provided consistent reductions in both phosphorus and nitrogen loads. This indicates the need for nonpoint source controls to effectively reduce nitrogen and phosphorus loadings.

Table 37 summarizes the present-value implementation cost and effectiveness of management strategies in reducing future (2000) nutrient loads from the major drainage basins discharging to the Chesapeake Bay. Not all strategies tested against existing (1980) conditions were tested against future (2000) conditions. In basins where strategies were effective in reducing existing loads but not applied to future (2000) loads, their effectiveness was extrapolated and included in the discussion of that basin. The table indicates that future (2000) loadings can be reduced to levels below existing (1980) loadings, although with great cost. Data calculated from Table 36 for the present-value cost per pound of nutrient removed strongly indicate that nonpoint source control is a cost-effective way to reduce both phosphorus and nitrogen loadings and should be included in any nutrient reduction strategy.

TABLE 36.
SUMMARY OF PERCENT REDUCTIONS AND IMPLEMENTATION COSTS FOR MANAGEMENT STRATEGIES UNDER EXISTING (1980) CONDITIONS

Basin	Existing Nutrient Loads (March-October)		Phosphorus Ban: Present Value (Millions, 1982 dollars)		Phosphorus Ban: Percent Change		TP=2: Present Value (millions, 1982 dollars)	TP=2: Percent Change	
	TP	TN	Consumer Costs	POTW O & M savings	TP	TN		TP	TN
Susquehanna	2,900,000	58,200,000	105.4	33.2	-4	+4	188.7	14	+19
W. Chesapeake	2,391,000	15,984,000	53.0	19.7	-19	0	152.9	-43	0
Eastern Shore	833,000	8,741,000	11.8	0.17	-9	0	15.6	-14	0
Patuxent	478,000	2,493,000	19.3	4.05	-10	0	38.7	-55	0
Potomac	2,866,000	35,077,000	103.3	49.9	-5	+1	66.5	-12	+3
Rappahannock	278,000	3,995,000	4.2	0.7	-4	0	not tested	—	—
York	221,000	2,329,000	5.2	0	-6	0	not tested	—	—
James	3,741,000	20,505,000	56.9	23.8	-18	0	207.6	-44	+2
Total	13,758,000	146,225,000	359.1	131.5	-11	TN incr.	669.5	-28	TN incr.

Basin	TP=1, TN=6: Present Value, (millions, 1982 dollars)		TP=1, TN=6: Percent Change		Level=2: Present Value (millions, 1982 dollars)	Level=2: Percent Change		TP=2+Level 2: Present Value (millions, 1982 dollars)	TP=2+Level 2: Percent Change	
	TP=1	TN=6	TP	TN		TP	TN		TP	TN
Susquehanna	201.4	779.1	-17	+12	4.65	-16	-1	191.8	-29	+18
W. Chesapeake	177.8	524.4	-51	-49	0.38	-2	-2	153.3	-45	-2
Eastern Shore	17.9	36.9	-15	-7	1.44	-14	-7	17.0	-25	-7
Patuxent	41.9	93.8	-64	-30	0.07	-1	-1	38.5	-55	-1
Potomac	115.2	1,272.4	-22	-21	2.13	-4	-1	68.5	-17	+2
Rappahannock	8.2	16.3	-17	-6	0.35	-5	-2	not tested	—	—
York	0	0	0	0	0.51	-8	-3	not tested	—	—
James	242.2	589.7	-55	-30	1.0	-1	0	208.0	-45	0
Total	804.6	2,533.5*	-35	-26*	10.53	-6	-1.3	678.6	-33	TN incr.

*Does not include Susquehanna where TN load increases.

TABLE 37. SUMMARY OF PERCENT REDUCTIONS AND IMPLEMENTATION COSTS FOR MANAGEMENT STRATEGIES UNDER FUTURE (2000) CONDITIONS

Basin	Future Nutrient Loads (March-October) TP	TN	Percent Change* TP	TN	TP=1, TN=6: Present Value (millions, 1982 dollars) TP=1	TN=6	TP=1, TN=6: Percent Change* TP	TN	Future TP=2+Level 2: Present Value (millions, 1982 dollars)	Future TP=2+Level 2: Percent Change* TP	TN
Susquehanna	3,820,000	55,900,000	+ 32	− 4	286.9	1194.8	−13	+18	273.3	−23	+22
W. Chesapeake	3,524,000	19,767,000	+ 46	+23	254.1	718.9	−42	−14	247.4	−28	+22
Eastern Shore	1,016,000	9,281,000	+ 22	+ 6	31.4	66.6	− 4	− 5	29.9	−13	− 6
Patuxent	851,000	3,332,000	+ 77	+34	73.2	176.6	−54	−19	67.0	−37	+36
Potomac	4,717,000	36,864,000	+ 65	+ 5	140.3	1581.0	−14	−18	130.2	− 3	+15
Rappahannock	282,000	2,809,000	+ 1	− 5	11.7	24.3	−13	− 5	11.2	−12	+ 4
York	492,000	2,935,000	+122	+26	17.5	44.0	+18	+ 8	16.0	+25	+24
James	5,007,000	25,102,000	+ 32	+22	339.2	847.7	−49	−24	290.3	−41	0
Total	19,709,000	155,990,000	+ 43	+ 7	1154.3	3459.1**	−29	−10**	1065.3	−24	TN incr.

*(relative to existing)

**Does not include Susquehanna where TN load increases.

CHAPTER 6
BAY MANAGEMENT

Harry W. Wells, Jr.
Caren E. Glotfelty

INTRODUCTION

Previous chapters have discussed the nature and extent of water quality problems in Chesapeake Bay, and have suggested a range of actions to solve these problems. It is clear that more effort is necessary at all levels of government to control the sources of nutrients and toxic materials reaching the Bay and its tributaries. Responsibility for implementing Chesapeake Bay Program recommendations does not rest solely with the EPA, the states, individual local governments, or private individuals. Everyone must play a role in improving the water quality and resources of Chesapeake Bay. This chapter will help policy makers consider alternate options for Bay management including the use of existing institutions or the creation of new mechanisms. It will help Federal, state, and local officials review the options, consider the recommendations, and select the mechanism or sequence of events which can most effectively manage the Bay's water quality and productivity. A more comprehensive discussion of existing institutions is included in Appendix G.

Part of the directive to the EPA from Congress when it initiated the Chesapeake Bay Program was to "determine what units of government have management responsibility for the environmental quality of Chesapeake Bay and define how such management responsibility can best be structured so that communication and coordination can be improved not only between the respective units of government but also between those units and research and educational institutions, and concerned groups and individuals on Chesapeake Bay."

The CBP has determined that effective management of Chesapeake Bay requires a management structure which is responsive to the diverse commercial and recreational needs of the Chesapeake Bay basin. If this management structure is to maintain or improve the quality of Chesapeake Bay, it must act on CBP findings at all levels. It must also improve coordination among the various agencies taking actions to solve Bay water quality problems.

The process of review to determine or confirm the optimal structure is too important to be left to chance. This chapter describes and evaluates managment structures and recommends an approach for Bay management.

HISTORY AND BACKGROUND

A report prepared by John Capper et al. (1981) under contract to the EPA's Chesapeake Bay Program traced the early attempts to manage the Bay. The following brief review will help the reader understand the most recent approaches to Bay-wide management.

In 1965, the Congress authorized the Corps of Engineers "to make a complete investigation and study of water utilization and control of the Chesapeake Bay basin . . . including . . . navigation, fisheries, flood control, control of noxious waste, water pollution, water quality control, beach erosion and recreation." To aid in the Chesapeake Bay study, the Corps was authorized to build a hydraulic model of the Bay. The resulting study has covered a span of approximately 18 years, and led to the publication of the multi-volume Existing Conditions Report and

Future Conditions Report (U.S. Army Corps of Engineers 1973).

In 1978, the General Assemblies of Maryland and Virginia passed resolutions creating the Chesapeake Bay Legislative Advisory Commission to evaluate existing and potential management institutions for Chesapeake Bay. The Commission reviewed seven general types of alternative management institutions which could be adapted for use in improving and coordinating Bay management activities in the two states. The following alternatives were considered: (1) reliance upon existing government agencies with no new entity being created; (2) a bi-state commission without Federal participation; (3) a Federal-interstate commission; (4) a commission created under Title II of the Water Resources Planning Act of 1965; (5) a commission or agency created pursuant to Section 309 of the Coastal Zone Management Act of 1972; (6) an interstate planning agency created under Section 208 of the Federal Water Pollution Control Act Amendments; and (7) a Federal regional management authority.

The Chesapeake Bay Legislative Advisory Commission concluded that a greater level of cooperation was needed between state policymakers; the primary responsibility for governing Chesapeake Bay should remain with the states and their political sub-divisions; and management difficulties arising from intra and interstate jurisdictional boundaries should be resolved through the efforts of the states. Accordingly, in 1980, the Maryland and Virginia General Assemblies created the Chesapeake Bay Commission, which consists primarily of legislative members from both states, with one executive agency and one citizen member from each state.

In 1979, the Governors of Virginia and Maryland formalized an agreement to coordinate research, planning, and management activities affecting the Bay through the formation of a Bi-State Working Committee of executive agency representatives from both states.

In 1980, Congress enacted the Chesapeake Bay Research Coordination Act, creating a Chesapeake Bay Research Board, comprised of state and Federal members, to coordinate research efforts in the Chesapeake Bay region. Although never funded, a Research Board has been established in the National Oceanographic and Atmospheric Administration (NOAA) in the U.S. Department of Commerce.

There are two other regional institutions operating in the Chesapeake Bay region. These are the Susquehanna River Basin Commission and the Interstate Commission on the Potomac River Basin. The Susquehanna River Basin Commission is a Federal-interstate compact commission, created in 1970, to coordinate Federal, state, local, and non-governmental plans for water and related land resources through centralized and comprehensive planning, programming, and management. The Interstate Commission on the Potomac River Basin is also a Federal-interstate compact commission which was organized in 1940 to promote interstate cooperation in the prevention of stream pollution through water quality and land-planning measures.

BASIS FOR EVALUATION

The Capper Report shows that there are many institutions involved in Chesapeake Bay evaluation and management. However, many critical questions remain—is a new institution needed and, if so, are any of the five existing institutions noted suitable for carrying out the activities and responsibilities, and what other alternatives exist?

The Chesapeake Bay Program commissioned a report from Resources for the Future, Inc. to evaluate institutional arrangements for water resource problems (RFF 1979). The report was designed to examine alternative water management arrangements used by other domestic and international groups to accomplish regional environmental objectives. The report did not recommend a particular institutional arrangement for Chesapeake Bay management. Rather, it primarily discussed organizational behavior as applied to regional environmental management institutions, based on the review of existing institutions.

The RFF report concluded that, in general, regional institutions in the United States have not performed as expected in solving the problems that they were designed to address. This has occurred because new regional institutions tend to be resisted by existing local, state, and Federal entities; thus, the exercise of authority by such new regional institutions tends to be limited, regardless of how strong their actual authority is. The authors of the RFF report identified criteria to be considered in designing a new regional institution. These criteria, which are summarized below, are useful in evaluating the various institution alternatives.

1. The jurisdictional scope of institutions should correspond to the impact boundaries of problems insofar as adequate knowledge about impact boundaries is available. This criterion is based on the conclusions that:
   - Small institutions are more efficient and responsive than large institutions; therefore,
   - Institutions should be no larger than necessary to incorporate all relevant parties affected by a problem.
2. A multiple-institution structure is most desirable for dealing with problems having potentially serious consequences where adequate information about the impact boundaries of those problems is not available. This criterion is based on the conclusions that:
   - Where very little is known about the effects of a problem, the most important function an institution can perform is to collect and generate new information about this problem;
   - Unbiased information can best be collected and generated through a multiple-institution structure; and
- The cost of a multiple-institution structure for collecting and generating new information about a problem is justified if the problem has potentially serious consequences. This criterion suggests that complex problems are best handled by a number of institutions rather than a single institution. Further, the potential inefficiencies of a multiple-institution structure are outweighed by the benefits of a number of different perspectives on complex problems.
3. Creating a new institution is feasible only if a favorable incentive structure exists for the participants in that institution. Incentives are most likely to be favorable if the participants:
   - Receive side benefits merely by participating in the new institution;
   - Gain benefits from collective resolution of a problem;
   - Lose only small amounts of autonomy, power, and representation in the new institution; and
   - Spend only a small amount of time and resources to participate in the new institution.

   In other words, the prospective members must believe that the advantages outweigh the disadvantages by participating in the institution.

The criteria suggest that the institution should correspond to the states and municipalities which drain or border the Bay. Because the Bay drainage area encompasses significant portions of five states and the District of Columbia (D.C.), the institution should encompass either all five states and D.C., or at least those states whose land area or volume of effluent can significantly affect the Bay and its tributaries. The last criterion suggests that lacking an incentive, the existing mechanisms should be tried as is until it is demonstrated that those mechanisms cannot achieve the desired objectives.

GENERAL GOALS AND OBJECTIVES

The institution or management mechanism should ideally be able to influence a coordinated approach to managing the Bay's water quality and biological resources. Its goal should be to restore and maintain the Bay's ecological integrity. To accomplish this, the structure should ideally be able to perform or coordinate all of the tasks which relate to the objective. Those tasks include: comprehensive planning, technology transfer, data management and analysis, model refinement and development, conflict resolution, progress reporting, monitoring, research, and public information and education.

ALTERNATIVE MANAGEMENT MECHANISMS

The following evaluation further explores a range of potential actions from relying primarily on existing institutions to creating a comprehensive Bay-wide Authority. It must be stressed that while ten options are explored, this is not a finite list. Any number of variations could be recommended or could evolve.

Three broad classes of action could be taken. The first, that of using existing structures, contains two options; the second, to modify an existing institution, contains six options; the last, to establish a new institution, contains two options. The ten options are as follows:

1. EPA Region III
2. EPA Region III and the CBP Management Committee.
3. Chesapeake Bay Policy Board and Management Committee
4. Bi-State Working Committee
5. Chesapeake Bay Commission
6. Interstate Commission on Potomac River Basin
7. Susquehanna River Basin Commission
8. Chesapeake Research Coordination Board
9. Basin Commission
10. Comprehensive Bay-Wide Authority

Maximum Utilization of Current Programs

This option continues existing institutional mechanisms and current programs with no new management entity. Each Federal and state agency would be responsible for incorporating recommendations of the Chesapeake Bay Program into their existing regulatory structure. For example, states would be responsible for revising their water quality standards and funding priority lists to satisfy nutrient loading recommendations of the Chesapeake Bay Program. The EPA would retain its responsibility to implement the Chesapeake Bay Program recommendations within the provisions of the Clean Water Act, and local governments would focus on POTW compliance, urban runoff, and other local issues.

Many observers feel that sufficient laws and programs exist to create significant improvement in the Bay's waters. The problem could be one of enforcement of existing laws and possible inadequate use of authority already vested in certain institutions. Under existing authority the EPA could negotiate "tough" state and EPA agreements to:

- Channel 201 money to protect the Bay;
- Expedite permit efforts to protect the Bay;
- Target monitoring to protect the Bay in a coordinated way;
- Bring all three states to equal performance;
- Guide state programs aimed at reducing runoff from agricultural lands, construction sites, and urban stormwater;
- Force states to act, not study;
- Establish a 404 wetlands protection policy for the Bay; and
- Establish oil and hazardous chemical spill prevention plans for all sites in the Bay drainage area.

The states have the authority to:

- Require gas chromatograph/mass spectophotometer (GC/MS) analysis of all POTW and major industry sources;
- Require bio-monitoring of the same;
- Expedite pretreatment program compliance by POTWs;
- Enforce permits against POTWs and industry;
- Push for coastal zone plans to protect the Bay; and
- Apply vigorous controls under 208 on nonpoint sources.

Local and county governments could:

- Improve performance at POTWs;
- Apply tough pretreatment programs;
- Sample effluents with GC/MS to monitor other than sanitary flows;
- Apply user-charges and other financial methods to ensure that funds are adequate for operation, maintenance, and replacement costs; and
- Promote agricultural urban nonpoint source programs.

The major Federal responsibility is the enforcement of abatement programs under the Clean Water Act (CWA). While nonpoint source programs are generally considered to be in the primary domain of state and local governments, the EPA does have review and approval authority for state water quality standards, total maximum daily loads, continuing planning processes, and water quality management plans. Given the CBP findings, the EPA could use these authorities to influence state and local nonpoint source approaches and practices. Utilizing the consistency requirements of section 208 (d and e) of the NPDES construction grant water quality management plan, the EPA should attempt to assure nonpoint source implementation where needed to protect water quality in the Bay. These various CWA authorities provide the opportunity to coordinate Federal, state, and local point and nonpoint source decisions and responsibilities to address these issues without minimizing state and local responsibilities and actions.

Some of the CBP recommendations, however, fall outside the EPA's jurisdiction. The EPA has a minimal role in storm-water management (urban runoff) and fisheries management, and has no authority to implement programs in these areas.

1. EPA Region III — The Environmental Protection Agency's Division of Water Quality Standards and Enforcement has the explicit charge under the Clean Water Act to enforce abatement programs in Region III. This region includes all the states which drain into the Bay except New York. The EPA, under the criterion of abatement, has the authority, structure, and staff to address certain aspects of Bay management. Although legal authority exists, formalized enforcement activities can be tedious and time consuming due to inherent checks and balances in the legal process. It should also be noted that some states tend to be cautious in dealing with any Federal regulatory agency that has potential oversight of state resources.

2. EPA Region III and the CBP Management Committee — All comments regarding the appropriateness of option number 1 apply. It should be noted that it is not necessary to have a formalized Management Committee that reports to the EPA, as the EPA already has the authority to convene meetings with state representatives. Under this option, the present CBP Management Committee could continue to function after September 30, 1983. The Committee has been effective in providing program guidance to the EPA on an informal consensus building level. The result has been an effective approach to managing a complex Congressionally-mandated Federal and state program. The Management Committee could oversee the implementation of a Chesapeake Bay Data Management Center and encourage the initiation of monitoring activities recommended by the EPA's CBP.

The Management Committee could be modified to include representatives of state and Federal agencies responsible for managing resources. The voluntary consensus building characteristic of the Committee would remain unchanged, and staff support would be provided by the states and the EPA.

Modification of an Existing Institution

This second category assigns the primary responsibility to an institution which already exists, and modifies that institution to carry out the necessary role. This approach does not suggest that the existing state and Federal management agencies would cease to carry out their present planning and regulatory functions, nor that other existing interstate institutions would cease to function in a coordinating role. It does suggest that the institution being modified could acquire the following purpose, structure, function, and funding arrangements:

- It could include policy-level coordination of water quality and resource management programs at the state and Federal level to achieve long-term goals for enhancing the environmental quality of the Bay.
- It could be structured to include participation by important Federal agencies (EPA, NOAA, USDA, and others), the States of Maryland, Virginia, Pennsylvania, the District of Columbia, and local governments.
- It must be capable of performing or managing technical analyses, oversight of monitoring programs, maintenance and use of computer models, public outreach programs, and interaction with the scientific community. This presupposes that staff support and funding would be available which would be devoted wholly or largely to the tasks.

One advantage of modifying an existing institution is that minor changes could be made with relative ease, and the institution could begin operating immediately in its new or expanded role. If staff are already available, one may only need to shift emphasis of activities and avoid lengthy start-up delays. On the other hand, if modification requires a fundamental change in the institution's purpose or structure, the situation would be similar to creating a new institution.

In establishing a new institution or mechanism, greater use of both citizen and technical advisory committees should be considered. Committees or subcommittees could be established in areas of public participation, monitoring, and research.

3. Chesapeake Bay Policy Board and Management Committee—A Chesapeake Bay Policy Board could be composed of representatives of the Federal Government, states, or municipalities whose jurisdictions are within the Bay and contain either significant land area or facilities which affect water quality resources. The Board membership would be limited to appointed policy level officials who report directly to a Federal Administrator, Governor, or Mayor. Board members would be individuals who have the authority to directly implement programs and policies agreed upon at Board meetings. The Board could meet bi-annually and be administratively coordinated by the EPA Region III Administrator. Other representatives from Federal agencies, non-member states, or River Basin Authorities could, depending on the agenda, attend Policy Board meetings at the invitation of the Region III Administrator. The Policy Board would be supported a Management Committee and a staff.

The relative functions and structure of a Policy Board and the Management Committee could be as follows:

Membership:
Four representatives, appointed by the Governors of Maryland, Virginia, Pennsylvania, and the Mayor of Washington, D.C.

Chairman:
Regional Administrator, EPA Region III

Meeting Frequency:
No less than semi-annually

Functions:
- Maintain a strong role for the Federal government and the affected states;
- Set policy and make resource-allocation decisions at the highest levels of government;
- Mobilize and build upon existing laws and institutions;
- Involve all appropriate institutions in specific activities in the most effective manner possible;
- Accomodate the diverse needs of the Federal, state and local governments; and
- Provide a continuing forum for discussion and resolution of issues and disputes over policy affecting the ecological health of the Bay.

The Policy Board could be responsible for coordinating the work of appropriate Federal and state agencies to carry out certain planning and implementation components of a Bay-wide effort to ensure adequate control of all sources of pollutants. Therefore, the EPA Regional Administrator could initiate cooperative activities with the National Oceanographic and Atmospheric Administration, the Corps of Engineers, the Department of Agriculture, and other Federal jurisdictions affecting the quality of Chesapeake Bay. Likewise, senior regional, state, and District of Columbia officials could coordinate and organize efforts of their respective counterparts.

A management committee supporting the policy board could have the following structure:

Membership:
Two representatives each from the states of Pennsylvania, Maryland, and Virginia, for water quality and resources, and one representative from each Federal agency with regulatory responsibilities affecting the water quality and resources of the Bay

Chairman:
Director EPA Region III, Water Division

Meeting Frequency:
Monthly

Functions:
- Implement control strategies based on the findings of the Chesapeake Bay Program;
- Implement comprehensive Bay-wide monitoring programs to evaluate the effectiveness of control efforts;
- Develop comprehensive basin-wide plans to control nutrients and toxic substances;
- Investigate and develop regional approaches to setting water quality standards, making waste load allocations and establishing priorities for funding;
- Identify and review conflicts regarding

regional water quality issues and make recommendations as appropriate; and

- Review ongoing Bay research efforts and recommend additional research needs on specific issues.

4. *Bi-State Working Committee*—The Bi-State Working Committee ensures the day-to-day working level coordination of a multitude of existing state programs. It has not been charged with setting goals for the Bay, other than generally improved management through coordination. To evaluate the EPA's CBP findings and recommendations, the committee would have to more narrowly focus its efforts toward water quality and aquatic resource effects, and set long-term goals for its efforts in this endeavor.

To function as the CBP management mechanism, the Bi-State Committee would have to add, at a minimum, Federal members and Pennsylvania members. Because the Committee has no full-time staff, arrangements would need to be made to assign full-time staff (possibly from EPA and the states) to the management of the computer data base, development of management proposals, and oversight of monitoring efforts.

The Bi-State Committee cannot employ independent staff and has no budget. Staff members would have to be provided by assignment by each member agency. The current Governor's agreement does not commit any member to providing specific resources; this should be spelled out in any modification of the Agreement. Funding and personnel assignments would be subject to regular Federal and state bugetary processes.

Modification of the Bi-State Committee would require action by the Governors of Maryland and Virginia to modify the charge of the committee, and to invite Federal and Pennsylvania membership. The Governor of Pennsylvania and the heads of Federal agencies would have to agree to participate. These executive actions could be accomplished in a matter of months.

5. *Chesapeake Bay Commission*—The purposes of the Chesapeake Bay Commission are consistent with the implementation recommendations of the CBP. The Commission is not limited in focus, however, to water quality and living resource issues. It also deals with commercial shipping, and other economic uses of the Bay.

The Commission, however, was directed not to actually carry out the administrative functions of state government (i.e., planning, regulating, or funding water quality or fisheries programs), but rather to serve as an advisor and catalyst for action by administrative agencies. Thus, carrying out the maintenance and operation of the computer system or data base, and acquiring sufficient staff to do technical planning and analysis, might be outside of its current mandate. Most of the resources of the Commission have been directed toward achieving legislative solutions to mutual problems.

The Commission currently has no Federal membership and does not include Pennsylvania. Including Pennsylvania could be a minor effort but providing for Federal membership would involve a fundamental change in the Commission. Some form of Federal participation short of membership may be preferable.

The Commission has a permanent staff but does not currently have the technical expertise required to maintain and operate the computer and associated data base and models, and to oversee monitoring. An increase in staff by at least four positions would be required. The Commission's 150,000 dollar budget is not sufficient to handle this level of expansion, but there is no limitation on the amount of funding the Commission can request of its member states. The Commission is authorized to accept grants and contracts from Federal, state, or private sources. Thus, while the change in funding level would involve a 3- to 4-fold increase, the administrative structure exists to receive funds and devote them to the appropriate tasks.

Modification of the Commission would involve: ammendment to the enabling legislation by Maryland and Virginia, adoption of the Ammendment by Pennsylvania, and some means of Federal recognition. This change would require at least one full session of each state's General Assembly. The timing of Federal recognition would depend on whether this involved executive action or Congressional action.

6. *Interstate Commission on Potomac River Basin (ICPRB)*—The ICPRB currently deals only with the Potomac River Basin and, thus, a fundamental change would be required to expand it to deal with the Bay as a whole. The ICPRB

already has membership from Maryland, Virginia, West Virginia, Pennsylvania, the District of Columbia (D.C.), and the EPA. A review of Federal membership would be necessary to ensure that necessary agencies were involved. Furthermore, the way in which states are involved revolves around its Potomac focus: West Virginia has not been proposed for inclusion in the CBP implementation mechanism. Thus, to be consistent, New York, Delaware, and D.C. would also have to be included.

In its functioning as a planning analysis and coordinating body, the ICPRB would not require much change. Some expansion of existing staff might be required to provide appropriate data management expertise. The ICPRB has a budget in excess of 500,000 dollars and has appropriate mechanisms to receive funds to accomplish CBP tasks. It would be necessary to supplement the ICPRB budget to ensure sufficient funds to cover an expanded role.

Modification of the ICPRB Compact would involve Congressional action and approval by all state legislatures of changes. This could easily involve several years.

7. *Susquehanna River Basin Commission (SRBC)* – The SRBC is oriented toward improving the Susquehanna River as an entity, rather than as a tributary of the Bay. Its charter and comprehensive plan recognizes the river's influence on the Bay and the need to deal with adverse impacts on the Bay. The SRBC was originally proposed as a regulatory and management institution, as well as a planning and coordinating body.

The SRBC participants include Maryland, Pennsylvania, and New York. Thus, at minimum, the State of Virginia should be added to be consistent. The States of New York, West Virginia, and Delaware might also be added. Federal membership is provided through the Interior Department. Arrangement should be made for EPA and NOAA involvement.

In function, very little change would be needed. The SRBC currently operates in a planning, technical analysis, and coordination mode. Some expansion of staff may be necessary to provide appropriate expertise. A change in issue-focus to more specifically deal with water quality and living resource concerns would be necessary, but this would be consistent with its current mandate. In addition, the SRBC has the authority to act in a regulatory and management capacity if this were necessary to implement CBP findings.

The SRBC currently has a budget in excess of 500,000 dollars and is set up to receive funds from all signatories and dispense funds for appropriate activities. It does not currently devote this level of funding to Chesapeake Bay concerns and, thus, significant reorientation of the current budget or addition of new funds would be necessary.

Modification of the SRBC compact would require Congressional action and action by each state legislature involved. Traditionally, adoption of major modifications of interstate compacts requires several years.

8. *Chesapeake Research Coordination Board (CRCB)* – The CRCB is currently mandated to deal only with the coordination of research. The development of strategies, resource planning, and oversight of monitoring are not part of its role. Thus, major modification would be required.

As currently composed, the Board has appropriate Federal membership and involvement. Maryland and Virginia have members but Pennsylvania does not. The Board was proposed to be staffed by an office within the National Oceanic and Atmospheric Administration (NOAA) with a budget of 300,000 dollars. The National Oceanic and Atmospheric Administration has set up an ad hoc committee, but no office has been set up to date, and no funds have been provided. States do not provide any funds.

Modification of the Board's role and the inclusion of Pennsylvania would require an act of Congress and appointment of members by the Secretary of Commerce and the Governor of Pennsylvania. It would also require authorization of funds through NOAA – something that NOAA and Congress have been reluctant to do. Several years could be required to make legislative changes and at least one year would be needed to set up the office.

Establishment of a New Institution

The third approach to managing the Bay includes two alternative options to create a new institution. Suggestions to create new institutions to deal with insterstate management issues have been discussed extensively and a number of models exist. Strong and pursuasive agreements are heard on both sides of the question.

At a 1977 Bi-State Conference on the Chesapeake Bay, Senator Charles McC. Mathias, Jr., suggested that a single institution was needed to coordinate all of the Federal, state, local, and private agencies with an interest in the Bay. At that time he estimated that there were 10 Federal agencies with some jurisdiction over the Bay, five interstate agencies and commissions, 31 state agencies in Maryland and Virginia dealing with the Bay, seven Maryland and Virginia colleges and universities studying the Bay, and scores of private organizations and citizens groups concerning themselves with some aspect of the Bay. Senator Mathias argued his preference for establishment of a Title II Commission as provided by the Water Resources Planning Act of 1965. His preference for a single comprehensive institution to manage all Chesapeake Bay problems has been shared by a number of observers in the Bay region.

On the other hand, as stated earlier, the RFF report (1979) concluded that, in general, regional institutions in the United States have not met expectations about their performance and ability to solve problems they were designed to address. This has occurred because new regional institutions tend to be resisted by existing local, state, and Federal entities, and thus the exercise of authority by such new regional institutions tends to be limited, no matter how strong their actual authority is.

9. *Basin Commission* — A Basin Commission could be established by one of three mechanisms, Water Resources Planning Act (Title II), Coastal Zone Managment Act (CZMA) (Section 309), or Clean Water Act (CWA) (Section 102c). The Commission would be empowered to:

- Have Chesapeake Bay designated as a priority water body;
- Have a portion of the construction grant program authorized by Section 205 reserved for Chesapeake Bay activities;
- Influence the construction grant priority lists;
- Have nonpoint loadings considered as water quality standards and control measures adopted; and
- Influence the NPDES program.

Such an organization has several advantages. First, it could be established at the request of a majority of the affected states. Its jurisdiction, however, would be basin-wide. Second, being clearly an interstate entity, it would have visibility and a role in regional regulations. As such, it could serve as an advisor to the EPA during agency reviews of individual state water quality standards, construction grant priority lists, waste-load allocations, procedures for administration of the NPDES program, and priorities for use of Federal environmental grants. Advantages of a Basin Commission include:

- Required state and Federal participation;
- Required petition from a majority, but not all, of the Governors in the drainage basin;
- Has interstate authority;
- Has authority to recommend treatment needs and how they should be financed; and
- Could recommend necessary research.

10. *Comprehensive Bay-Wide Authority* — This option for the Chesapeake Bay would create an Authority which could be charged with the responsibility of protecting and managing the Chesapeake Bay estuarine system and its resources. The Authority could have all the necessary powers and resources to manage and coordinate all aspects of the Bay as a national resource.

A Chesapeake Bay Management Authority could be created to manage the Chesapeake Bay estuarine system as a single national resource. The functions of the Authority could be those necessary to ensure the protection and beneficial use of the Bay's waters and resources. The Authority's primary means for carrying out its responsibilities would be Federal water quality and resource laws and programs. The secondary means would be the coordination of other efforts with relevant state laws and programs. The Authority would be a creation of Congress and would include voting representatives of Federal and state governments as well as representatives of private sector and public interest groups.

Because the Authority would have a wide range of responsibilities, it would require the creation of a substantial new "agency" with specialized staff devoted to various aspects of its responsibilities. Effective coordination of Federal and state programs, in particular, would require a large technical and legal staff. The Authority could be directed by a board of voting representatives, and the chairmanship of that board would be determined by its members on an annual basis. The Authority could require an Executive Director and an administrative staff to manage the activities of the staff specialists as well as other ordinary administrative tasks.

Creating a special Authority for the management of Chesapeake Bay would require Federal legislation unless the Authority were to be based upon a Federal and interstate compact of some type. If such a law could be passed, the creation of an effectively operating organization could be accomplished within two to three years. Funding for the Authority could be primarily Federal with in-kind contributions from the states. A procedure could be devised to draw a major percentage of funding for the Authority directly from the budgets of appropriate Federal agencies.

SUMMARY AND RECOMMENDATIONS

The current state of the Bay and the forecast for the future requires that immediate steps be taken to halt the deterioration of the Bay. As outlined in the previous chapters, many Federal, state, and local entities must be involved in the Bay clean-up. Also, the costs of such a clean-up are significant. As discussed in Chapter 5, the cost of implementing the specific basin recommendations is approximately one billion present-value dollars. The longer-term costs of implementing the general monitoring and programmatic recommendations outlined in Chapters 2 through 4, will probably range between 1 to 3 billion dollars over the next 20 years. These costs are in addition to our current expenditures. It is probable that they will double or triple if there are significant delays due to lack of coordination.

The need for immediate action and the costs involved make it essential that an existing mechanism with basin-wide Federal-state representation be responsible for coordinating the Bay clean-up. The Chesapeake Bay Program believes that option #2, EPA Region III and the Management Committee can best serve this immediate coordination function. Specifically:

> *It is recommended that the Management Committee be the coordinating mechanism to ensure that actions are taken to reduce the flow of pollutants into the Bay and to restore and maintain the Bay's ecological integrity. The Committee should periodically brief the EPA Regional Administrator and state secretaries or their equivalent. In addition, the committee should submit a written annual report to the EPA Administrator and Governors outlining new initiatives, implementation plans, and changes in the environmental quality of the Bay.*

The Management Committee's specific responsibilities should include:

- Coordinating the implementation of the Chesapeake Bay Program recommendations;
- Developing a comprehensive basin-wide planning process in conjunction with ongoing planning efforts;
- Investigating new regional approaches to water quality management including creative financing mechanisms;
- Resolving regional conflicts regarding water quality issues; and
- Reviewing ongoing Bay research efforts and recommending additional research needs.

It is anticipated that these responsibilities may be modified and/or expanded as a result of deliberations of the Chesapeake Bay Conference to be held December 1983.

The Management Committee will be supported by a staff office comprised of Federal and state personnel. The Chesapeake Bay Office will maintain the computer data base, coordinate the Bay-wide monitoring program, refine the CBP water quality models, coordinate public education activities, and provide ongoing analyses in support of implementation efforts. The Office will be located at the EPA's Central Regional Laboratory in Annapolis, Maryland.

To assure public participation and effective coordination between Federal, state, and local entities, the Management Committee should establish subcommittees, as appropriate, to provide insights and recommendations from a broad range of technical areas as well as public and private interest groups. Subcommittees could be established to address the following issues: nonpoint source controls, point source controls, model development, monitoring, and research needs. It is anticipated that these subcommittees could provide the "network" that is critical to the successful implementation of control programs. In the final analysis, the people of Chesapeake Bay will be responsible for its protection.

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NOTES

1. The nutrient loads in this chapter are reported as total phosphorus and total nitrogen. They are not divided into more specific forms, such as orthophosphate, organic phosphorus, nitrate, nitrite, ammonia, and etc. Some sources may contribute greater amounts of nutrient forms which are more readily available to Bay organisms as compared to other sources. For example, sewage treatment plants discharge primarily orthophosphate and ammonia which are both readily available to phytoplankton, while agricultural runoff contributes phosphorus, generally in forms attached to soil particles, and nitrate which is less preferred by phytoplankton than ammonia. The CBP, however, has developed estimates of total nitrogen and phosphorus loads because, over the long term, all nutrient forms are transformed and recycled in the Bay, thereby becoming biologically available at some point in time.
2. Personal Communication: "Compliance with Permit Limitations," C. Charles, MD OEP, 1983.
3. Personal Communication: "Compliance with Permit Limitations," C. Charles, MD OEP, 1983.
4. Personal Communication: "Agricultural Runoff in Terms of Dollars Lost," D.E. Baker, Professor of Soil Chemistry, Pennsylvania State University 1983.
5. The "States" refers to the District of Columbia, Maryland, Pennsylvania, and Virginia.
6. Personal Communication: "Biofouling of Condensors at Steam Electric Plants," R. Roig, MD DNR, 1983.
7. Personal communication: "Current Studies on Acid Precipitation," R. Roig, Maryland Department of Natural Resources, 1983.
8. Personal Communication: "Conventional Street Sweeping," S. Martin, Baltimore Regional Planning Council, 1983.
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