

Implementation Committee

A Commitment Renewed
Restoration Progress and the
Course Ahead Under the
1987 Bay Agreement



**Chesapeake
Bay
Program**



February 1988

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The Chesapeake Bay Program: A Commitment Renewed

**Restoration Progress and the Course
Ahead Under the 1987 Agreement**

**A Report of the
Chesapeake Implementation Committee**

February 1988

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Preface

Restoration of the Chesapeake Bay's water quality and living resources will require many years of sustained effort by governments and citizens alike. The cumulative effects of decades of environmental decline and surging population growth combine to challenge the will, imagination and resources of both government agencies and private organizations.

People of the Chesapeake Basin want to know how much more must be done, where, at what cost, for how long and with what anticipated results in the Bay. To help answer these questions, the Chesapeake Executive Council in 1986 adopted a new program evaluation and development process -- the Phase II process. Since the Phase II process will evolve over the next five years or more, the Council asked for this interim report to give Bay managers, decision makers, legislators and interested members of the Bay community information they can use now to further advance state and federal cleanup activities. Those activities are described in the 1985 Chesapeake Bay Restoration and Protection Plan ¹. The annual reports under the 1983 Chesapeake Bay Agreement document the progress of these programs ^{2, 3}.

Members of the Executive Council recognized that specific goals and milestones are necessary to retain public support. In January 1987, Virginia Governor Gerald Baliles, Chairman of the Council, proposed that the adequacy of the 1983 Agreement ⁴ be examined and that a new Agreement be developed if necessary. In May of last year a drafting committee of Council members was formed and charged with the tasks of expanding the original Agreement to address key issues and proposing specific goals and milestones necessary to provide public accountability and retain citizen support. In August, a Draft Agreement ⁵ was released and a public review process launched. That process, along with information developed for this report, helped the drafting committee to revise and complete the new Bay Agreement ⁶, which was signed December 15, 1987.

This report summarizes current knowledge about the problems of the Bay, identifies emerging issues, and

presents new information about the effectiveness of cleanup programs. It documents the findings and works performed since 1983, and explains how they led to a new, expanded Agreement. Chapter 1 outlines restoration and protection efforts, which focus on reducing the flow of nutrients and toxic substances to the Bay, and relates them to Chesapeake Bay Program goals. It also summarizes key commitments and objectives of the 1987 Chesapeake Bay Agreement. Habitat and living resources goals for the Bay and its tributaries are detailed in Chapter 2.

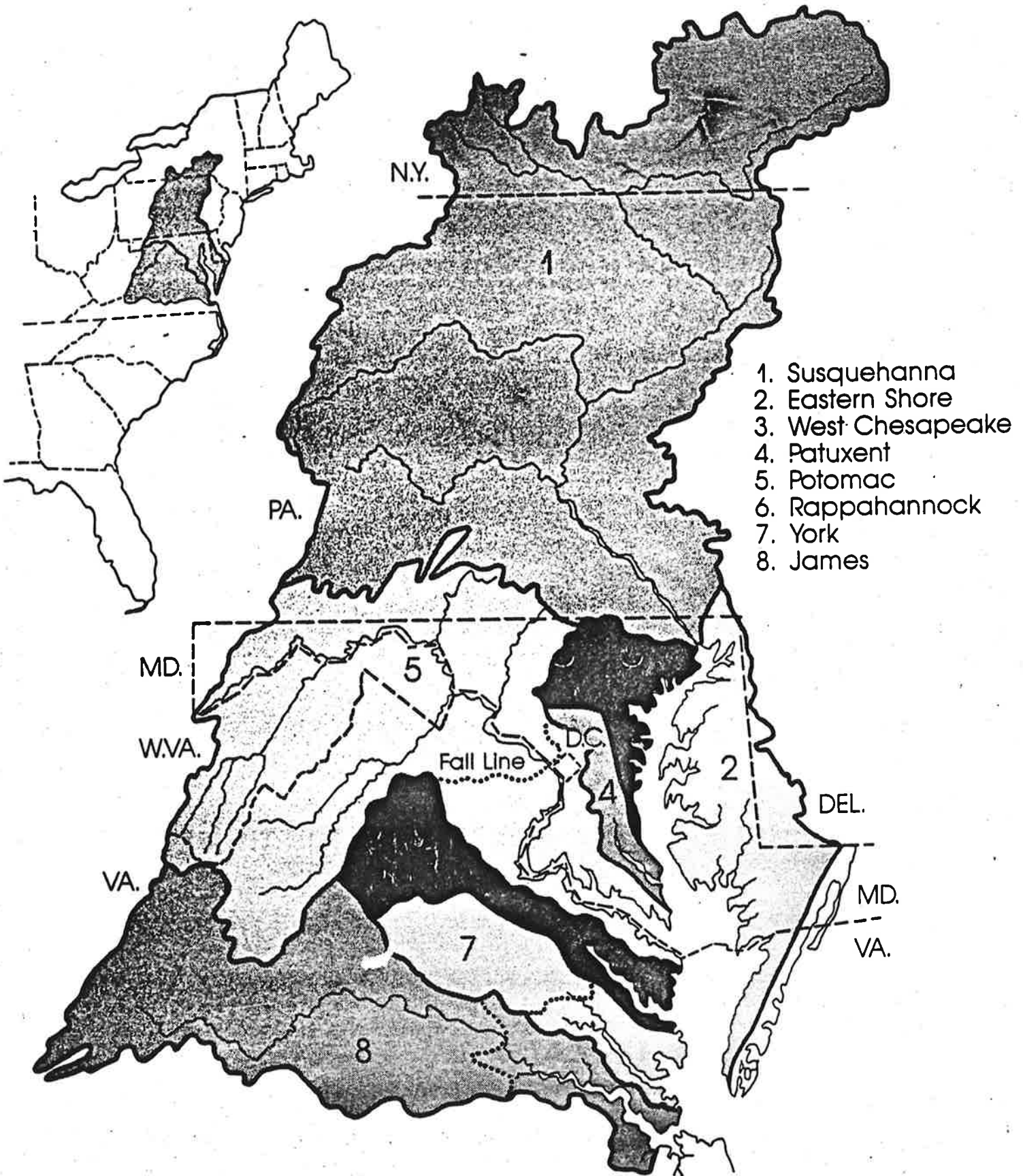
Alternative nutrient control strategies and their potential to achieve water quality conditions necessary to restore and protect living resources are presented and discussed in Chapter 3. Evaluations of strategies are based on projections made from computerized models and the best judgment of Bay region scientists and managers. Problems of toxic contamination and current efforts to reduce the levels of toxicants in the Bay system are outlined in Chapter 4. Possible long-term strategies to control and manage toxic pollutants also are described.

The information provided in chapters 2, 3 and 4 forms a foundation for meeting living resource commitments and formulating the nutrient reduction and toxic substance control strategies required under the 1987 Agreement.

In the course of preparing the interim report, writers and reviewers have focused on new areas where more knowledge is needed for major program decisions yet to come. These research needs, identified in Chapter 5, will be useful in developing the comprehensive research plan called for in the 1987 Agreement.

State and federal agencies are committed to consider the information presented in this report, to decide how they can most effectively and efficiently apply this information to their programs, and to use it to help meet the commitments in the 1987 Chesapeake Bay Agreement. Any resulting changes in programs will be reflected in future Chesapeake Bay Restoration and Protection Plan supplements.

Chesapeake Bay Drainage Basin



Chapter 1

The Chesapeake Challenge

Though signs of the Bay's decline were evident long before the 1970s and some studies had been conducted, there had been no comprehensive attempts to gather and evaluate data for the watershed as a whole, to determine the cause and effect relationships underlying the Bay's problems, and to recommend remedies. The major environmental problems of the Chesapeake Bay and its tributaries were investigated in a comprehensive study initiated by the Environmental Protection Agency (EPA) in 1975 at the direction of Congress.

Final research findings and recommended remedial strategies were published in September 1983⁷. The study identified ten areas of environmental concern in the Bay (see box). The EPA Chesapeake Bay Program (CBP) then selected three specific problems for concentrated examination: nutrient enrichment, toxic substances, and declines in submerged aquatic vegetation (SAV).

Researchers concluded that excessive nitrogen and phosphorus in the Bay were causing the overgrowth of ecologically undesirable species of phytoplankton (microscopic floating plants). Effects of this overgrowth included increases in the extent and duration of low dissolved oxygen in the deep waters of the Bay, chiefly as a result of plankton decay processes. Adequate levels of dissolved oxygen are essential to animals and plants of the Bay.

Toxic substances are a prime concern because of their potential chronic and lethal effects on the Bay's living resources. They can accumulate in the tissues of fish and shellfish or attach to sediment, eventually recycling through the water, plants and animals in the ecosystem. Contamination in the Bay is most severe near heavily industrialized areas along the Elizabeth and Patapsco rivers. In these waters and sediments both heavy metal and toxic organic compound concentrations are found at elevated levels. Toxic contaminants are found in lower concentrations in other portions of the Bay.

The sharp decline of SAV throughout the Bay (especially in its upper reaches) created concern over the loss of habitat and indicated that the Bay was in trouble. More than any other single group of organisms, SAV can provide a biological index of the "health" of the Bay's shallow waters. SAV functions as a critical link among the different levels of the Bay food web and the physical environment. It provides both food and habitat for species occupying the higher levels of the Bay's food web. SAV abundance is limited by turbidity and the amount of phytoplankton in the water. The distribution of various SAV species is dependent mostly on salinity and bottom sediment types.

The Bay study concluded that nutrient enrichment was

Other Areas of Environmental Concern 1977

The seven other areas of environmental concern identified during the Bay Study have been investigated as they relate to the three priority issues, and specifically addressed by:

- Wetlands alteration
- Shoreline erosion
- Hydrologic modification
- Fisheries modification
- Shellfish bed closures
- Dredging and dredged material disposal
- Effects of boating/shipping on water quality

the primary factor in the decline of SAV beds. Nutrients, by fueling the growth of excess phytoplankton, cause a decrease in water clarity and an increase in the number of organisms that grow on the leaves of the SAV. Both of these responses, in turn, cause a decrease in available light for the SAV. Suspended sediments also block light, contributing to the decline.

In addition to the three primary problems, a characterization of the Bay⁸ through time revealed discouraging trends in other aspects of the Bay's ecosystem. Long-term decreases in the harvests of several species of finfish and shellfish were indicative of poor water quality, loss of habitat, and over-harvesting of these species.

The CBP recommended various actions to restore and protect the Chesapeake Bay. Measures to limit the amounts of nutrients and toxics reaching the Bay were emphasized. CBP also proposed a coordinated Baywide water quality monitoring system to develop baseline data and record subsequent environmental changes. These data provide the means to measure the success of remedial actions and help to discriminate between natural variability and man-induced change.

Population Growth

The EPA Bay Study recognized that land use and population growth are major factors shaping environmental conditions in the Chesapeake Bay watershed. Ultimately, the number of people living in the Bay basin determines how much water, energy and land are used,

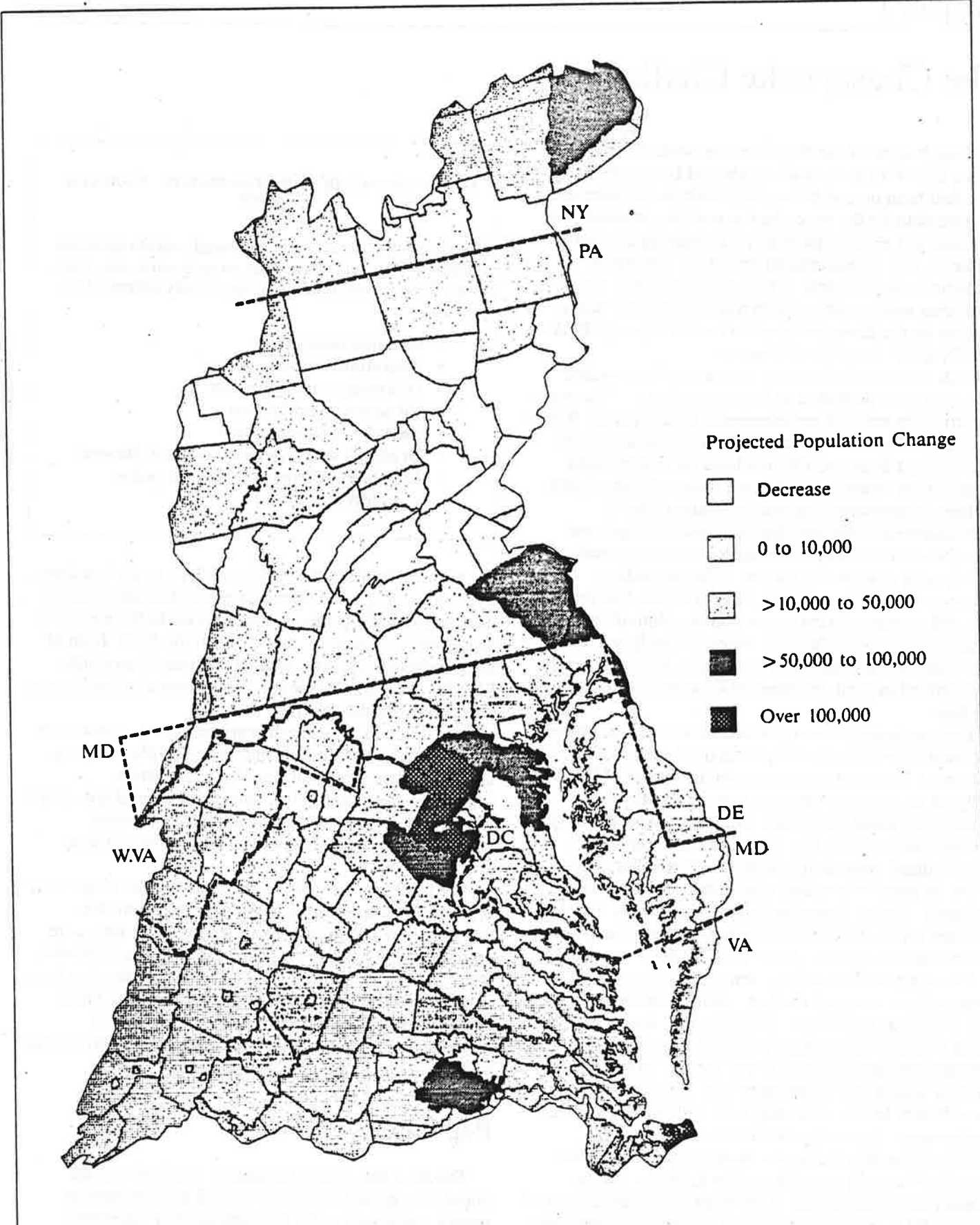


Figure 1-1. Projected Population Change in the Chesapeake Bay Watershed (1985-2000)

Table 1-1
Projected Population Growth in the Chesapeake Bay Watershed

	1985	2000	% CHANGE
BELOW FALL LINE			
Population:	8,416,476	9,495,1011	12.8
Acres:	8,960,000	8,960,000	
Density*:	0.94	1.1	
ABOVE FALL LINE			
Population:	7,460,32	8,101,382	8.6
Acres:	27,600,000	27,600,000	
Density*:	0.27	0.29	
TOTAL			
Population:	15,876,798	17,596,483	10.8

*Density =
persons/acre

as well as how much and what types of wastes are generated. The wastes then adversely affect long-term biological and economic productivity in the watershed. Population size dictates the demands placed on the Chesapeake Bay ecosystem, and those demands are growing.

In the Bay watershed, population increased 50 percent overall from 1950 to 1980⁸. The environmental impact was clearly defined in some areas. For example, in the Patuxent River basin, the population increase was greater than 200 percent. The increased municipal sewage discharges and land use changes that accompanied the population growth resulted in low dissolved oxygen levels and high chlorophyll concentrations in the Patuxent. These water quality problems, in turn, were likely the major causes of reduced numbers of finfish and shellfish, loss of species diversity, large reductions of SAV acreage, and low oyster spat set.

The states of the Chesapeake watershed anticipate continued growth in the years ahead. Based on their estimates, population will increase about 11 percent basinwide between 1985 and the year 2000. Figure 1-1 illustrates this projection. It shows high or medium projected increases in counties nearest the Bay, and low increases or actual declines in population in counties above the fall line (zone where a river changes from free-flowing to tidally-influenced). Historically, the area below the fall line has been more attractive to settlement. It now supports a population density three and one-half times greater than that above the fall line (Table 1-1). This concentration of human activities and land use changes below the fall line raises the potential for adverse effects on the Bay.

Population growth brings parallel increases in industry, commercial development, transportation and housing. These increases create conflicts over land use as development competes for farm acreage and wildlife habitat. Changes in land use lead to increased loadings of nutrients and toxic substances, and can modify or even

destroy critical living resources habitats (e.g. wetlands). Growth brings construction which disrupts the soil and alters natural runoff and streamflow patterns, and can change water temperature and the salinity regime. As a result, greater volumes of sediment frequently reach Bay tributaries, causing decreased penetration of sunlight vital to vegetation. Sediment also clogs larval fish gills and smothers nonmobile organisms such as clams and oysters. Along with sediments come increasing loads of nutrients, particularly phosphorus.

An increasing population generates additional waste which must be collected, treated, discharged and assimilated. For every 1,000 additional residents, for example, a community must handle roughly 1.5 million more pounds of solid waste a year — not counting any industrial waste generation that might be related to population growth⁹. Each person also means another 75 to 100 gallons of municipal wastewater a day, or 27 to 36 million more gallons per year for every 1,000 additional persons¹⁰.

These additional wastes stress existing solid and hazardous waste and municipal wastewater facilities, as well as the assimilative capacity of air, land and water. Treatment and disposal facilities will need to be upgraded, expanded or constructed just to maintain present water quality conditions. These changes, in themselves, increase demand for land and resources. To restore conditions more favorable to the living resources of the Bay, the means must be found to reduce inputs of nutrients and toxic substances, despite the demands of population growth.

The 1987 Chesapeake Bay Agreement recognizes the need to mitigate the potential adverse effects of continued growth and development. It calls for "development policies and guidelines" to be adopted by January 1989; assistance to local governments in evaluating land use and development decisions; incentives, technical assistance and guidance to encourage wetlands protection; and

steps to ensure that state and federal development projects serve as models for the private sector. Finally, it calls for commissioning a panel of experts to report by December 1988 on anticipated growth and land development patterns to the year 2020 and to outline what will be needed to manage the projected growth.

The 1983 Bay Agreement

Until the 1987 Agreement was signed, the Chesapeake Bay Agreement of December 1983 was the cornerstone of the restoration and protection program. The 1983 Agreement set in motion a coordinated campaign to reverse the decline of living resources in the Bay. It also established the major elements of a cooperative structure to develop and coordinate the comprehensive Bay cleanup: the Chesapeake Executive Council, its Implementation Committee, and EPA's Chesapeake Bay Liaison Office.

Maryland, Virginia, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission and EPA were the original partners in the Chesapeake Bay Agreement. Six other federal agencies formally joined in the Bay cleanup in 1984: Soil Conservation Service (SCS), Fish and Wildlife Service (FWS), National Oceanic and Atmospheric Administration (NOAA), Geological Survey (USGS), U.S. Army Corps of Engineers (CoE) and the Department of Defense (DoD) ¹¹.

Organization

Commitment to restoring the Bay has enabled states whose institutions and political traditions differ and federal agencies with diverse missions to work together to solve common problems while retaining the independence of their programs. The Chesapeake Executive Council provides the leadership and focus that shapes their work (Figure 1-2).

The Council membership includes representatives from each of the four jurisdictions and from the EPA. Chairmanship of the Council rotates among the three State Governors, the Mayor of the District of Columbia, and the representative of the EPA. Operating by consensus, the Council's primary functions are planning and coordination to ensure efficient implementation of programs and projects to restore the Bay.

The Implementation Committee, the Council's operating arm, has 26 members: delegates from the jurisdictions, and representatives of the seven federal agencies and three interstate commissions (Chesapeake Bay Commission, Interstate Commission on the Potomac River Basin, and Susquehanna River Basin Commission). Subcommittees for Planning, Nonpoint Sources, Data Management, Modeling and Research, Monitoring, and Living Resources coordinate work in those categories across agency and state lines. A Scientific and Technical Advisory Committee (STAC),

The Chesapeake Bay Agreement of 1983

We recognize that the findings of the Chesapeake Bay Program have shown an historical decline in the living resources of the Chesapeake Bay and that a cooperative approach is needed among the Environmental Protection Agency (EPA), the State of Maryland, the Commonwealths of Pennsylvania and Virginia, and the District of Columbia (the States) to fully address the extent, complexity, and sources of pollutants entering the Bay. We further recognize that EPA and the States share the responsibility for management decisions and resources regarding the high priority issues of the Chesapeake Bay. Accordingly, the States and EPA agree to the following actions:

1. A Chesapeake Executive Council will be established which will meet at least twice yearly to assess and oversee the implementation of coordinated plans to improve and protect the water quality and living resources of the Chesapeake Bay estuarine system. The Council will consist of the appropriate Cabinet designees of the Governors and the Mayor of the District of Columbia and the Regional Administrator of EPA. The Council will be initially chaired by EPA and will report annually to the signatories of this Agreement.
2. The Chesapeake Executive Council will establish an implementation committee of agency representatives who will meet as needed to coordinate technical matters and to coordinate the development and evaluation of management plans. The Council may appoint such ex-officio nonvoting members as deemed appropriate.
3. A liaison office for Chesapeake Bay activities will be established at EPA's Central Regional Laboratory in Annapolis, Maryland, to advise and support the Council and committee.

whose membership includes directors of major Bay area research institutions, also assists the Implementation Committee. The Chesapeake Research Consortium*, an organization of Bay research institutions, provides support for STAC through an EPA grant.

The Council has a Citizens Advisory Committee (CAC) to provide a public perspective on policy issues. CAC has 25 members: four appointed by the chief executive in each state, and nine at-large members nominated by the Citizens Program for the Chesapeake Bay, Inc.,

* The Consortium's administration center rotates among member institutions, and currently is located at the Virginia Institute of Marine Science.

Chesapeake Bay Program Committee Structure

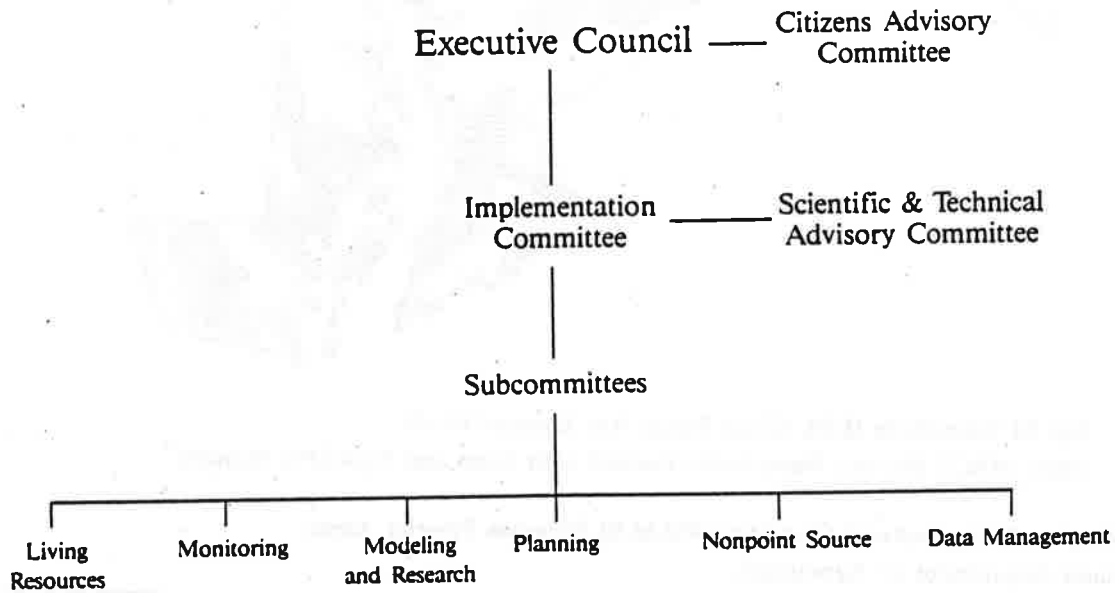


Figure 1-2. Chesapeake Bay Program Committee Structure

which also staffs the CAC under an EPA grant.

EPA's Chesapeake Bay Liaison Office provides administrative, technical and public information support to the Council and its auxiliary groups. Staff members administer grants and contracts, perform special projects and provide technical advice and support.

State Programs

Participants in the Bay cleanup recognize that the economic future of the region is dependent on a revitalized Bay. They look forward to a time when Bay waters can again produce rich annual harvests of fish and shellfish. Therefore, even before the Bay Agreement was signed, the four jurisdictions had programs in place and plans underway for additional corrective action. Together, they have spent over \$250 million since 1984 to support Bay initiatives.

State programs are comprehensive. They include varied projects to restore living resources and research to better understand the habitat requirements of desirable plant and animal species, as well as point and nonpoint source pollution control programs and legislative initiatives ^{12, 13, 14, 15}.

Through their leadership and participation in Agreement groups, the states have shared information on technology improvements, experiments and demonstrations, implementation of nonpoint source controls, and innovative citizen involvement and information projects. They have advocated the adoption of both agricultural and urban best management practices (BMPs) which

reduce runoff, erosion and sedimentation, and improve water quality. Each state targets its control efforts to the areas which have the greatest potential for generating water pollutants (see Figures 1-3 through 1-6)

Federal Programs

Each of the seven federal agencies in the Bay Program participates in Executive Council committee work, contributes staff experience and expertise to the Program and the states as needed, and helps to build public awareness of the Bay restoration effort. Some of the agencies have initiated programs specifically for the Chesapeake Bay; all have focused on the Bay in regional implementation of their national programs ³.

The SCS placed a coordinator in the EPA Bay office in November 1984 to ensure that its many field people in the region were closely tied to the Bay Program. Through them, SCS has reached, and helped the states to reach, many farmers with information and technical assistance to implement practices to prevent erosion and improve water quality. USGS provides fall line monitoring on Bay tributaries and works with Pennsylvania and Maryland to perform intensive monitoring of pilot watersheds and plots of land to demonstrate the impact of nonpoint source controls.

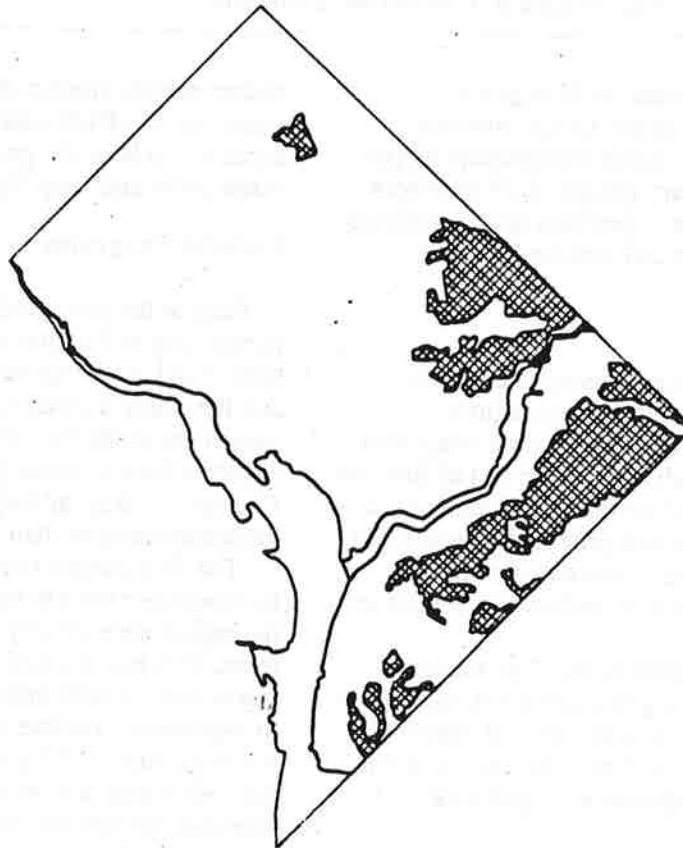
The FWS has been particularly effective in developing and disseminating public information about the Bay's living resources, and continues to give key support to citizen volunteers who annually survey SAV in the Bay and its tributaries. The FWS also conducts limited point



- ▣ Top 24 Watersheds (EPA Grant Funds Are Targeted Here)
- ▨ Other MACS Priority Watersheds (Funded with State and Non-EPA Monies)

Figure 1-3. Maryland's Agricultural Cost-Share (MACS) Program Priority Areas.

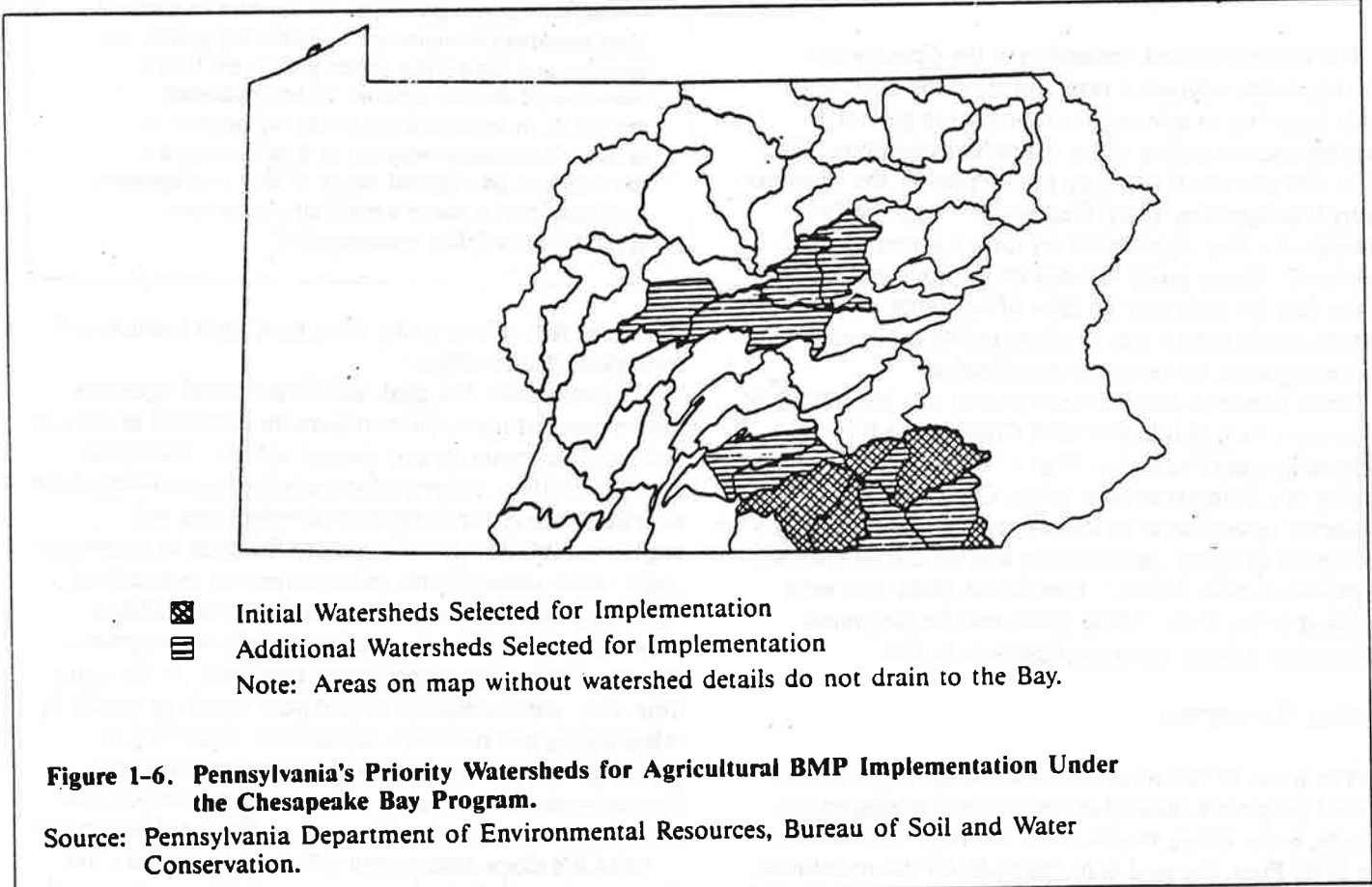
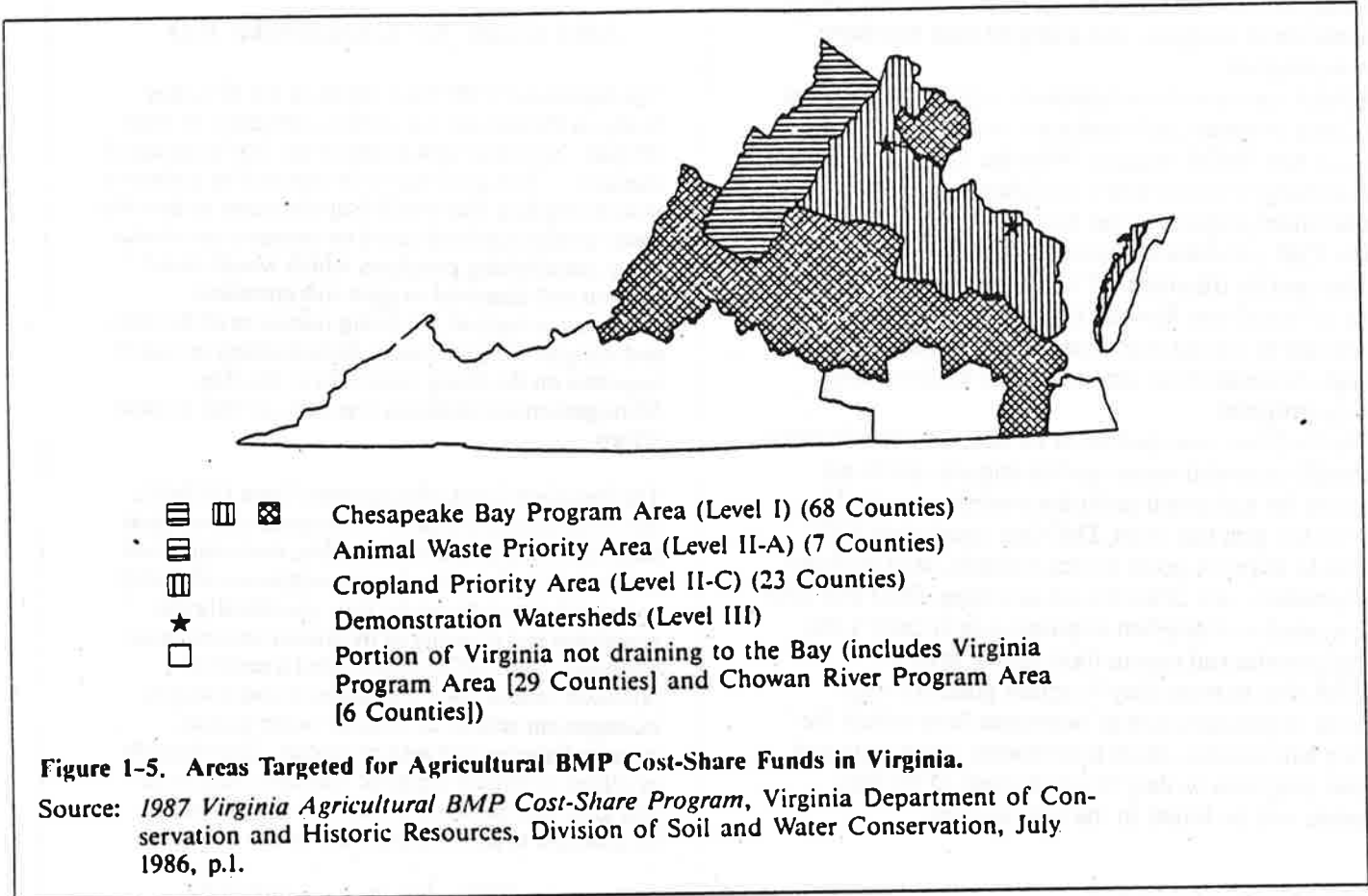
Source: Maryland Department of Agriculture.



- ▣ Christiana-Sunnyside association: urban land and deep, nearly level to steep, well-drained soils that are underlain by unstable clayey sediment; on uplands

Figure 1-4. Highly Erosive Soils of the District of Columbia.

Source: *General Soil Map District of Columbia*, USDA Soil Conservation Service, U.S. DOI, National Park Service, National Capital Press, 1975.



and nonpoint source monitoring, biomonitoring, living resource trend analysis, and a striped bass hatchery release program.

NOAA has contributed research support through its Sea Grant Program and conducted stock assessment work on key finfish species. With the CoE, NOAA is also working with the states on fisheries habitat enhancement projects in the Bay ¹⁶.

The CoE provides expertise for developing models of the Bay and its tributaries. The Corps performed a study of the effect of low flow on living resources, and contributes to habitat and water quality enhancement through demonstration projects under its shoreline erosion program.

The DoD has assessed 66 of its Bay area installations to identify potential water quality impacts and to set priorities for additional pollution control projects ¹⁷.

Over the past ten years, DoD has spent over \$200 million to improve point source controls, land management practices and other related activities. DoD and EPA have agreed to strengthen requirements in DoD's discharge permits and ensure their timely review.

EPA also pursues Bay Program goals through regional implementation of numerous laws which the agency administers. More information about state and federal programs as they relate to goals of the Bay Program will be found in the next section.

Evolution of Goals

The restoration and protection of the Chesapeake Bay has been a dynamic program from the start, with goals evolving as scientists and managers gained a broader understanding of the estuarine ecosystem. The 1983 Chesapeake Bay Study final report ¹⁸, the Resource Users Management Team final report¹⁹ and the 1983 Chesapeake Bay Agreement set forth a series of goals (see box). These goals focused on improving the health of the Bay by reducing the flow of nutrients, sediments and toxic substances into the Bay and its tributaries. All also recognized the need for coordination.

These common threads were woven into the statement of purpose included in the 1985 Chesapeake Bay Restoration and Protection Plan ¹: "to improve the water quality and living resources of the Chesapeake Bay estuarine system so as to restore and maintain the Bay's ecological integrity, productivity and beneficial uses and to protect human health." Five broad goals also were outlined in the Plan. These goals and the programs initiated to achieve them are described below.

Living Resources

The focus of nutrient, toxic substances control and related programs, as well as institutional management efforts, is the living resources of the Bay. As stated in the 1985 Plan, the goal is to "provide for the restoration

1983 Goals for Chesapeake Bay

The September 1983 final report of the EPA Bay Study, *A Framework for Action*, contained an overall goal: "to restore and maintain the Bay's ecological integrity." That goal was to be pursued by gathering monitoring data that would help the states to develop water quality standards based on resource use attainability, establishing programs which would attain nutrient and dissolved oxygen concentrations necessary to support the living resources of the Bay, and mitigate the potential or demonstrated impact of toxicants on the living resources of the Bay. Management coordination was seen as vital to these efforts.

The Resource Users Management Team (RUMT), the Study citizen advisory committee, chose a goal they felt would be comprehensible, measurable and achievable: to "provide for the restoration of finfish and shellfish stocks on the Bay, specifically the abundance and diversity of freshwater and estuarine spawners." RUMT recommended a series of pollution control, land management and resource management actions to enhance water quality, manage fisheries and restore habitat. Coordination of efforts to reduce inputs of nutrients, sediments and toxic contaminants to the Bay system had to be provided to achieve best results.

In December 1983, when they announced the Chesapeake Bay Agreement, the signatories issued a joint statement containing the following goals: "to improve and protect the water quality and living resources of the Bay system; to accommodate growth in an environmentally sound manner; to assure a continuing program of public input and participation on regional issues of Bay management; to support and enhance a regional cooperative approach toward Bay management."

and protection of the living resources, their habitats and ecological relationships."

To accomplish this goal, state and federal agencies have expanded resource management activities as well as point and nonpoint source control efforts. Each year over \$10 million is directed toward fisheries management activities. These funds support development and implementation of specific species fisheries management plans, stock assessments, enforcement of regulations regarding catches, and protection of critical habitats.

Maryland, the District and Virginia have programs to regulate fishing for striped bass (rockfish). At the same time, they are increasing striped bass breeding stocks by releasing tagged hatchery-raised fish. The FWS is assisting with the hatchery and tag-return programs. Pennsylvania is continuing to implement a striped bass stocking program in the Conowingo Pool and Reservoir.

NOAA's stock assessment efforts help monitor the

results. NOAA, FWS and the four jurisdictions are developing Baywide stock assessment plans to monitor important species and to examine historical trends and relationships between fisheries abundance and environmental conditions.

Under the Susquehanna River Anadromous Fish Restoration Committee's program to restore the American shad to the Susquehanna River, over 7200 fish were stocked upstream of the Conowingo Pool in 1987 for spawning in the river. Maryland and Virginia annually plant oyster shell and seed oysters in an attempt to rebuild the oyster fisheries of the Chesapeake.

SAV has been the focus of major cooperative efforts by Virginia, Maryland, the CoE, USGS, FWS, EPA, area universities and citizen organizations for several years. Experiments in replanting Bay grasses in areas where they were known to exist in the past have helped develop an understanding of the water quality conditions they require. Mapping their distribution from periodic photographic surveys (see SAV in section following) helps indicate improvements in water quality. Species information is obtained mainly from state supported ground surveys supplemented by a citizens' "ground-truthing" program which has been operating since 1985.

Recent FWS mapping of wetlands, another category of critical habitat, produced a mixed picture²⁰. In some areas, programs to protect, maintain, and even create wetlands are working well. In the case of tidal wetlands, the depletion rate has decreased greatly since 1970, thanks to state legislation. However, nontidal wetlands are still being lost to development at an alarming rate, and protective legislation is needed. The 1987 Agreement commits participating governments "by December 1988, to develop, and begin to implement a Baywide policy for the protection of tidal and nontidal wetlands" and to encourage local governments to incorporate protection of wetlands in land use and other growth-related decisions.

The states are working with local land owners and developers to explain the value of retaining all wetlands. They are also helping land owners to reduce shoreline erosion and to find ways to maintain low density land uses near the shore. In Maryland, the Critical Areas statute²¹ requires counties and major municipalities to submit plans for development in a 1,000 foot zone surrounding the Bay and along its tributaries using state guidelines for density. In "Resource Conservation Areas," only low density development is allowed.

In 1987, the Living Resources Task Force of the Implementation Committee began to define the optimal water quality conditions and ranges necessary to support and maintain key living resources, their habitats, and support organisms. Chapter 2 describes the processes used and the progress made in developing living resources objectives. The newly formed Living Resources Subcommittee has a major role in meeting several of the key commitments in the 1987 Bay Agreement: the development and adoption of guidelines to protect water quality and habitat conditions necessary

for the Bay's living resources by January 1988; implementation of a Baywide plan to assess commercially, recreationally and selected ecologically valuable species and adoption of a schedule for developing management strategies by July 1988; and a start on implementing Baywide management plans for oysters, American shad, and blue crabs by July 1989.

Nutrients

State and federal participants in the Bay Agreement have expanded and begun programs to meet the nutrients goal of the 1985 Plan: "to reduce point and nonpoint nutrient loadings to attain nutrient and dissolved oxygen concentrations necessary to support the living resources of the Bay."

Sewage treatment plant construction and upgrading continue to be a priority throughout the region. More than \$200 million has been spent on treatment plants in the Chesapeake drainage basin since 1984. The successful operation of the Blue Plains Wastewater Treatment Facility in the District produced nearly immediate improvements in living resources⁹.

Proper operation and maintenance of plants also is reducing amounts of inadequately treated wastewater being discharged. Projects to demonstrate the cost effectiveness of dual nutrient biological treatment of sewage are under way. These projects on the Patuxent River in Maryland and on the York River and at Kilmarnock in Virginia also will influence development of a Baywide nutrient policy as well as state standards for phosphorus and nitrogen.

In Virginia, the legislature has ordered development of nutrient standards for the waters of the state²². Implementation of these standards is to begin by July 1, 1988. Maryland's General Assembly in May 1986 required that by July 1, 1988, the State's Executive Council members modify the Chesapeake Bay Restoration Plan as it pertains to Maryland to include specific goals and strategies to address nutrients, including suggested target loads for each tributary, and point and nonpoint control strategies capable of achieving those loads²³.

Pennsylvania has had phosphorus control standards for point source dischargers within the Lower Susquehanna River basin since 1970. These regulations were revised and strengthened in 1985 and are being implemented.

DoD has conducted a demonstration operator maintenance training and assistance program at two of its Bay area wastewater plants, and the Army has implemented a similar program at most of its plants. Performance improvement is measurable.

The states also have been working to reduce the flow of nutrients from nonpoint sources such as faulty septic systems, urban and farmland runoff, and leaching.

Voluntary cost share projects helping farmers to prevent erosion and manage animal waste are supported

by the states, EPA, SCS and local conservation districts. The Cooperative Extension Service and the Agricultural Stabilization and Conservation Service (ASCS) also have programs which deliver financial, technical and information services to farmers. With their Mobile Nutrient Laboratory (PA) and Rainfall Simulators (VA/MD), the states have demonstrated to the agricultural community crop nutrient requirements and methods to reduce losses of chemicals and nutrients through specific farming practices. Results of nonpoint efforts are monitored by the states, USGS and, in selected areas, the FWS. Maryland's demonstration farm has monitoring equipment which is assessing BMP effectiveness.

As a demonstration of nonstructural techniques to reduce shoreline erosion, the states and the CoE are planting vegetation to stabilize river and shoreline banks, curbing another nonpoint source of sediments carrying nutrients to waterways. In urban and suburban areas stormwater management has taken on increased importance. States and counties are emphasizing enforcement of erosion and sedimentation regulations. In Maryland, Virginia and the District of Columbia, for example, regulations require developers to maintain runoff at no more than pre-construction rates.

Phosphate detergent bans are now in place in Maryland, the District of Columbia and Virginia. Pennsylvania members of the Chesapeake Bay Commission are having a study conducted to determine the potential effects on Bay water quality of a phosphate ban in that state.

As the states and federal agencies continued to implement their point and nonpoint source control programs, the Bay Program completed the Steady-State Model of the Bay. This water quality model uses mathematical equations to simulate the Bay's response to nutrient loadings. The model helped solve an important piece of the nutrients puzzle. Scientists knew that nutrients from the land, air and decayed organic matter (algae) are stored in and released from bottom sediments. The model demonstrated that sediments in the Chesapeake Bay hold a tremendous reserve of nutrients, and that "fluxes" of nutrients can be released to the overlying water column in much greater quantities than previously thought.

Reductions in the supply of algae-fueling phosphorus and nitrogen to the Bay are vital to stop their continued build up in bottom sediments and subsequent recycling. A slowdown in algae production and recycling is critical because of the high oxygen demand during algae decay. Low oxygen availability severely limits biological processes, especially those of bottom-dwelling species (see Chapter 3).

Toxic Substances

Elevated levels of toxic compounds, like excess nutrients, adversely affect finfish, shellfish and Bay grasses. Both individual organisms and the diversity of the ecosystem are threatened by toxic pollutants. The

higher the concentrations of heavy metals and organic chemicals in an area, the less likely that desirable species will be found in numbers capable of maintaining populations. The toxics goal stated in the 1985 Plan is to "reduce or control point and nonpoint sources of toxic materials to attain or maintain levels of toxicants not harmful to humans or living resources of the Bay."

Since the major sources of toxic contaminants are industries and sewage treatment plants, provisions and enforcement of wastewater discharge permits under the National Pollutant Discharge Elimination System (NPDES) are of priority concern to the states and the EPA. Because chlorine can be toxic to finfish and shellfish, states have reduced use and discharge of the chemical at wastewater treatment plants, especially during critical life stages of marine life. Alternative chemicals (ozone) and techniques (ultraviolet, dechlorination prior to discharge) are used to remove chlorine from the discharge and still assure that public health is protected.

Pretreatment requirements are beginning to reduce amounts of metals and chemicals in wastewater these industries send to sewage treatment plants. In Pennsylvania, 35 plants in the Susquehanna River Basin required to have pretreatment now have EPA-approved programs in place. State regulations were approved in final form in December 1987. Pennsylvania anticipates applying for EPA delegation of the pretreatment program authority in 1988. Virginia also expects to get delegation authority in 1988; Maryland was given delegation previously. The District's pretreatment program has been developed, and permits for industrial dischargers are being prepared.

Stormwater management and other nonpoint source controls in urban areas also reduce the flow of toxic contaminants reaching surface waters of the Bay area. Similarly, agricultural nonpoint source controls to reduce runoff, nutrient loadings and sedimentation also decrease the flow of soil-associated pesticides and other chemical organics to waterways.

Sediments in harbors, embayments and the Bay are a sink which can accumulate toxic substances, just as they do nutrients. Continued sediment monitoring in such areas can indicate whether control programs are successful in reducing the flow of contaminants.

Two highly industrialized areas with recognized accumulations of toxics in sediments, Baltimore Harbor and the Elizabeth River at Hampton Roads, were selected for concentrated study and toxic contaminants control actions. Maryland and Virginia are working with EPA to improve detection of toxic contaminants and trace their sources, using both biological and chemical testing. FWS is also involved in biological testing at selected locations. EPA demonstrated new marine chronic toxicity testing procedures in Virginia in 1986, and that Commonwealth has since incorporated this biologically oriented examination of effluents into its other regular procedures¹⁴. Working with USGS and SCS, Virginia is developing a geographic information system (GIS) for the Elizabeth River. The GIS technology improves Virginia's

capability to detect and identify both point and nonpoint sources of toxic contaminants.

The Baltimore Harbor integrated environmental management study is examining how EPA's regulatory programs for air, water and land management relate to each other and to decisions of state, county and local government units in Maryland.

Related Matters

The Baltimore Harbor study recognizes that many decisions, programs and projects that affect the Bay are not directly tied to the Chesapeake Bay Program. Cooperating federal agencies administer many laws which affect the Bay though they are national in scope (e.g., Toxic Substances Control Act; Clean Water Act; Marine Protection, Research and Sanctuaries Act; Comprehensive Environmental Response, Compensation and Liability Act (Superfund); Resource Conservation and Recovery Act (RCRA); River & Harbors Act; Fish & Wildlife Coordination Act; Safe Drinking Water Act; Coastal Zone Management Act, and the Food Security Act of 1985). Many other state and federal programs and laws relevant to the Bay are the responsibility of agencies not involved in the Agreement. With this in mind, the Executive Council's 1985 plan included this goal: "develop and manage related environmental programs with a concern for their impact on the Bay."

Cross-media pollution (e.g. land generated pollutants to water and air) has long been recognized, but managing programs to alleviate cross-media effects is relatively new. At times, integrated approaches can be difficult to implement, even within a single agency. Specific missions and methods can differ, though the goals of environmental enhancement and protection are the same.

At EPA, cross-media integration became a national priority in 1986. This step, combined with the Water Quality Act of 1987²⁴, which not only recognized the Chesapeake Bay Program, but also the potential effectiveness of a geographic specific approach to pollution control and resource enhancement, has stimulated and simplified cross-program cooperation. Within EPA, the Bay Program has ties with national wetlands protection, pesticides management, ground water protection and nonpoint source control programs, as well as Superfund and RCRA.

Because of those ties, the Bay Program is the starting place for many regional environmental management efforts. In 1986, tributyltin sampling efforts undertaken by EPA²⁵, Navy, Maryland, and Virginia were coordinated through a multi-agency technical work group. The states of Maryland and Virginia used findings from these studies to restrict the use of tributyltin-based paints on recreational boats and commercial vessels. EPA is continuing to use the same data in its development of national water quality criteria and as part of the technical basis for national regulatory action.

The states have worked to explain the implications for

the Bay of activities such as highway construction and maintenance. Through SCS's efforts, the Bay area staff of ASCS and the Forest Service (both in the U.S. Department of Agriculture) recognize the impact their work has on the Bay. The CoE considers the environmental impacts of dredged and fill materials, construction permits and changes to wetlands. As part of the Baltimore Harbor and channel deepening project in Maryland and Virginia waters, the CoE is monitoring the effects of dredging.

Leachate to ground water from hazardous and solid waste disposal sites, sludge and dredge disposal, long range transport of air pollutants and the potential effects of nonpoint source controls on ground water are now being factored into the development of control strategies. It is also recognized that local land use decisions can have a major impact upon the Bay, indicating a need for closer integration with the Bay Program in the future. (Maryland's Critical Areas Program, with its county orientation, provides opportunities for such integration.) The 1987 Chesapeake Bay Agreement also underscores the importance of these factors in its sections on Water Quality and Population Growth and Development.

Though regulation is the primary focus, the states also are working to improve and maintain public access to the resources of the Bay. If people can use and enjoy the bounty of the Bay, they are more likely to understand and value it. Public access to beaches, parks and forested lands, as well as recreational and commercial fishing opportunities, are being improved and expanded in a manner consistent with the Related Matters goal in the Plan. Further, the 1987 Bay Agreement pledges to "intensify our efforts to improve and expand public access opportunities being made available by the Federal government, the States, and local governments by developing a strategy by July 1988."

Institutional/Management

Coordination and cooperation are the keystone for successful accomplishment of the entire Bay Program. For that reason the Chesapeake Executive Council and many federal, state, regional, and local private and public organizations have long been working together to implement a fourth goal: "support and enhance a cooperative approach toward Bay management at all levels of government."

Through the Nonpoint Source Subcommittee, the states have shared their knowledge and techniques to enhance their programs in stormwater management, sedimentation/erosion control, and targeting for BMPs implementation. As another example of cooperation, the states agreed in 1987 to reduce the amount of EPA money available for state implementation grants in order to support development of improved Bay modeling capability.

A prime example of cooperation is the comprehensive Baywide monitoring program in which all four jurisdictions and many of the federal agencies participate. Sam-

pling and analysis techniques are compatible, and data management, the acquisition of additional data bases, and necessary computer equipment are cooperatively funded.

The monitoring program is supplemented by citizen monitoring on the James (VA), Patuxent (MD) and Conestoga (PA) rivers. The success of these pilot programs funded by the Bay Program grant to the Citizens Program for the Chesapeake Bay, Inc., has prompted many watershed associations and some local government units to request help in starting similar projects. In addition, Maryland and Virginia are developing plans to expand the participation of citizens in collecting water quality data. Citizen near-shore monitoring data will be used to supplement tributary and Bay mainstem information collected by the states.

Now an integral part of the Bay Program, citizen monitoring began as one of many educational opportunities to increase public awareness and understanding of the Bay system. The states and federal agencies have been expanding such opportunities since the 1983 Agreement was signed. They have used radio, television and print media, speakers bureaus, literature, exhibits, field trips, slide shows and films, demonstrations, citizen advisory groups, in-school education, public meetings and other mechanisms to disseminate Bay Program information.

People of the region can expect further expansion of these opportunities for information and participation. The 1987 Agreement calls for coordinated education and information communication plans, and provision for public review and comment on all implementation plans.

The Executive Council's CAC and the Citizens Program for the Chesapeake Bay, Inc., have proven to be excellent links to the concerned public of the region, and state committees have been helpful to policy making agencies in Pennsylvania, Maryland and Virginia. Such mechanisms provide a means for public input and participation. They also help assure the accountability of state and federal agencies and the Bay restoration and protection effort as a whole.

Tracking and evaluating programs are other ways to provide accountability. But the ultimate measure of success will be the effects upon the water quality and living resources of the Bay.

Measuring Results

Implementation of the Chesapeake Bay monitoring program reflected the need for a coordinated and integrated data-gathering network in order to characterize the Bay system as a whole and to establish short- and long-term water quality trends. Prior to 1984, the existing data base was sufficient for characterizing the Bay's conditions and determining its most severe problems. The data base provides historical information through 1980. This can be used to expand trend analysis capabilities now available. However, the EPA study data base was of limited value due to differences in metho-

dology and discrepancies in sampling times and locations.

In 1984, expanding on their existing tributary monitoring programs, Maryland and Virginia began monitoring water quality conditions in the mainstem of the Bay with a 50-station network supported by EPA grants. By 1986 the overall coordinated network had expanded to 167 stations. Today, it reaches all major tributaries up to and beyond the fall line, and includes biological sampling and collection of sediment cores as well as water quality analysis. The 1987 Agreement calls for continued support of the monitoring efforts and accompanying data management work.

Results of the monitoring program from 1984 and 1985 have been summarized in the "State of the Bay Report" ²⁶ and its supporting "Technical Compendium." ²⁷ The publications emphasize that trend analysis will require several years of systematic data collection.

Initial results, however, do begin to provide the new requisite Baywide baselines to measure the effects of remedial actions.

Submerged Aquatic Vegetation

The SAV photographic survey, funded jointly by the FWS, EPA, Maryland Department of Natural Resources (DNR), Virginia Council on the Environment, NOAA, and the CoE, has been conducted annually since 1984. There were occasional surveys prior to 1984, including a major Baywide baseline survey in 1978 and annual field surveys conducted by Maryland DNR since 1971. In addition to the aerial photographs used to locate SAV beds and "groundtruthing" by survey teams, supplementary information is provided by citizens participating in the "SAV Hunt." This composite information is used to create SAV maps for the entire Bay, providing year-to-year comparisons of SAV distribution and abundance.

SAV in the Chesapeake Bay was in decline from the 1960s to the early 1980s. Findings from the 1984 and 1985 SAV surveys, however, provide some measure of hope that in some areas this trend has been reversed. Over that one-year period, SAV increased by 26 percent (47,893 acres) Baywide, with the largest rise occurring in the mid-Bay ²⁸. Recently released 1986 figures show a slight increase (369 acres) over the 1985 coverage ²⁹.

It is not yet clear whether the increases were due to natural variability, including rainfall changes, or occurred in response to Bay management efforts. An 18-year trend analysis of Baywide SAV data is being carried out by FWS to establish more precisely the changes in SAV abundance and to attempt to discriminate between natural and man-induced changes. For two areas, one in Maryland, another in Virginia, FWS is reviewing information on SAV back to the 1930s. SAV will continue to be an important measure of the revitalization of the Bay. As annual and long-term fluctuations in abundance and distribution are more fully understood, SAV will become more important in assessing the health of the Bay's shallow waters (see Chapter 2).

Nutrient Enrichment

The States of Maryland and Virginia, under grants from EPA, are responsible for monitoring in the Bay's mainstem. Although nutrients (nitrogen and phosphorus) are of primary concern, other physical and chemical parameters also are analyzed under the scope of their programs. Through the Monitoring Subcommittee, methodologies are being standardized and sampling schedules coordinated as closely as possible, allowing data from the two state programs to be treated statistically as a whole ³⁰.

Along with Maryland and Virginia, the District of Columbia, Pennsylvania, the Susquehanna River Basin Commission and the USGS are involved in monitoring Bay tributaries. FWS had a two-year sampling and analysis effort on the Choptank River. Monitoring both the tributaries and fall line is crucial to understanding nutrient cycling within the Bay system. In addition, small scale intensive monitoring projects such as those in Nomini Bay and Double Pipe Creek are important to demonstrate the effectiveness of best management practices in defined geographic areas. The magnitude of freshwater flow in a river is closely related to nutrient loads ultimately discharged to the Bay. Findings of 1984-1985 tributary monitoring indicate that other factors specific to individual watersheds (e.g. weather conditions which change flows) also dictate the nutrient loads delivered by each tributary. The 1984 and 1985 water quality data from the mainstem monitoring program provide two contrasting sets of information on the Bay: 1984 was a wet year and 1985 was dry.

The difference in basinwide precipitation had a major effect on Bay dynamics. The greater than average precipitation in 1984 flushed higher nutrient loads to the Bay and intensified stratification, the layering of fresh and saltwater that inhibits vertical mixing of surface and bottom waters. The result was an increase in anoxic and hypoxic bottom waters. The less than average precipitation in 1985 allowed saline waters to reach further into the Bay and up the tributaries. With those waters came some of the parasites and diseases which affected Maryland's oyster fishery.

The natural variability inherent in the first two years of water quality data underscores the need to maintain a consistent, quality-controlled data collection effort over the long term. The baseline against which the success of management actions must be measured cannot be truly delineated until sufficient data are available to statistically distinguish natural responses of the system from those induced by man. Against a noisy background of natural variability, it may take several years before the effects of management actions become apparent. Satellite imagery and other high technology methods may help distinguish trends from natural variability. The sophisticated Time Variable Model being developed by the EPA and CoE should also help by more accurately predicting the impacts of nutrients on the Bay and evaluating potential point and nonpoint control strategies.

Toxic Substances

Because of concern over toxic contaminants raised by findings of the original research study, monitoring programs for numerous toxicants in the bottom sediment also began in 1984.

Benthic surveillance data from Maryland and Virginia provide a picture of the broad distribution of toxic substances throughout the Bay. In addition, monitoring is clarifying the dynamics of water column/sediment exchange of toxic substances in relation to grain size and organic content of the sediment. Information from NOAA's Status and Trends Program supplements the Maryland and Virginia monitoring efforts. The NOAA Program focuses on biological accumulation of toxic materials in certain Bay species. In 1985 and 1986, FWS also obtained data on toxics accumulation in certain organisms from selected sites.

The initial monitoring of toxic substance levels and their relationship to sediment distribution is providing the information necessary to develop a toxics baseline for the Bay. Ongoing monitoring will allow assessment of the effects that control measures are having on reducing input of toxic contaminants to the Bay. Special studies, such as EPA's survey of TBT ²⁵, supplement monitoring data.

Making the Connections

Monitoring of nutrients, toxic substances, and SAV abundance undertaken since 1984 is beginning to provide, for the first time, a Baywide perspective on the various responses and fluctuations of this complex ecosystem. As monitoring continues, these different data sets will be integrated so critical links between the water and sediment quality and living resources can be better understood. Comprehension of these relationships will be an important element in the next phase of the Chesapeake Bay restoration program.

Future Directions

The Chesapeake Bay Study initiated in 1975 forged the first links in the state/federal/public partnership--the keystone of today's program. By the time the final reports of the congressionally mandated study were released by EPA in September 1983, the commitment to undertake and fund the Bay restoration was cemented.

The states and EPA then signed the Chesapeake Bay Agreement in December 1983, and began Phase I of the coordinated cleanup effort, building upon progress made in wastewater treatment plant construction and upgrading. Programs are in place to address the most obvious problems identified in 1983 (excess phosphorus and nitrogen, toxic substances and declines in living resources), monitoring data are being collected and analyzed, and models are providing theoretical projections of the pounds of nutrients and tons of sediment kept from Bay waters.

Monitoring data eventually will reflect the positive

results of state and federal pollution control programs. However, today it is still unclear whether the scope and size of restoration and protection programs are sufficient to produce reasonable progress. In 1986, the Executive Council decided that it needed a more precise measure of the impact of programs on water quality. How can the Council determine if the rate of progress is reasonable? Or be certain that results are occurring in areas that benefit living resources most effectively?

To answer these and other questions, the Executive Council adopted the Phase II program evaluation and development process in 1986³¹. Phase II is the next step in the Chesapeake Bay Program, the logical extension of a continuum that began in the mid-1970s (Figure 1-7). The process has four basic steps:

1. Establish water quality, living resources, and habitat objectives;
2. Determine reductions in pollution loadings needed to meet the objectives;
3. Evaluate the technical alternatives and pollution control measures which could be used, according to their costs and effectiveness;
4. Suggest what should be done, where, over what period of time, at what cost, and with what expected results.

Through the Phase II process, managers will gain a greater understanding of the Bay ecosystem and its needs. Based on that understanding they will be better able to

focus restoration and protection efforts and more clearly define the type and extent of additional pollution controls needed. Phase II also will enable managers to determine costs and predict results, including the potential consequences of future restoration and protection actions.

Phase II directly supports meeting the commitments in the 1987 Chesapeake Bay Agreement. The following objectives of Phase II tie to three major milestones in the Agreement:

Living Resources. Identify key species and associated support species, locations of their habitats, and conditions required during critical life stages of each species. The 1987 Agreement requires guidelines by January 1988.

Nutrients. Define the roles of phosphorus and nitrogen in polluting the Bay and its living resources, and determine how best to reduce loadings. The 1987 Agreement requires a plan by July 1988 to reduce loadings of these nutrients by 40 percent by the year 2000.

Toxic Substances. Develop a comprehensive strategy for controlling sources of toxic contaminants entering the Bay system and managing those now in the system. The 1987 Agreement pledges that a toxics reduction plan will be adopted by December 1988.

The approaches used in Phase II and the progress toward attainment of each of these objectives are described in Chapters 2, 3 and 4.

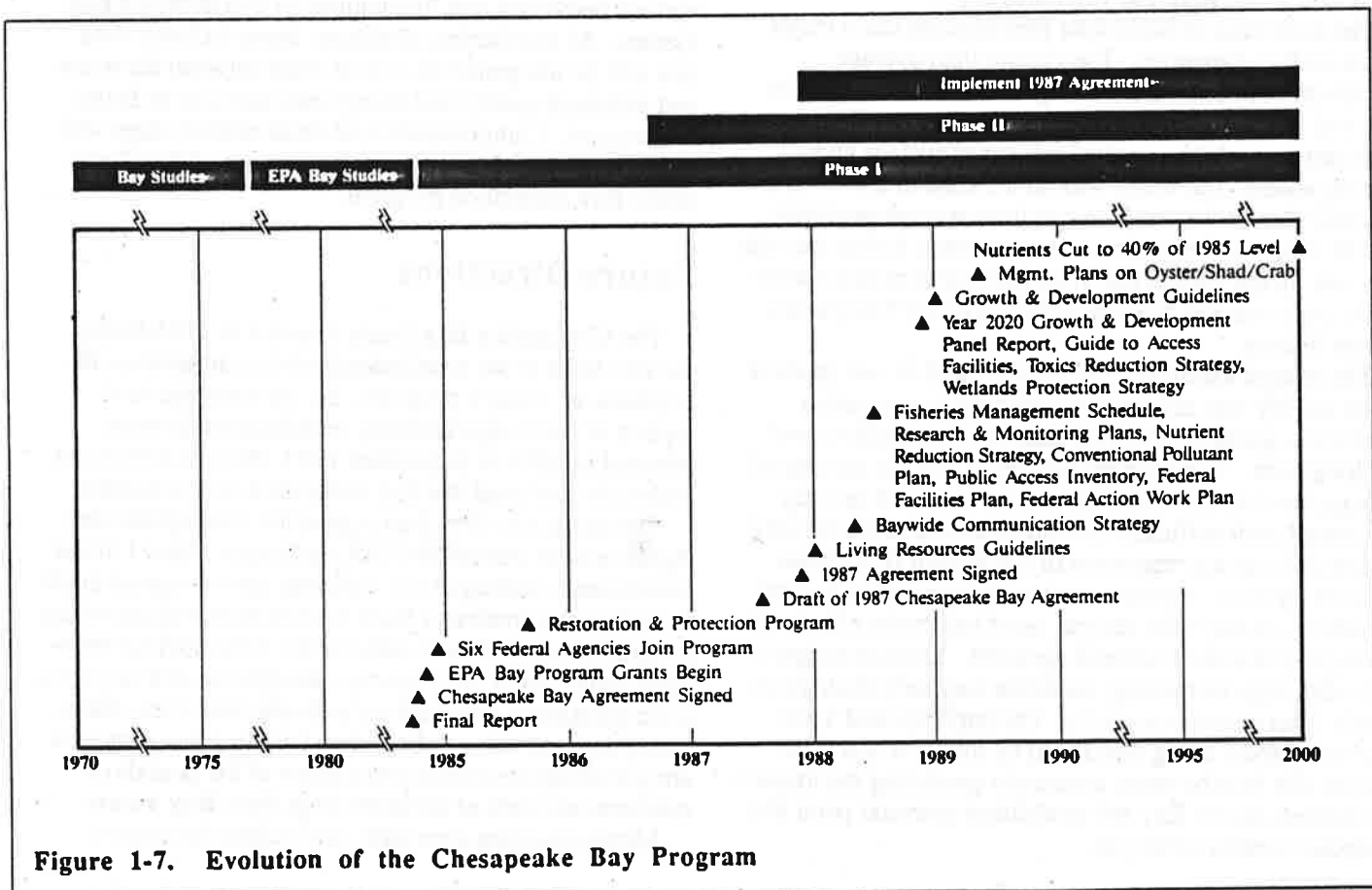


Figure 1-7. Evolution of the Chesapeake Bay Program

Chapter 2

Managing for Living Resources Goals

Establishing Living Resources Habitat Objectives

Declines in stocks of finfish, shellfish, waterfowl, and submerged aquatic vegetation in the Chesapeake Bay have prompted an unprecedented effort by state and federal agencies to determine the causes and to explore means of restoring and protecting these living resource populations. Studies completed in 1983 under the aegis of the EPA Chesapeake Bay Program concluded that the decline of important resources was due, in part, to deteriorating water quality, particularly nutrient enrichment and contamination by toxic metals and organic compounds ³².

Since 1983, most of the research and planning efforts for restoring and protecting the Chesapeake Bay have focused on documenting the present water quality of the Bay and refining strategies for reducing or preventing further increases in nutrient and contaminant loads. Strategies based primarily upon water quality, however, cannot necessarily ensure the restoration and protection of living resources. The most tangible warning signs of widespread environmental problems in the Bay have been shifts in the relative abundance of living resources. Therefore, living resources serve as excellent indicators of the Bay's recovery for Bay managers and the public.

The abundance and distribution of species within the Bay are related to many variables: climate, natural population cycles, reproductive potential, disease, predation, and the abundance and quality of food and habitat. Human activities impose another set of conditions which both directly and indirectly affect local and Baywide species abundance. Commercial and recreational fishing, land and water uses, contaminant discharges, and physical habitat alterations can directly affect important living resource populations. Indirect impacts of these activities can disrupt food chains and upset the ecological balance of the estuary.

The first measure of success in efforts to restore habitat conditions required to support continued propagation and increases in existing stocks should be ecologically significant changes in the abundance and composition of planktonic, benthic, and submerged aquatic vegetation communities. Restoration of a more balanced ecosystem at these lower trophic levels will then provide for increased abundance of commercially, recreationally, and ecologically important finfish and shellfish species over the long term.

To provide for the restoration and protection of living

resources, their habitats, and ecological relationships, it is necessary to set regional habitat objectives--those essential water quality, biological, and physical requirements necessary for continued propagation of the most sensitive stages of representative living resources within a defined geographical area. These regional habitat objectives can guide overall management of the Bay and provide useful measures of restoration progress. The ultimate measures of success will be the responses of living resources throughout the Bay.

Developing Habitat Objectives

In recognition of these principles, the Chesapeake Bay Program Implementation Committee established a Living Resources Task Force (LRTF) in 1986 to begin defining habitat objectives for the Bay as an integral part of the Restoration and Protection Phase II planning process. The LRTF immediately began to develop habitat requirements for representative Bay species. A series of workshops and meetings bringing together a wide spectrum of scientists and regulatory and resource managers aided in the species selection process and in the development of habitat requirements for individual species.

Representative species were first identified from all levels of the Chesapeake Bay ecosystem food web including plankton, benthos, submerged aquatic vegetation, shellfish, finfish, waterfowl, and wildlife. A smaller group of species, focused primarily on the upper food chain, was targeted for immediate attention in the development of habitat requirements. Criteria for selection included the commercial, recreational, aesthetic or ecological significance of the species and the potential threat to sustained production posed by population declines or serious habitat problems.

Matrices of habitat requirements for critical life stages and critical life periods of target species were developed and synthesized from existing literature and recent research findings. Bay geographic areas were charted where habitat requirements must be met to protect the critical life stages, and thus the survival, of target species.

The LRTF completed the first phase of this effort to identify target species and to define their habitat requirements in May 1987 (see box - page 16). A summary of the Task Force's findings was accepted by the Chesapeake Bay Program Implementation Committee in July and published in August 1987 ³³.

The report is a first effort, and is likely to change as the habitat requirements are used, and as new information becomes available to assist in refining or strengthening

Habitat Requirements Development Process

List of Representative Species



Identification of Target Species



Habitat Requirement Matrices for
Critical Life Stages



Habitat Requirements Workshop



Draft Reports and Review by
Managers and Scientific Community



Final Report by Living Resources Task Force

them. The document includes numerical and narrative habitat requirements for the critical life stage and life period of 26 target species. These requirements were determined from the best available scientific knowledge and by consensus of participants at the LRTF workshop held in February 1987³⁴. The distribution of each target species during its critical life stage is also presented in the report, drawn from available documents.

The Task Force's objective in producing the report was to document a technically defensible approach for setting regional habitat objectives for the Chesapeake Bay by first assembling habitat requirements for individual target species. The LRTF report summarizes results of the Task Force's efforts and outlines a process for refining these habitat requirements and compiling requirements for other species, particularly those organisms which target species need for food.

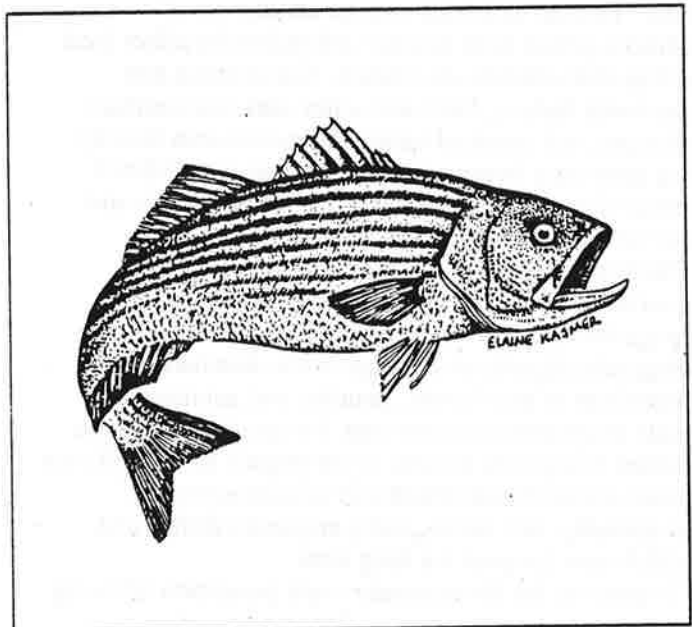
Habitat is defined in the report as the biotic and abiotic conditions upon which living resources of the Bay depend. Abiotic conditions include water quality, substrate, circulation patterns, water depths, and weather. Biotic conditions are governed by variables such as vegetative cover, quality and quantity of prey species, population size, species composition, and primary productivity. Habitat requirements quantify or describe the preferred abiotic and biotic conditions that Bay species need for long-term survival. For some conditions, such as toxic chemical concentrations, there are no preferred conditions, so the habitat requirements contain tolerance limits. Knowledge about habitat requirements is limited mostly to water quality parameters; additional conditions can be added as they are identified by research.

Three examples of the target species descriptions and habitat requirements presented in the LRTF report are summarized below, including an anadromous fish sensitive to tidal freshwater habitat conditions (striped bass), an immobile shellfish species which cannot escape from hypoxic waters (American oyster), and a major group of plants which live rooted underwater, creating habitat for themselves and many other living resources in the Bay (submerged aquatic vegetation). The distribution and abundance of all three of these target species have undergone drastic reductions in recent years, due, in part, to deteriorating habitat quality.

Striped Bass Habitat Requirements

Striped bass spawn during spring (late April to early June) in most of the tidal-freshwater areas of the Chesapeake Bay and its tributaries. Major spawning regions include the tidal-fresh reaches of the James, Pamunkey, Mattaponi, Chickahominy, Rappahannock, Potomac, and Patuxent rivers on the western shore; the Susquehanna Flats, Elk River, and the Chesapeake and Delaware Canal in the upper Bay; and the Chester, Choptank and Nanticoke rivers on the Eastern Shore (Figure 2-1). The critical life stages are the egg and larval stages. Minute planktonic crustaceans, specifically copepods and cladocerans, are the major food items of larval striped bass.

Toxic-effects information is more complete for striped bass than for any other target species examined by the Task Force. Still, the link between contamination of spawning and nursery areas and low survival rates of larval and juvenile striped bass has not been clearly established. The information on toxicity of chemicals to young striped bass cannot be ignored, however. Known tolerances of striped bass to specific chemicals should be documented and used in refining habitat requirements (Table 2-1).

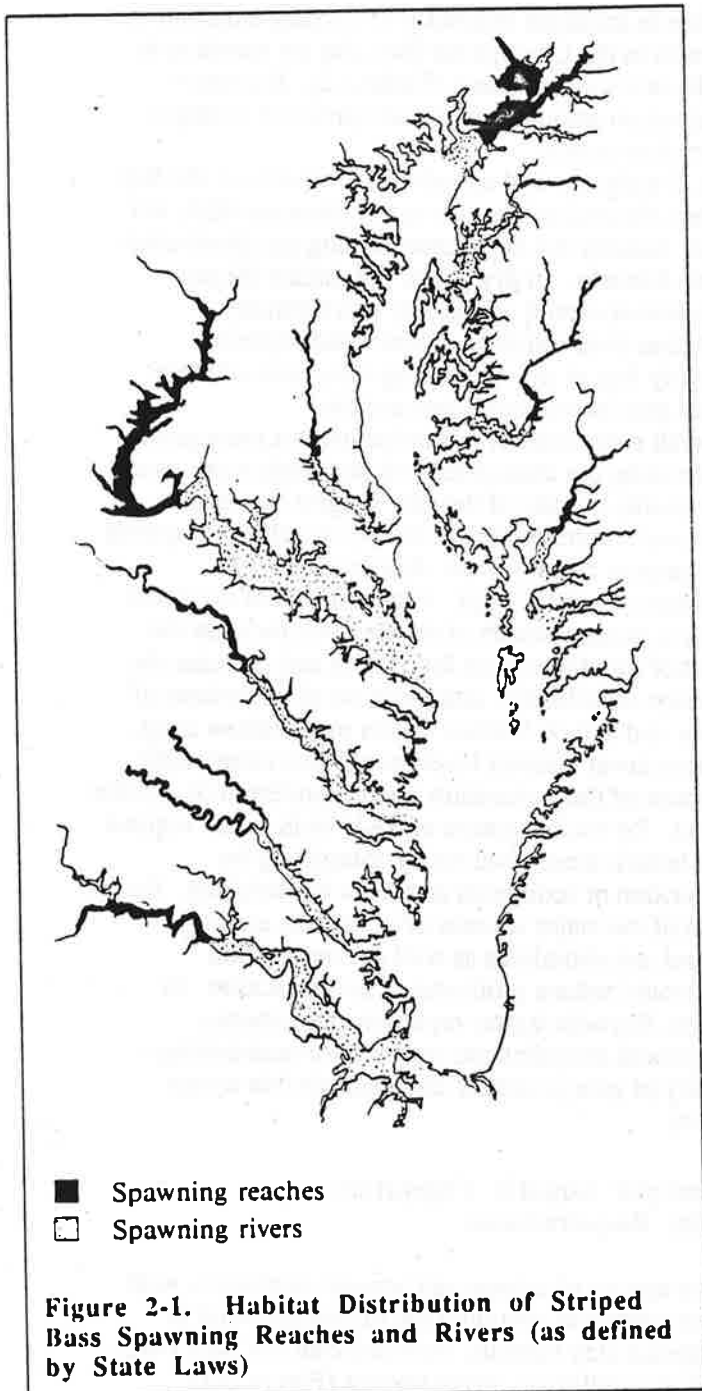


American Oyster Habitat Requirements

The American oyster is not only the most important bivalve in the Chesapeake from an economic standpoint, but it also has a significant ecological role within the Bay's benthic (bottom-dwelling) community. Oyster distribution in the Bay is determined largely by salinity, bottom substrate and adequate dissolved oxygen levels (Figure 2-2). Although oysters are tolerant of a wide range of salinities (5 to 35 ppt salinity), they cannot survive in tidal-freshwater or oligohaline (low salinity) regions of the Bay. The depths at which oysters can survive are limited by dissolved oxygen concentrations. Natural episodes of hypoxia--when dissolved oxygen concentrations in bottom waters are less than 2 mg/l--are thought to have limited oyster distribution in the past to the shallower, more highly oxygenated waters of the Bay. In recent years, the increasing duration and distribution of hypoxia in the Bay have been responsible for local areas of oyster mortality at depths less than the historical 10-meter limit.

Oysters spawn in the summer when water temperatures are over 15 degrees C. Spawning rates are highest between 22 and 23 degrees C. Free-swimming oyster larvae permanently attach their newly-formed shell to firm substrate and become spat, or young oysters, a process known as spat setting. Critical for their survival is the availability of firm foundations, such as pilings, hard rock bottoms, and particularly old shells, known as cultch, left naturally on oyster bars or "planted" by resource management agencies and watermen.

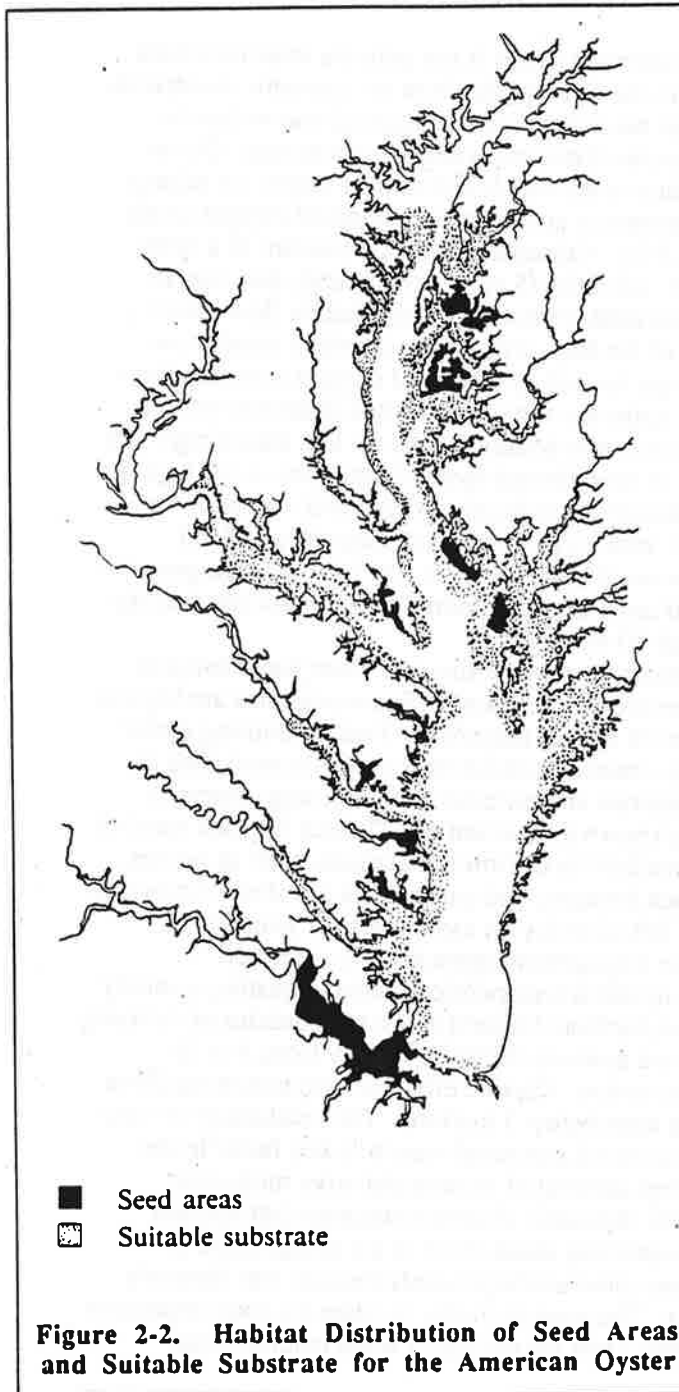
The oyster is a suspension feeder, ingesting a variety of phytoplankton, bacteria and small particles of decaying plants and animals (detritus), mostly from 3 to 35 microns in size. Capture efficiency decreases rapidly at particle sizes below 3 microns. The availability of food within a critical size range may be a key factor in the long-term survival of oysters and other molluscan shellfish. Scientific evidence suggests that nutrient enrichment may cause shifts in the composition of plankton communities towards smaller, less desirable species. The oyster's ability to filter out food organisms efficiently from the overlying water column could



**Table 2-1
Summary of Habitat Requirements for Striped Bass**

Critical Life Stage(s): Egg, larval
 Critical Life Period: April - June

Habitat Zone	Salinity (ppt)	Flow (m/s)	Temp. (C)	pH	Dissolved Oxygen (mg/l)	Alkalinity (mg/l)	Total Chlorine (mg/l)	Metals (mg/l)	Insecticides (ug/l)
Water Column, Demersal	0-5	0.3-5.0	16-19	7.5 - 8.5	Tolerate: 4.5-20 Optimal: 6.0-12	>20	(See LRTF Report)	(See LRTF Report)	Malathion <14 Chlordane <2.4 2,4,5-TP <10



therefore be impaired indirectly by nutrient enrichment.

Oysters in the Chesapeake Bay also are sensitive to turbidity and sedimentation (Table 2-2). Excessive sedimentation smothers adults and prevents setting of spat on clean cultch.

The distribution and abundance of oysters in the Bay has been affected by the two oyster diseases MSX and Dermo. Salinity is a key factor limiting the distribution of these diseases. In dry years, polyhaline (highly saline) waters extend up the Bay into normally mesohaline (mid-salinity) waters where oysters previously free of the weakening symptoms of these diseases may become infected and die.

Overall restoration of oyster habitat is a prerequisite for increasing the abundance and distribution of oysters. Water quality models of the Bay suggest that drastic reductions in nutrients are necessary to achieve Baywide mean summer bottom water dissolved oxygen concentrations of 1-2 mg/l. Higher levels of dissolved oxygen in bottom waters of the Bay will increase the amount of suitable habitat for oysters and decrease the frequency, distribution, and duration of excursions of hypoxic and anoxic bottom waters into shallow areas.

These lower nutrient levels could also increase the abundance of those plankton species preferred by oysters for food. Re-establishment of SAV beds in key regions would benefit these bivalves by controlling the resuspension of sediments and reducing turbidity. Better control of the major sources of sediment--eroding farmland and shorelines as well as construction sites--would reduce problems of sedimentation. In addition, Baywide oyster repletion and fisheries management programs are essential for maintaining a diversity of genetic stocks and a sustainable oyster industry.

Submerged Aquatic Vegetation Habitat Requirements

Five species of submerged aquatic vegetation, with salinity tolerances spanning the full range found in Chesapeake Bay habitats, were selected for Task Force review as a collective target species (Figure 2-3).

Table 2-2
Summary of Habitat Requirements for the American Oyster

Critical Life Stage(s): Larval, spat, adult
 Critical Life Period: Entire life cycle

Habitat Zone	Salinity (ppt)	pH	Dissolved Oxygen (mg/l)	Suspended Solids (mg/l)	Prey Species
Firm substrate, cultch	5-35	6.8-8.5	>2.4	<35	Phytoplankton (size range of 3-35 microns)

Eelgrass is representative of the polyhaline zone; widgeongrass is representative of both mesohaline and polyhaline zones. Sago pondweed and redhead grass are tolerant of oligohaline and mesohaline salinities. Wild celery inhabits tidal-fresh and oligohaline waters.

Light penetration limits the depth at which SAV can survive and propagate. In the Chesapeake Bay, this depth is usually less than 2 meters, although some SAV species can grow at depths of 3 meters or more in less turbid waters. The amount of light reaching SAV leaves can be reduced by several factors. High turbidity levels act like clouds in reducing available light underwater and can be caused by suspended sediments, high densities of zooplankton, or algal blooms. Table 2-3 summarizes recent scientific findings for the summer averaged habitat conditions which support healthy SAV in mesohaline regions³⁵. The numbers presented are derived from laboratory research confirmed by studies in the Choptank River in Maryland. Scientists who have been investigating the causes of declines in SAV are beginning to develop habitat requirements for selected SAV environments based on field validation of years of laboratory study and in-situ monitoring efforts. Thus, additional information may soon be available to aid in refining SAV criteria for use throughout the Bay system.

Organisms growing directly on SAV leaves (epiphytic growth) are natural sun blocks and, like algae and zooplankton, are stimulated by high nutrient levels. Research suggests that in polyhaline waters, nitrogen is generally responsible for an over-abundance of planktonic and epiphytic growth. In the mesohaline zone, excessive levels of either nitrogen or phosphorus may stimulate noxious growth. In the tidal-freshwater reaches of the Bay, SAV grows well in the presence of high nitrogen levels when localized phosphorus concentrations are low enough to limit phytoplankton growth. However, excessive growth of plankton caused by high phosphorus concentrations and high turbidity levels has largely prevented the reestablishment of SAV in the upper reaches of the Bay and its tributaries. Average concentrations of dissolved inorganic phosphorus and nitrogen below 0.01 and 0.14 mg/l,

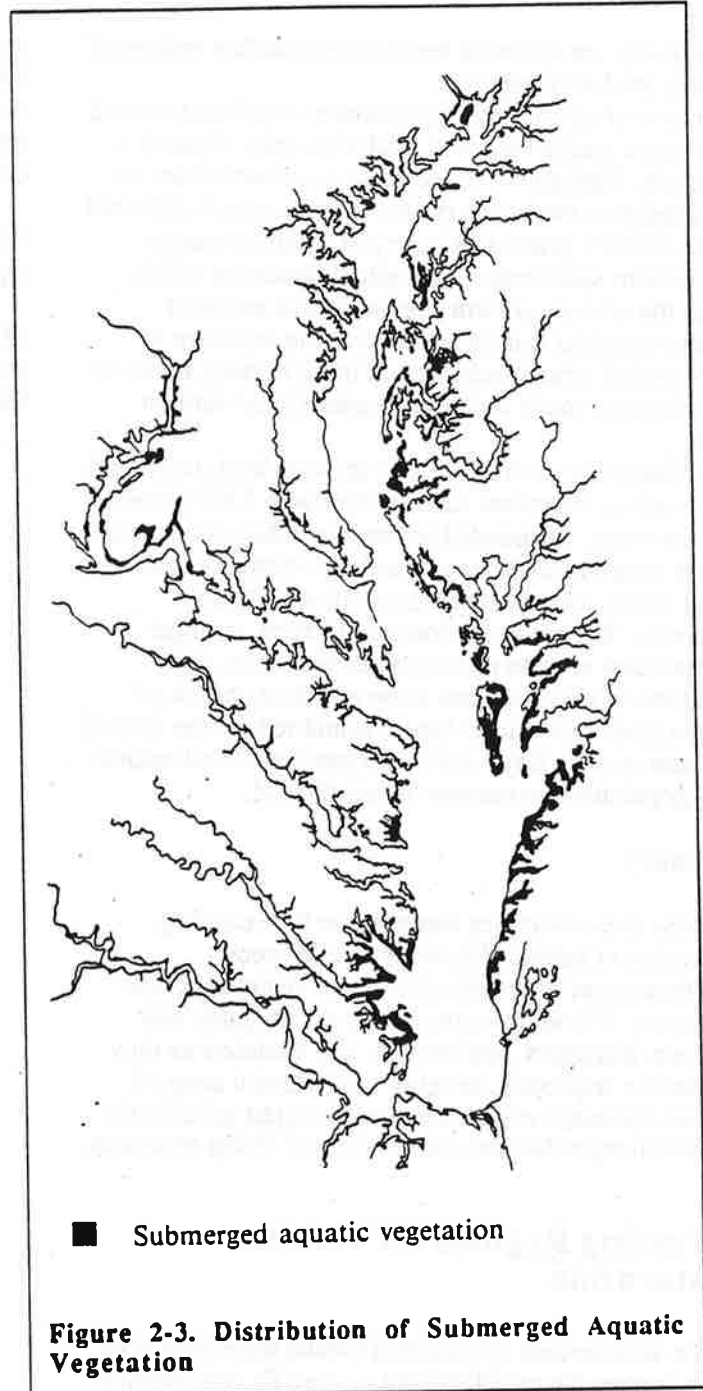


Table 2-3
Summary of Habitat Requirements of Selected
Submerged Aquatic Vegetation Species in the Mesohaline Zone

Critical Life Stage(s): All life stages
 Critical Life Period: April - September

Habitat Zone	Salinity (ppt)	Temp. (C)	pH	Dissolved Inorganic Nitrogen (mg/l)	Dissolved Inorganic Phosphorus (mg/l)	Chlorophyll <i>a</i> (ug/l)	Turbidity (NTU)	Secchi Depth (m)	Light Attenuation Coeff. (Kd) (m ⁻¹)	Herbicides (ug/l)
Littoral < 3 m.	5-18	15-35	6-9	<0.14	<0.01	< 15	< 20	> 1.0	< 2	< 10

respectively, are optimum levels in mesohaline regions of the Bay, the LRTF reported.

Impacts of agricultural herbicides on SAV are centered in the upper reaches of small tidal tributaries adjacent to farmlands. Springtime concentrations of herbicides are high enough in these waters after a rain to cause sublethal effects on SAV plants that have just begun to emerge from bottom sediments. Agricultural practices which reduce the amount of farm chemicals and sediment flowing into tidal waters would curb the exposure of SAV--and all other inhabitants of these nursery areas--to toxic chemical loads and would control local nutrient loads.

Sediment carried into the Bay in watershed runoff and from eroding shorelines can interfere with SAV growth in many ways. Suspended sediments reduce the amount of light reaching SAV leaves, and sedimentation can bury young shoots and alter the composition of bottom sediments. Shoreline erosion stabilization, stronger sediment and erosion control on construction sites, protection of wetlands, and more effective control of erosion from agricultural lands, would reduce the flow of sediment into the Bay, enabling transplanted and natural SAV populations to become re-established.

Summary

These three examples demonstrate how existing knowledge of habitat requirements and species distribution can be combined to shape regional habitat objectives. These objectives, in turn, can guide Bay planners, managers, researchers, and modelers as they explore the feasibility, benefits and potential costs of various options to restore estuarine habitats suitable for successful reproduction and survival of living resources.

Targeting Regions for Habitat Restoration

The achievement of proposed habitat objectives does not guarantee the establishment of specific population or harvest levels for any species. Total compliance with the habitat requirements for striped bass larvae, for example, will not necessarily produce an improvement in the annual juvenile index, a measure of young striped bass populations. But the recovery of living resources now in decline and the re-establishment of a more balanced ecosystem--the ultimate measures of success in restoring the quality of the Chesapeake Bay--will be unattainable unless certain minimum habitat requirements are achieved.

The large number of species in the Chesapeake Bay (more than 2,300) and the diversity of requisite habitats necessitate regional pollution control and resource management strategies. Baywide restoration goals can only be achieved by implementing strategies tailored to defined regions or, on a larger scale, to individual river basins. When data now available on the distribution of

representative species are combined with their individual habitat requirements, Bay managers will have more complete information for allocating present and future resources to restore and protect critical habitats within the Chesapeake Bay basin.

A series of maps illustrates the habitat areas critical to the targeted finfish, shellfish, waterfowl and submerged aquatic vegetation species.

Figure 2-4 displays spawning and nursery habitats of targeted anadromous finfish (striped bass, white perch, blueback herring, alewife, American shad, and hickory shad) and nursery habitats of marine spawning

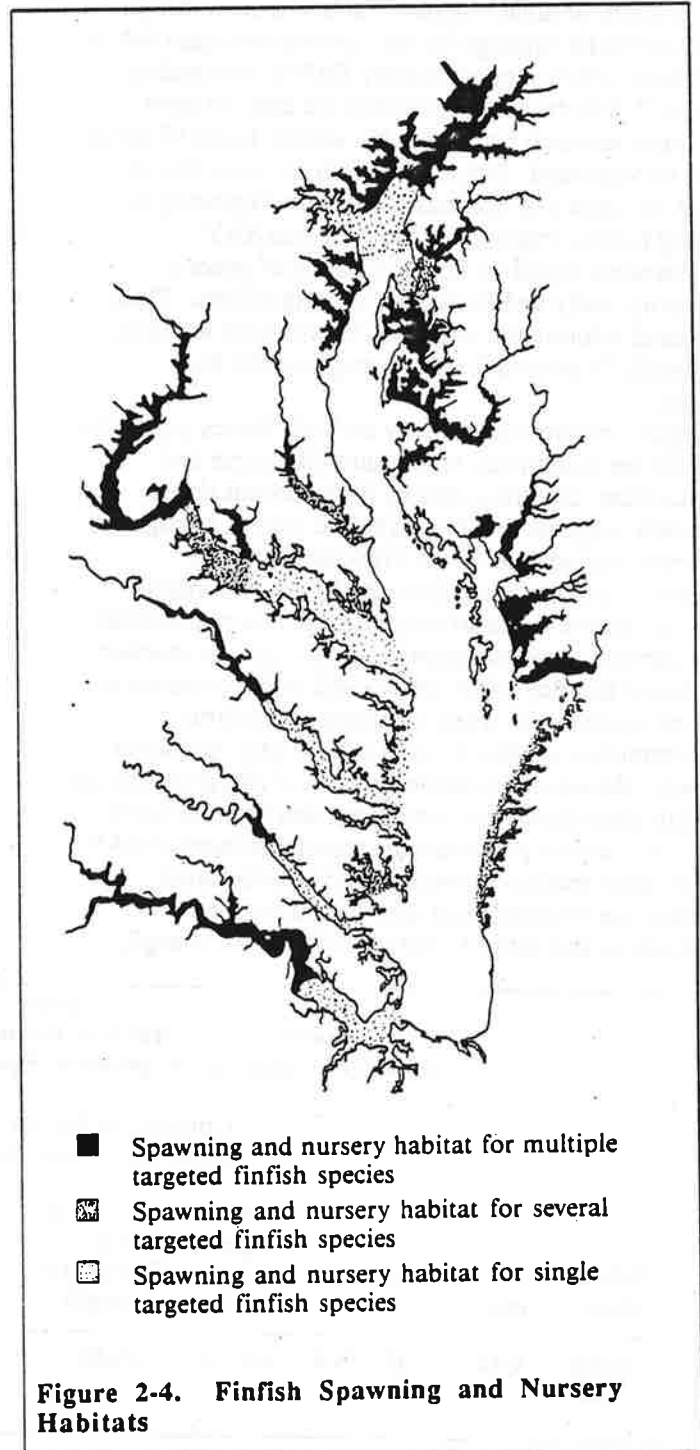


Table 2-4
Finfish Spawning and Nursery Areas

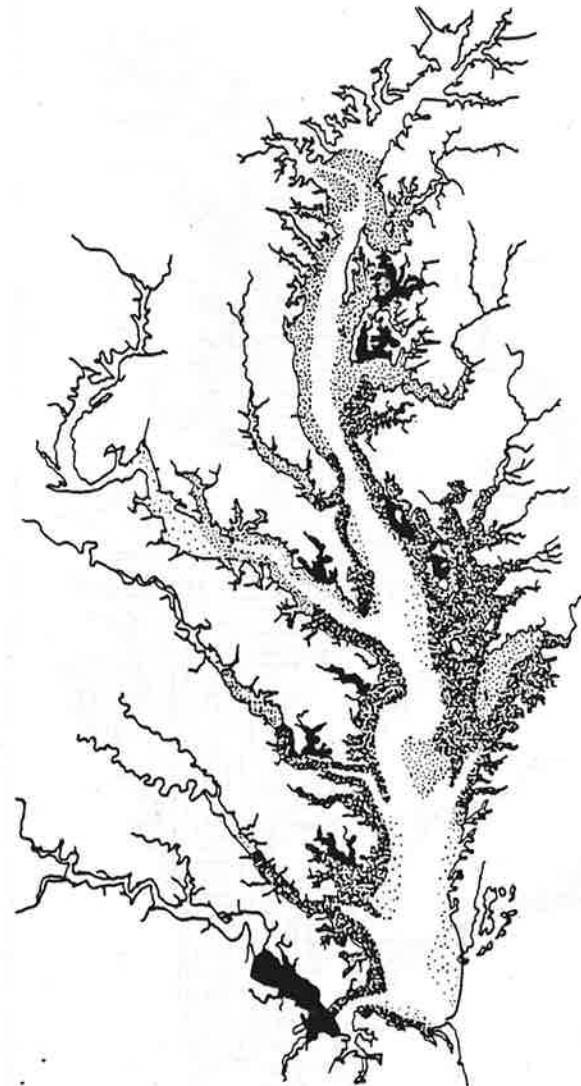
James River	Susquehanna Flats
York River	Elk River
Pamunkey River	Upper Chester River
Mattaponi River	Choptank River
Rappahannock River	Nanticoke River
Upper Patuxent River	Wicomico River
Gunpowder River	Pocomoke River
Bush River	Virginia Eastern
Upper Mainstem Bay	Shore Embayments

finfish (menhaden and spot) (Table 2-4). The map draws attention to the significance of the tidal freshwater and riverine/estuarine transition (oligohaline) zones as spawning and nursery areas for anadromous finfish species. Mesohaline and polyhaline creeks and marshes are critical nursery areas for marine spawners.

Anadromous and estuarine finfish are generally most vulnerable during their egg and larval stages in spring. During this season, they occupy tidal-freshwater and oligohaline habitats of the Bay and its tributaries. Marine spawners inhabit mesohaline and polyhaline tidal creeks and marshes in the spring. Large amounts of nitrogen and phosphorus pour into these areas just prior to and during the spawning and nursery season, adding excessive nutrients at a time when they could alter the species composition of existing plankton population, potentially affecting the availability of food throughout the year. In the spring, agricultural chemicals and sediments are carried into tidal waters from recently cultivated farmland, potentially affecting the survival of the young fish. In addition, these high loading rates stimulate the growth of plankton in oligohaline and mesohaline portions of the Bay and contribute indirectly to periods of hypoxia later in the year. These springtime loads thus can limit the extent of habitat for both maturing juvenile finfish and adult estuarine and marine finfish that use Bay waters in the summer.

Figure 2-5 shows suitable bottom substrate for the American oyster, softshell clam, and hard clam (Table 2-5). Shaded areas denote overlapping species distribution. Shellfish habitats generally have been limited to water depths of less than 10 meters due to episodes of hypoxia and excursions of hypoxic bottom waters into shallow areas of the Bay.

Figure 2-6 combines the shellfish map with 1985 average summer (July-August) monitored dissolved oxygen levels at the 10-meter depth contour in the main channel and at the bottom for shoal areas less than 10 meters. The 10 meter contour closely matches the combined shellfish habitat distributions. For most of the deeper waters of the Bay, summer average dissolved oxygen levels are below 5 mg/l, the critical level for most estuarine organisms as well as shellfish. In the summer,



- ☒ Suitable habitat for all three species
- ▨ Suitable habitat for two species
- Suitable habitat for only one species
- Oyster seed beds

Figure 2-5. Habitat Distribution of the American Oyster, Softshell Clam, and Hard Clam

Table 2-5
Key Chesapeake Bay Habitats for Shellfish

Lower James River	Lower Chester River
Lower York	Eastern Bay
Lower Rappahannock River	Choptank River
Lower Potomac River	Tangier Sound
Lower Patuxent River	Virginia Eastern
	Shore Embayments

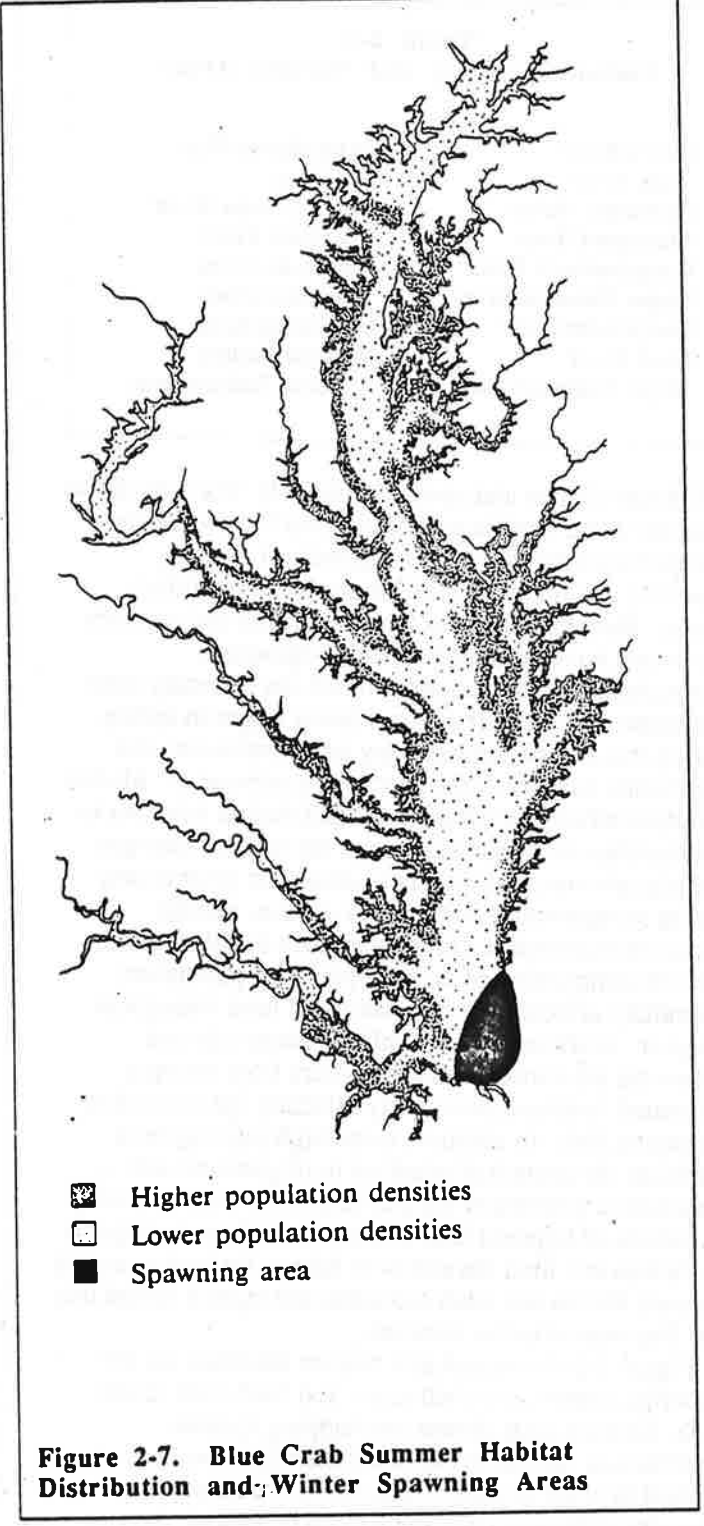
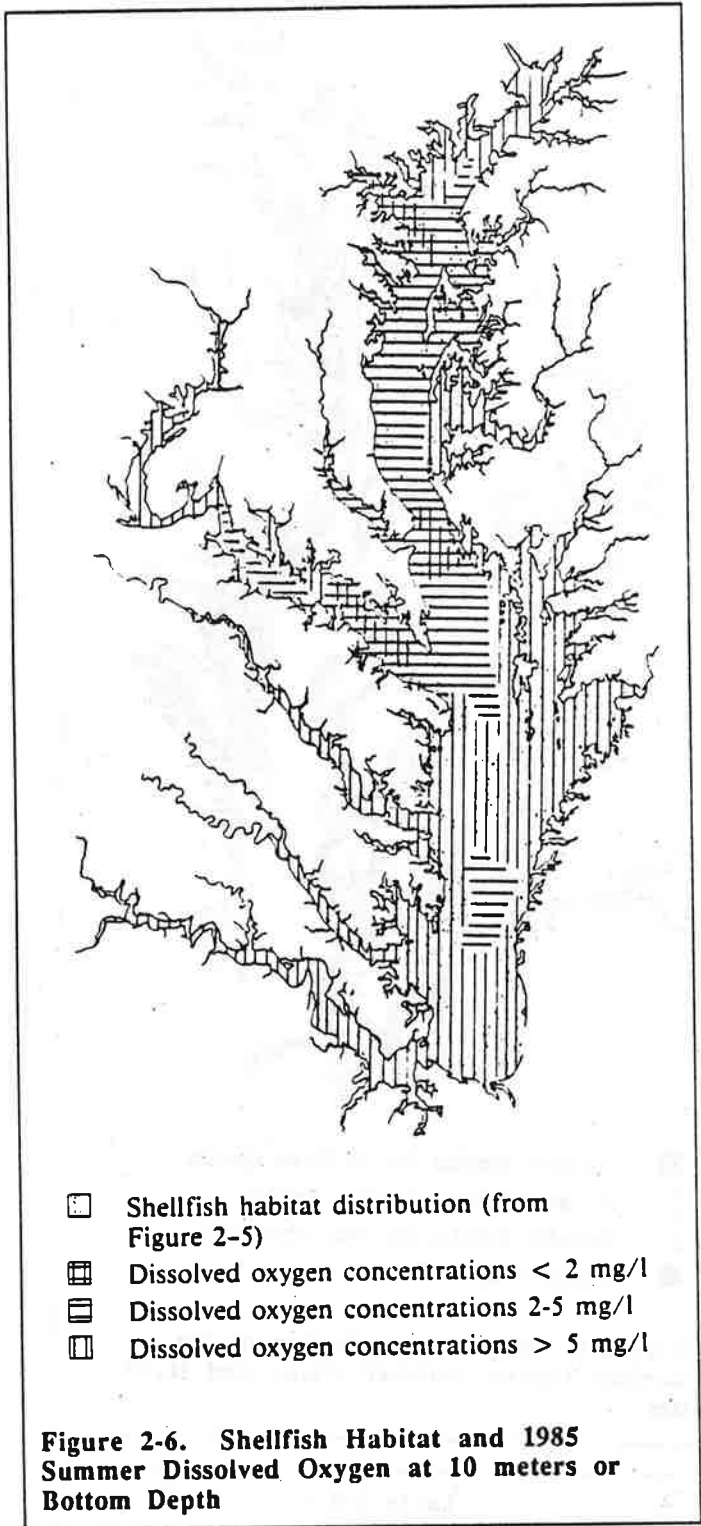


Table 2-6
Key Chesapeake Bay Habitats for Blue Crabs

- Chesapeake Bay Mouth
- Mainstem Bay
- Shoal and Shoreline Areas
- Tangier Sound

these deeper, low oxygen waters may be forced up into shellfish habitats if winds prevail for several days from a constant direction. Even within the shellfish shoal habitats, 1985 summer dissolved oxygen levels averaged below 5 mg/l.

Figure 2-7 displays the summer distribution of male and female blue crabs (Table 2-6). The spawning area for females extends from the mouth of the Bay to coastal waters over the continental shelf. This map illustrates that the potential habitat for blue crabs is distributed through-

Table 2-7
Key Chesapeake Bay Habitats for
Waterfowl and
Submerged Aquatic Vegetation

Mobjack Bay	Chester River
Lower York River	Choptank River
Upper Virginia	Eastern Bay
Western Shore	Tangier Sound
Upper Potomac River	Virginia Eastern
Maryland Western	Shore Embayments
Shore Tributaries	

out the Bay at all depths, emphasizing the significance of the entire Bay as habitat for living resources.

The map underscores the danger of increasing hypoxia in the Bay: juvenile crabs travel through bottom waters up the Bay in the spring and summer assisted by the salt wedge. In the fall the crabs, primarily adult females, move back into higher salinity waters to burrow into mud for the winter months. Many of these regions are often uninhabitable now because of dissolved oxygen concentrations less than 2 mg/l (the minimum requirement for crabs) throughout much of the summer. In contrast to the stationary habits of oysters, the ubiquitous nature and mobility of crabs may protect their population in the short term since they can usually escape from invading fronts of hypoxic water. Unless the duration and distribution of hypoxia are reduced, more frequent encounters with hypoxic conditions eventually could affect the long-term survival of this resilient crustacean.

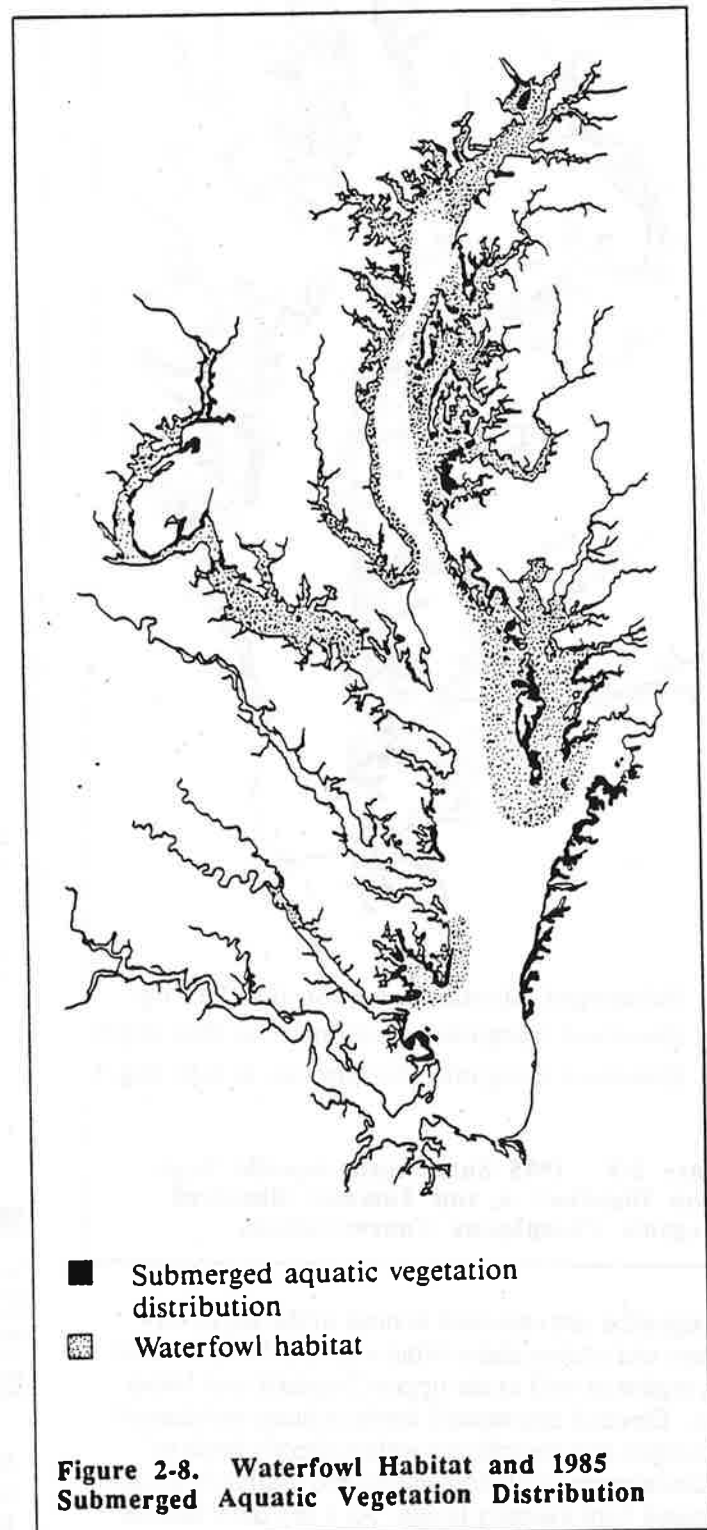
In addition to SAV's role as a biological indicator of the relative health of the Bay, SAV is an important source of food for migratory and resident waterfowl. Figure 2-8 shows present areas of submerged aquatic vegetation and the habitats of black ducks, redhead ducks, and canvasbacks (Table 2-7). The re-establishment of SAV beds would restore a critical food source and habitat on which waterfowl and many other declining Bay species depend.

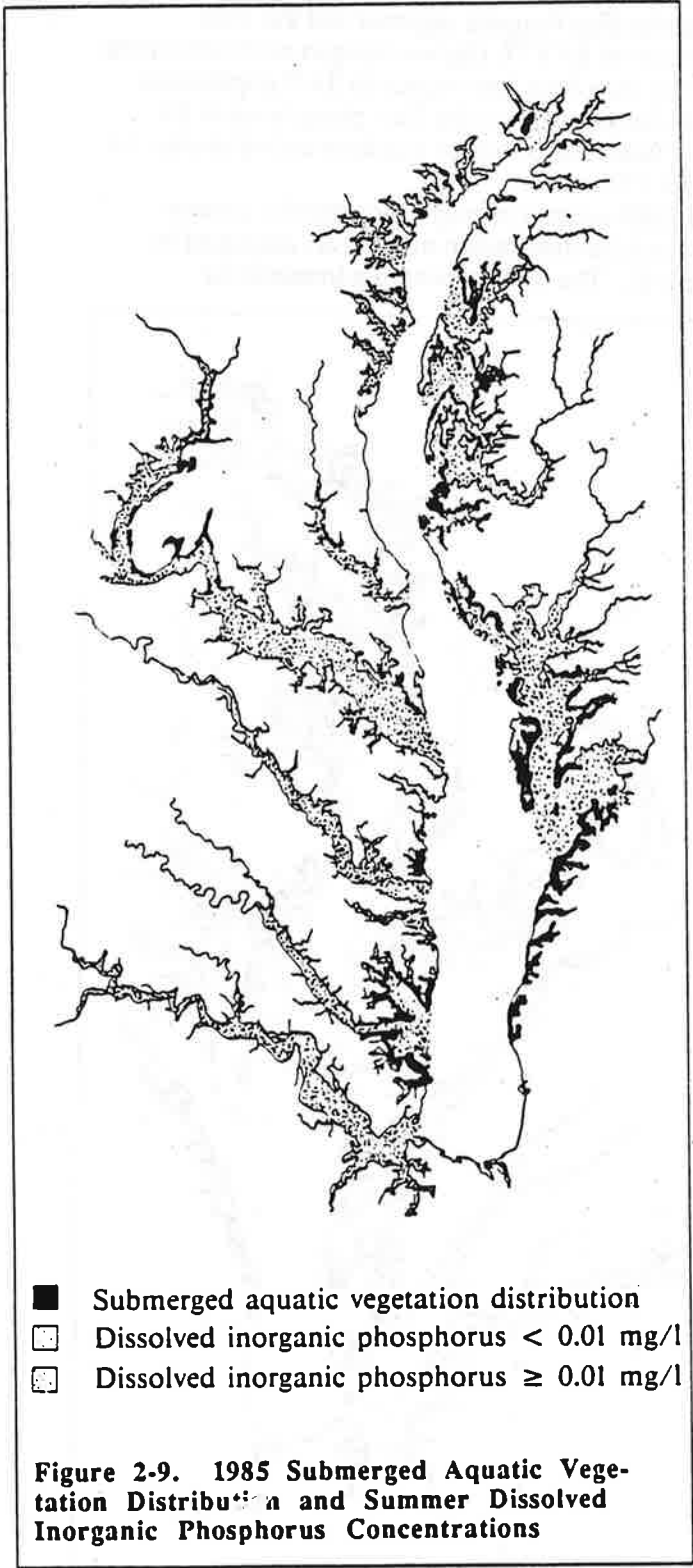
Figure 2-9 combines 1985 average summer surface dissolved inorganic phosphorus concentrations by Chesapeake Bay Program segment and the 1985 distribution of SAV. The map indicates areas where phosphorus concentrations are greater than the SAV habitat requirement for phosphorus, less than 0.01 mg/l, shown in Table 2-3. Although the phosphorus data were collected at stations representative of each Bay segment, the stations are not located in nearshore regions, so phosphorus concentrations in SAV habitats may be slightly different. The coordination of living resources habitat monitoring with water quality monitoring would help to determine more accurately whether habitat requirements are being met.

Figure 2-10 combines 1985 average summer surface

dissolved inorganic nitrogen concentrations by Chesapeake Bay Program segment and the 1985 distribution of SAV²⁹. Higher nitrogen conditions in the upper Bay may have less impact on SAV populations since, in fresher parts of the Bay, phosphorus is the limiting factor for growth of plankton and epiphytes that cover SAV leaves.

The 1985 summer average chlorophyll *a* concentrations and the distribution of SAV are displayed in Figure 2-11. The SAV habitat requirements for

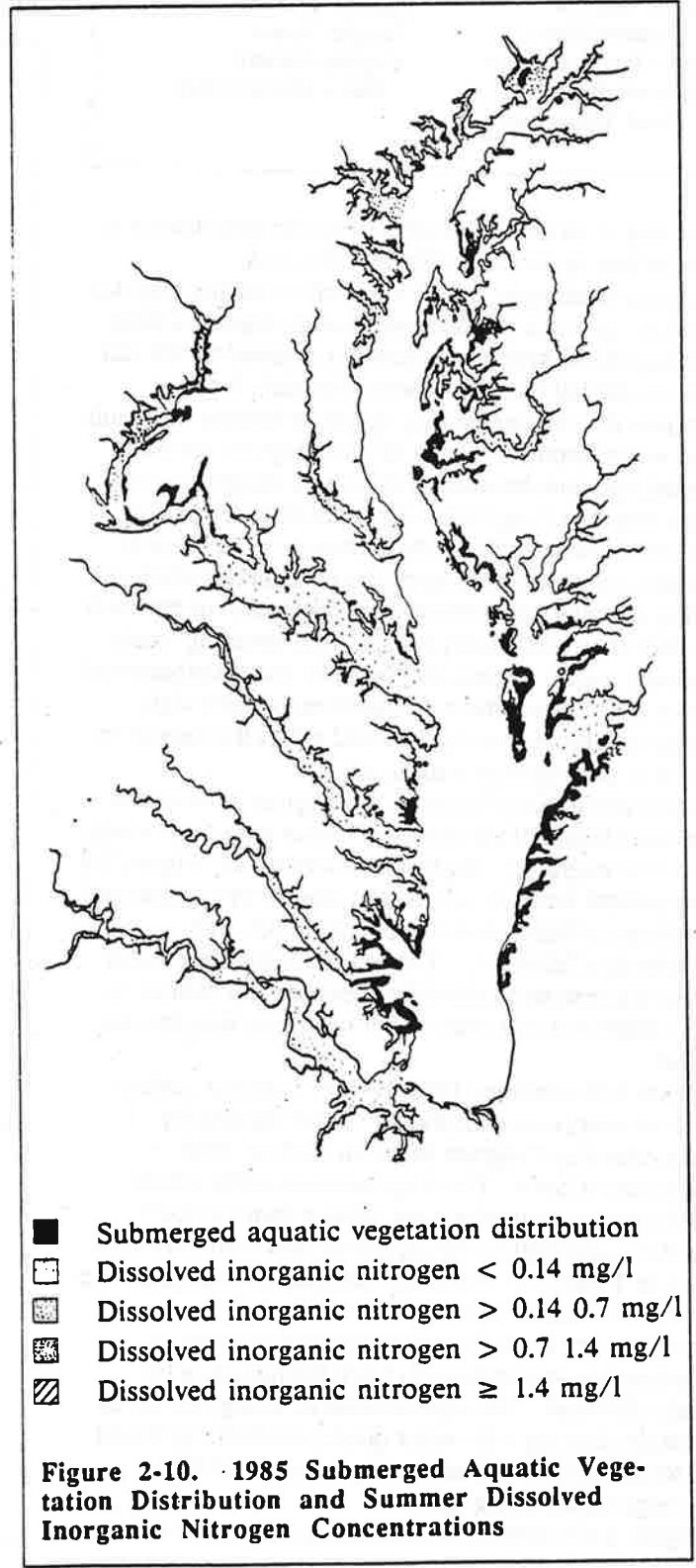




chlorophyll *a* are exceeded in most of the upper Bay western and eastern shore tributaries and Susquehanna Flats region as well as the upper Choptank and James rivers. Elevated chlorophyll levels indicate enrichment by nitrogen and phosphorus which directly leads to overabundances of phytoplankton and indirectly causes decreased light intensity levels. As a key SAV habitat requirement, chlorophyll can be considered an indicator

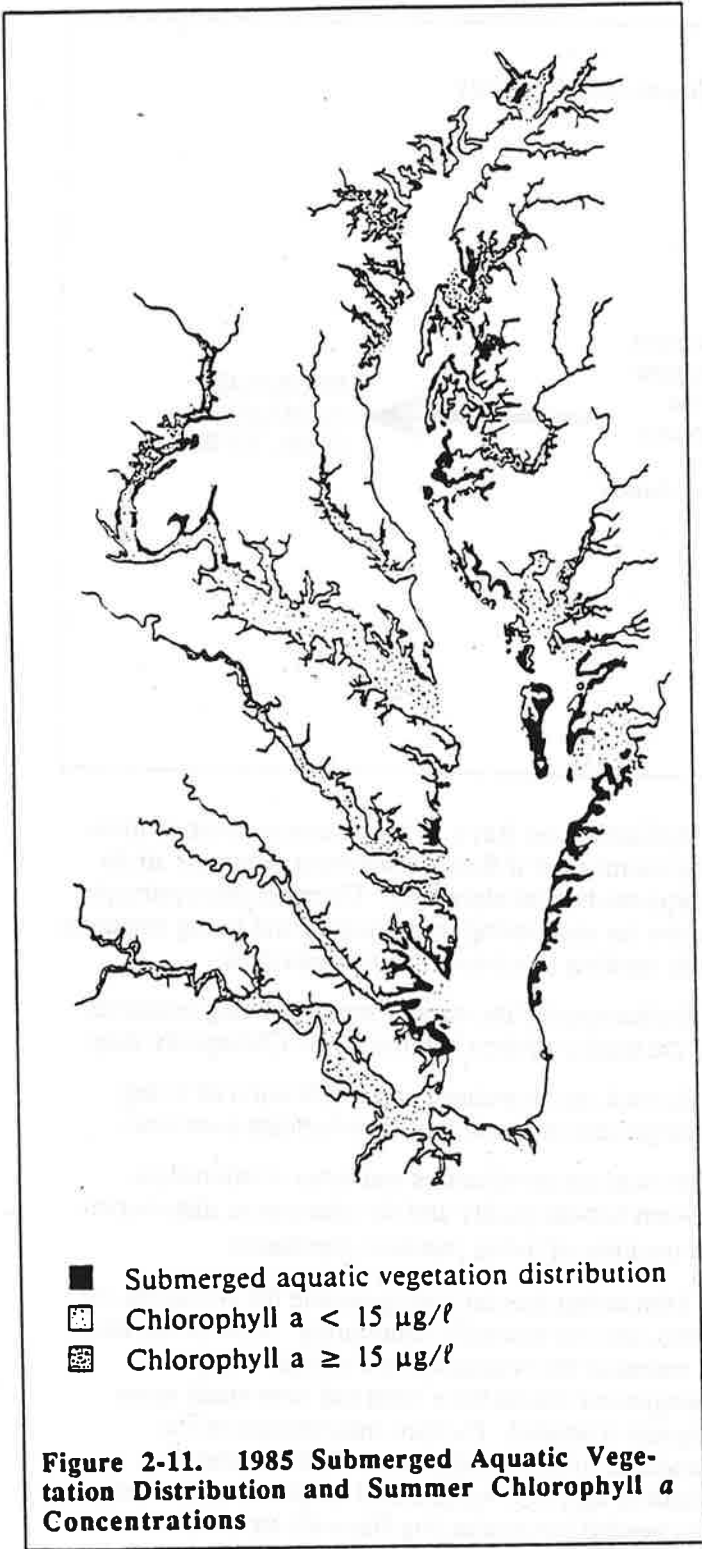
of existing nutrient conditions in the nearshore Bay grass habitats.

The combined influence of existing water quality conditions on SAV distribution and abundance is displayed in Figure 2-12. Chesapeake Bay segments are outlined where one or more of the chlorophyll *a*, phosphorus and nitrogen habitat requirements for SAV are "exceeded."



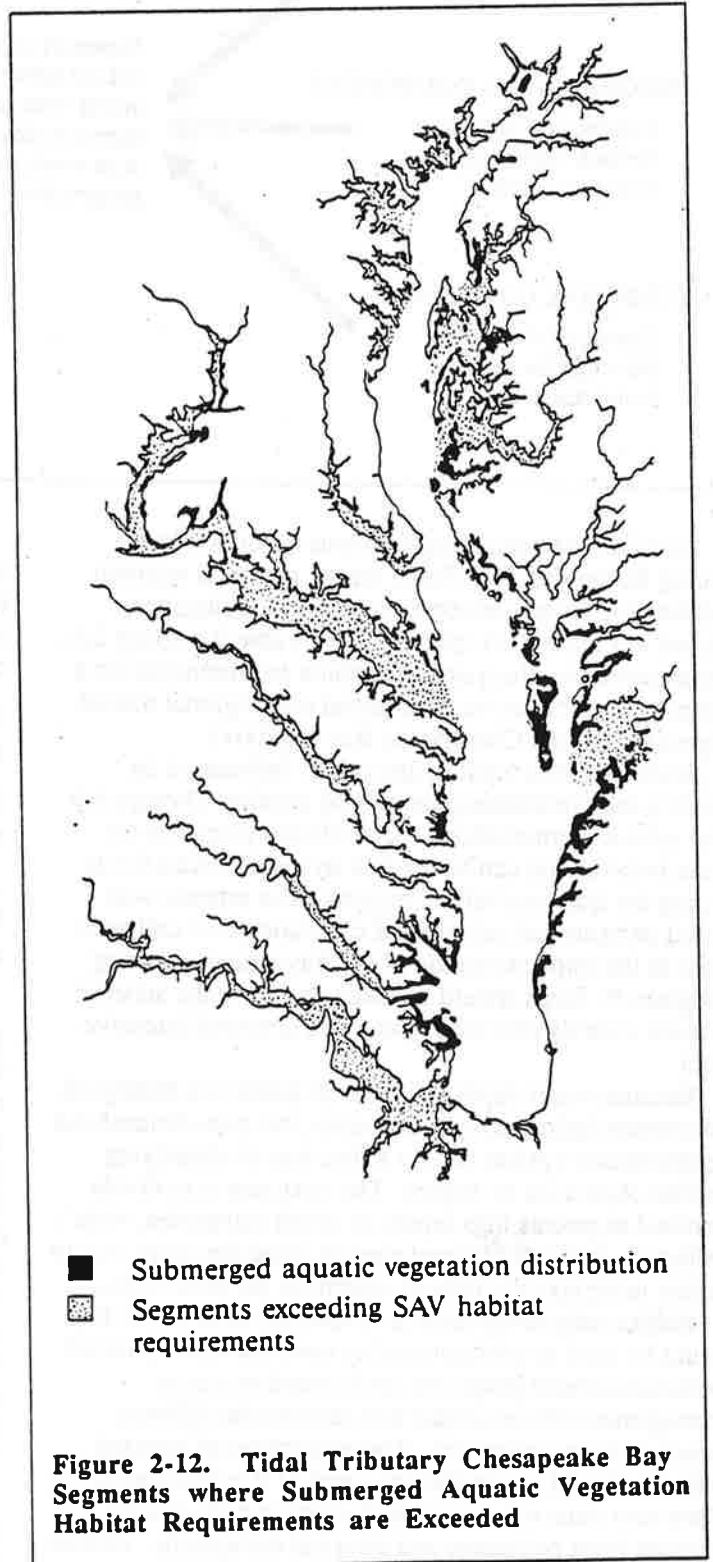
target species during the life stages most critical for survival. The Task Force report fulfilled this objective.

The next step is for regulators and resource managers to integrate habitat requirements into the overall management of the Bay's resources and clarify their own agencies' roles in achieving these habitat objectives. How, for example, could agencies factor habitat restoration and protection goals into decisions relating to wetlands, shoreline erosion, dredging and barriers to fish migration.

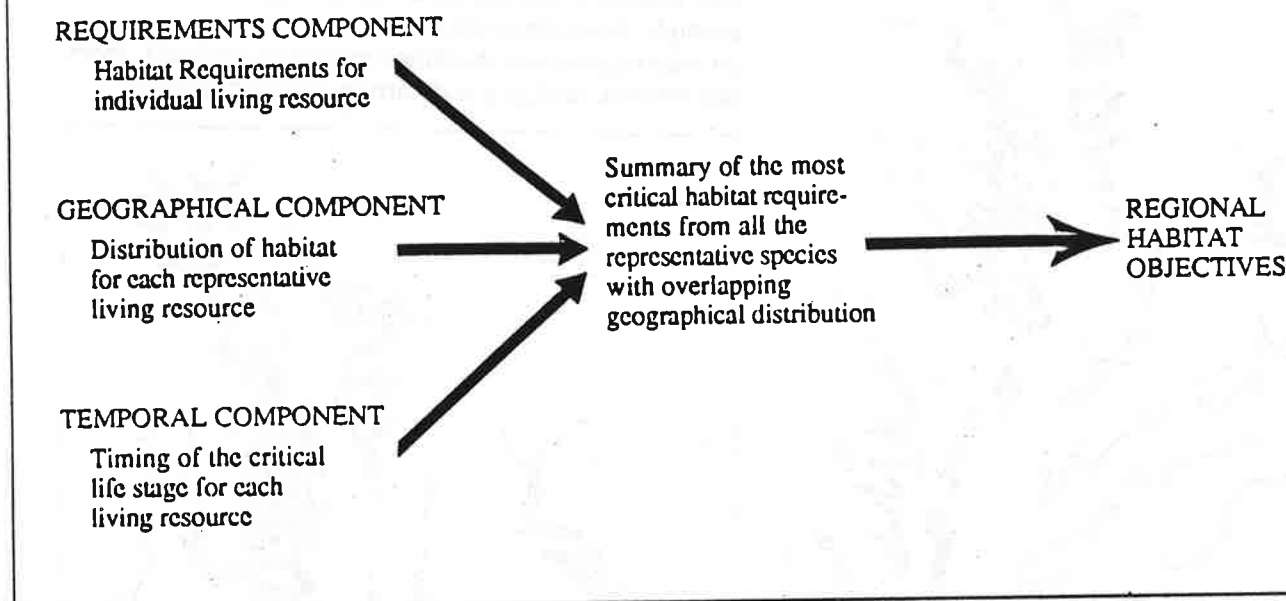


Habitat Objectives for Management: An Ecosystem Approach

The initial objective of the Living Resources Task Force was twofold: 1) to quantify the habitat requirements necessary to sustain and enhance reproduction and survival of target species and 2) to document where these conditions must be met, in terms of the distribution of



Habitat Objectives Development Process



Based on the habitat requirements described in the Living Resources Task Force report, potential regional habitat objectives were compiled. These objectives, shown in Figure 2-13 (page 27) and Table 2-8 (page 28), are presented to illustrate how habitat requirements for a range of species can be synthesized into regional habitat objectives for the Chesapeake Bay (see box).

Since estuarine habitats are greatly influenced by salinity and circulation patterns, the existing Chesapeake Bay spatial segmentation scheme (based primarily on these two factors) can be used as an initial model for dividing the Bay into habitat regions. The scheme was based on historical salinity and circulation data collected prior to the implementation of the Baywide monitoring program³⁶. Steps should be taken to ensure the scheme reflects recently collected spatial and temporal intensive data.

Because water depth and other physical and biological parameters influence habitat quality, this two-dimensional segmentation system is only a first step in classifying habitat objectives by region. The next step is to divide updated segments into layers, or depth categories, which reflect the habitats of target species more precisely, and to define more specific habitat objectives for these areas.

Habitat objectives tailored to specific areas of the Bay could be used to refocus existing environmental policies, pollution control programs, and natural resource management efforts to take into account the different needs of living resources. The restoration of stressed habitats should not be the only goal of Bay managers. They also must strive to protect existing high-quality habitats from pollutants and physical disruptions. Habitat objectives provide the technical basis for both these goals.

Monitoring the Bay's living resources must continue to be coordinated if Bay management programs are to incorporate habitat objectives. There are three principle reasons for monitoring water quality and living resources while working to achieve habitat objectives:

1. To characterize the current status of living resources and the quality of their habitats in the Chesapeake Bay;
2. To track the abundance and distribution of living resources and the quality of their habitats over time;
3. To examine correlations and other relationships between habitat quality and the abundance, distribution and integrity of living resource population.

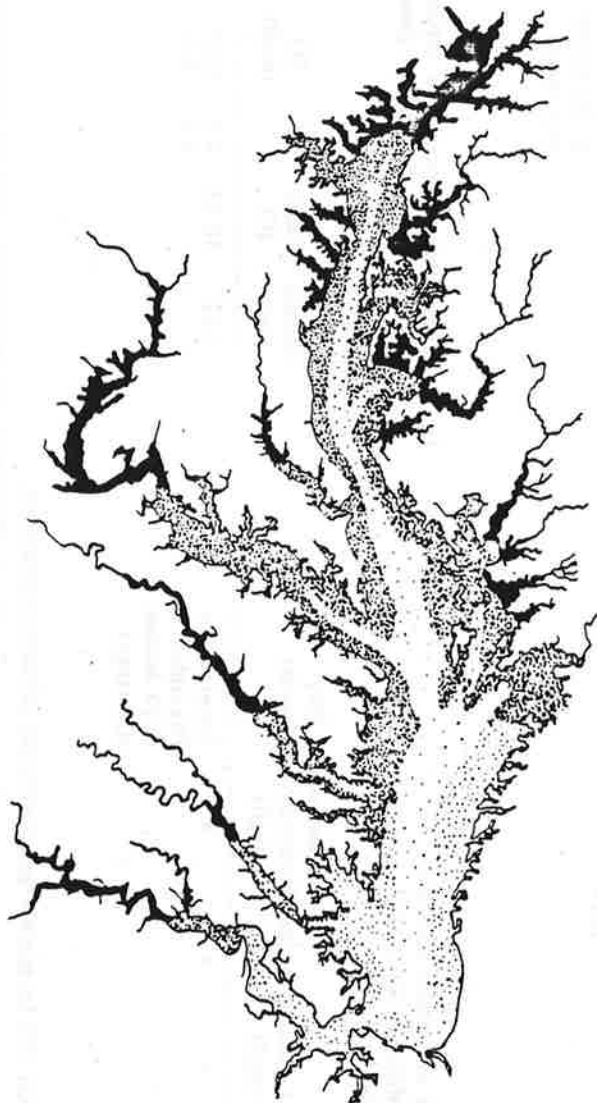
Monitoring data are indispensable for managers, the public, and the scientific community. Most of all, they are essential for evaluating how effective Bay management efforts have been and how much more progress is needed. Further, information on the abundance of adult and juvenile fish and shellfish, including age, sex, weight, and length data, has long been needed for conducting Baywide stock assessments to improve fisheries management in Chesapeake Bay. Data can be made available for scientific research to answer questions about the relative effects of climate, pollution, and habitat loss on living resource abundance and distribution. Defining the condition of the Bay in terms of the health of its plants and animals also is more understandable to citizens.

Achieving habitat objectives requires coordinated programs which do not stop at state boundaries or within one agency. Targeting Bay watersheds for nonpoint

integrated into existing Bay management policies and programs (see box). Research and monitoring of living resources are essential components for defining the problems at hand, measuring progress, refining objectives, and reporting to the public. Efforts to achieve habitat objectives should be regional in scope, taking into account the needs of estuarine organisms living in a wide range of conditions. At present, there is only a small number of water quality standards to guide the restoration and protection of the Chesapeake. They are divided into two basic sets--those for the tidal-freshwater regions and those for the remaining tidal waters. In relation to the range of habitat requirements identified in the LRTF report, the limited scope of water quality standards offers little guarantee that continued water quality management will protect estuarine living resource habitats.

EPA Water Quality Criteria

Multiple approaches are necessary to maintain the complex food web that sustains living resources in the Chesapeake Bay. Establishing and enforcing estuarine water quality standards which directly reflect living resource habitat objectives can be an important part of this effort. Existing EPA water quality criteria and state



- Tidal-fresh/oligohaline finfish spawning and nursery habitat zone
- ▣ Mesohaline shellfish and finfish habitat zone
- ▤ Polyhaline shellfish and finfish habitat zone
- ▥ Euryhaline pelagic finfish habitat zone

Figure 2-13. Geographical Zonation of Potential Living Resource Habitat Objectives

source control is one example of how habitat objectives could be blended into programs not directly related to managing living resources. Watersheds which contribute high nutrient loads to critical habitat areas (the tidal-freshwater spawning and nursery areas) could be selected. Intensive education, research, and technical assistance encouraging the use of best management practices to reduce nutrient loads would then be targeted to those areas. In short, to achieve habitat objectives, they must be

Building on the Findings of the Living Resources Task Force

Chesapeake Bay Program managers can build on the work of the Living Resources Task Force, extending and refining its findings by:

1. Establishing additional habitat requirements for a) the initial target species and b) the prey species upon which the target species depend. Special attention should be paid to plankton and benthic communities, important as indicators of ecosystem stress and as key sources of food for species at higher trophic levels;
2. Identifying those characteristics of living resource populations (e.g. distribution and abundance) or of Bay communities (e.g. species diversity) that will serve as measures of the Bay's recovery in response to management actions;
3. Refining programs for monitoring water quality, sediment quality, living resources, and habitat conditions to determine where and how much improvement is needed to measure restoration and protection progress, and to establish linkages between water quality and living resources; and,
4. Using computer models of the Chesapeake to predict the amount of nutrient reductions necessary to achieve habitat objectives in each region of the Bay.

Table 2-8.
Potential Chesapeake Bay Living Resources Habitat Objectives

A. Potential Habitat Objectives to Support Anadromous
Finfish Spawning and Nursery Areas and Oligohaline
Submerged Aquatic Vegetation Habitats

Salinity (ppt)	Flow (m/s)	Temp. (C)	pH	DO (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)	Secchi Depth (m)	Chlorophyll <i>a</i> (mg/l)	Dissolved Inorganic Nitrogen (mg/l)	Dissolved Inorganic Phosphorus (mg/l)	Alkalinity (mg/l)	Total Residual Chlorine (mg/l)	Metals (mg/l)	Herbicides (mg/l)	Chlorinated Hydrocarbons (ug/l)	Prey Species
0-5	SAV 0.3-5	16-19	7.5-8.5	>5	<20-50	<50-70	1.0	<15	<0.7-0.14	<0.01	>20	<0.15	*	<10	*	Zooplankton (Cladocerans) (Copepods)

B. Potential Habitat Objectives to Support Shellfish,
Anadromous and Marine Finfish, and Submerged
Aquatic Vegetation in the Mesohaline Zone

Salinity (ppt)	Cover (C)	Temp. (C)	pH	DO (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)	Secchi Depth (m)	Chlorophyll <i>a</i> (mg/l)	Dissolved Inorganic Nitrogen (mg/l)	Dissolved Inorganic Phosphorus (mg/l)	Alkalinity (mg/l)	Total Residual Chlorine (mg/l)	Metals (mg/l)	Herbicides (ug/l)	Chlorinated Hydrocarbons (ug/l)	Prey Species
5-18	SAV 15-30	6.5-8.5	>2.4	>2.4	<20	<35	1.0	<15	<0.7-0.14	<0.01	>20	0.15	*	<10	*	Zooplankton (3-35 micron size range)

C. Potential Habitat Objectives to Support Shellfish,
Anadromous and Marine Finfish, and Submerged
Aquatic Vegetation in the Polyhaline Zone

Salinity (ppt)	Temp. (C)	pH	DO (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)	Secchi Depth (m)	Metals (mg/l)	Herbicides (ug/l)	Chlorinated Hydrocarbons (ug/l)	Prey Species
18-32	15-30	6.5-8.5	>2.4	<15	<35	1.25	*	*	*	Zooplankton (3-35 micron size range)

D. Potential Habitat Objectives to Support
Finfish in the Euryhaline Pelagic Zone

Salinity (ppt)	Temp. (C)	pH	DO (mg/l)
5-32	10-25	6.5-8.5	>2.0-5.0

* See LRTF report (33) for specific quantitative and narrative requirements.

water quality standards may protect freshwater or saltwater organisms from acute and chronic effects of pollutants; however, direct application of these criteria and standards to the Chesapeake Bay requires technical consideration of their limitations in estuarine systems.

EPA freshwater criteria were developed to protect organisms in tidal and non-tidal freshwater systems using strictly freshwater species. The saltwater criteria have been based on bioassay results synthesized from a range of salinity test conditions using both estuarine and marine species.

The 1987 Federal Water Quality Act requires each state to adopt water quality standards to protect designated uses of its surface waters. The Act also requires EPA to publish water quality criteria and other information to assist the states in setting standards, and to review state standards for consistency with the Act's requirements²⁴.

Water quality standards both define the use of a particular body of water and describe the conditions necessary to protect or achieve its designated use, such as contact recreation or shellfish harvesting. Standards define, in numerical or narrative terms, levels of individual pollutants which cannot be exceeded if the designated uses of the water body are to be protected. Criteria, in contrast, are guidelines for specific pollutants to help state agencies develop freshwater or saltwater standards. They are similar to standards because they include recommended numerical limits and information on the environmental effects of pollutants.

Chesapeake Bay State Standards

Current standards for Chesapeake Bay and its tidal tributaries are based mainly on conventional physical, chemical and biological parameters--dissolved oxygen, temperature, pH, turbidity, and fecal coliform bacteria. A limited number of standards have been adopted for heavy metals and specific toxic compounds.

The District of Columbia, Maryland, Virginia, and Pennsylvania all define water quality standards as combinations of water uses to be protected and the water quality criteria necessary to protect those uses. Some standards have been adopted for specific chemicals other than conventional pollutants.

Throughout Chesapeake Bay, the classification of uses for tidal waters generally has been based on whether waterways are strictly fresh or saline. One set of standards applies to the tidal-freshwater areas of the Bay and another set to oligohaline, mesohaline, and polyhaline areas combined. Since the standards are so general for this two-class system--designed to protect human health first and the ecosystem second--they do not reflect the diversity of natural conditions within an estuarine environment. As a result, they are insufficient tools for restoring and protecting individual Bay habitats.

The current classification of uses for state water

quality standards in Chesapeake Bay tidal waters is shown in Figure 2-14. The state standards are described in Table 2-9, including the non-tidal waters of the lower Susquehanna River in Pennsylvania.

In Maryland, tidal surface waters designated for primary water contact recreation, water supply, and protection of aquatic life are located in the tidal-freshwater segments of the Bay. Remaining estuarine portions of the tributaries and the mainstem Bay are also designated as shellfish harvesting waters. The Upper Chesapeake Bay Phosphorus Limitation Policy adopted by Maryland contains effluent limitations for phosphorus discharged from large sewage treatment plants, but no nutrient standards.

Water quality standards for dissolved oxygen, pH, temperature, fecal coliform, and turbidity have been adopted by Maryland. There are six additional chemical specific standards that apply to Maryland's tidal waters.

All Virginia waters are designated to support recreational uses and for the propagation and growth of a balanced indigenous population of fish, shellfish and wildlife. As in Maryland, the estuarine portions of western shore rivers, the eastern shore tributaries and the mainstem also are specifically designated to support the propagation of shellfish. Virginia and District of Columbia tidal embayments on the Potomac River are subject to phosphorus effluent limitations for large sewage treatment plants under the Potomac Estuary Policy.

Virginia has adopted standards for dissolved oxygen, pH, and fecal coliform. The state has 24 water quality standards which apply to waters designated for public water supply. By July 1988, Virginia will be adopting nutrient water quality standards for certain waters of the state, including estuarine waters.

The District of Columbia has a tiered set of designated uses for its surface waters, including primary and secondary contact recreation, protection of aquatic life, public and industrial water supply, and navigation. The District's tidal waters are classified for all the above listed uses, with the exception of public water supply. District waters are all either tidal-freshwater (Potomac and Anacostia rivers) or free-flowing streams such as Rock Creek.

The tidal waters of the District have standards for dissolved oxygen, pH, temperature, fecal coliform, turbidity, and 70 specific organic chemicals and metals.

In Pennsylvania, the lower Susquehanna River has been designated to support warm water fisheries. Other uses designated in the Susquehanna River basin include potable, industrial, livestock and wildlife water supply, irrigation and recreational uses. Toxic substances are regulated through a comprehensive Toxics Management Strategy. Sewage and industrial waste treatment plants are subject to the phosphorus effluent limitations in the lower Susquehanna River in accordance with Pennsylvania phosphorus control regulations. The regulation enables Pennsylvania to control phosphorus whenever

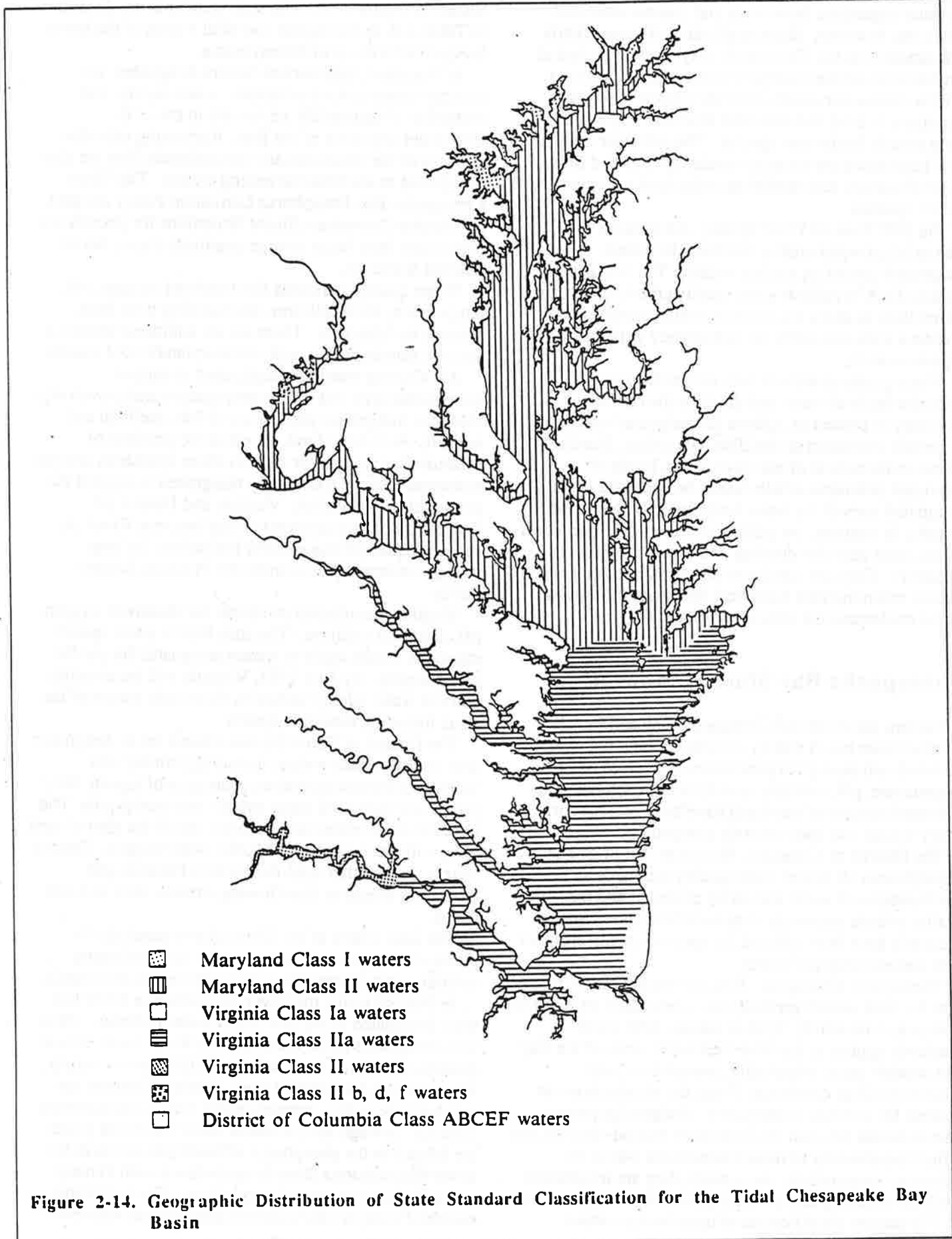


Figure 2-14. Geographic Distribution of State Standard Classification for the Tidal Chesapeake Bay Basin

Table 2-9. State Water Quality Standards for Chesapeake Bay, its Tributaries and the Lower Susquehanna River

State Class/ Designated Use	Description of Waters	Dissolved Oxygen (mg/l)		pH	Temp (F)	Fecal Coliform (max MPN/ 100 mg/l)	Turbidity (JTU)	Other Specific W.Q. Standards (ug/l)
		Min.	Avg. daily					
Maryland								
I	Water contact; recreation; aquatic life; water supply	5.0	-	6.5 to 8.5	90° or ambient	200	150	Aldrin-Dieldrin 0.003 Benzidine 0.1 DDT 0.001 Endrin 0.004 PCB 0.001 Toxaphene 0.005
II	Shellfish harvesting waters	5.0	-	6.5 to 8.5	90° or ambient	14	150	Aldrin-Dieldrin 0.003 Benzidine 0.1 DDT 0.001 Endrin 0.004 PCB 0.001 Toxaphene 0.005
Virginia								
I	Open ocean	5.0	-	6.0 to 9.0	-	200	-	(1)
II	Recreational use & wildlife	4.0	5.0	6.0 to 9.0	-	200	-	(1)
Ila	Propagation of shellfish	4.0	5.0	6.0 to 9.0	-	14	-	(1)
IIb	Propagation of shellfish	4.0	5.0	6.0 to 9.0	-	14	-	(1)
III	Public Water Supply	4.0	5.0	6.0 to 9.0	-	200	-	(2)

Table 2-9. (continued)

State Class/ Designated Use	Description of Waters	Dissolved Oxygen (mg/l)		pH	Temp (F)	Fecal Coliform (max MPN/ 100 mg/l)	Turbidity (JTU)	Other Specific W.Q. Standards (ug/l)
		Min.	Avg. daily					
District of Columbia								
A	Primary contact recreation	-	-	6.0 to 8.5	-	200	20	-
B	Secondary contact recreation	-	-	6.0 to 8.5	-	1000	20	-
C	Aquatic life; wildlife	4.0	5.0	6.0 to 8.5	90° (3)	-	20	Total Dis. Gases 110% Hydro. Sulfide 2.0 ug/l Oil and Grease 10.0 mg/l (4)
D	Public water supply	-	-	6.0 to 8.5	-	1000	20	(4)
E	Industrial water supply	-	-	6.0 to 8.5	-	1000	-	-
F	Navigation	-	-	-	-	-	-	-
Pennsylvania								
	Warm water fisheries	4.0	5.0	6.0 to 9.0	87° (6)	200	-	(7)

- (1) Additional chemical specific criteria for 35 selected metals and compounds.
- (2) Additional chemical specific standards for 24 selected metals and compounds.
- (3) Maximum change above ambient is 5° F
- (4) Additional chemical specific standards for 70 selected metals and compounds.
- (5) Mainstem from Juniata River to PA-MD border.
- (6) No change greater than 5o over ambient or 2o change per hour.
- (7) Additional chemical specific standards for 16 selected metals and compounds.

the state determines that instream phosphorus, alone, or in combination with other pollutants, or instream conditions contribute to impairment of designated uses identified in the water quality standards.

Pennsylvania has adopted standards for dissolved oxygen, pH, temperature, fecal coliform, and 16 selected metals and compounds for the lower Susquehanna River.

Adequacy of Existing State Standards for Tidal Waters

Conventional water pollutants (e.g. dissolved oxygen, pH) have in the past been considered to exert the greatest adverse impact on aquatic systems. Traditional water quality management since the early 1970s has been based upon the assumption that reducing pollutant loadings in line with water quality standards would result in attaining water quality goals in terms of use classifications. Implicit is the notion that meeting such water quality standards also would protect plants and animals dependent on the aquatic environment.

In the Chesapeake Bay, however, the achievement or the violation of standards does not always correlate with the survival or decline of living resource populations. Even strong enforcement of existing standards would not be adequate to protect estuarine habitats in an ecosystem as diverse as the Chesapeake Bay.

In some cases, existing standards may be unrealistic. A dissolved oxygen standard of 5 mg/l exists for all tidal waters of the Bay. Yet, deep areas of the mainstem Bay are thought to have undergone periods of hypoxia for centuries due to natural physical and chemical processes.

When criteria exist for non-conventional pollutants, primarily nutrients and toxic chemicals, they usually do not account for the relative effects of salinity on the processes of nutrient enrichment or on the toxicity of individual chemicals. For example, the toxicity of copper increases, but the toxicity of chromium decreases with increasing salinity. Levels of toxicants causing lethal or chronic effects are most often determined in tests using freshwater species. Saltwater criteria, in turn, are often based on results of toxicity tests using both estuarine and marine organisms. Neither set of criteria takes into account the gradations of salinity found in the Chesapeake Bay.

Like toxicity levels, the enrichment of estuarine waters with nutrients is tied closely to salinity patterns. In tidal-freshwater reaches of the Bay, an abundance of available nitrogen makes the scarcer forms of phosphorus the limiting factor in plankton growth. In polyhaline waters, nitrogen is the nutrient more often in short supply. Depending upon the salinity and local sources of nutrients, criteria for protecting waterways from hypoxia would differ. Water quality models developed for the Chesapeake Bay that incorporate the spatial and temporal

complexities of nutrient dynamics in tidal waters are necessary tools for establishing nutrient limitations or standards for individual regions of the Bay system.

As an interim measure, existing saltwater criteria for water quality parameters and toxicants could be utilized by the states for all the saline regions of the Bay. Where existing saltwater criteria do not provide adequate long-term protection, standards tied more tightly to variations in salinity, which can result in different toxicities for some compounds, could be developed.

Applied research should be directed to define the conditions necessary to support and protect estuarine life where existing scientific findings are insufficient. The adoption of standards and criteria designed to support regional habitat objectives should receive immediate attention by federal and state agencies responsible for criteria and standards development. The requirements assembled in the Living Resources Task Force report can be the basis for developing criteria, as outlined in the regional habitat objectives illustrated above, which are sensitive to the relative effects of toxics and nutrients in each region of the Bay.

Baywide Assessment and Management of Living Resources

The overall goal of the 1987 Chesapeake Bay Agreement is to provide for the restoration and protection of living resources, their habitats, and ecological relationships. The box on the following page lists specific commitments related to living resources that are contained in the Agreement. Overall, the Agreement calls for new Baywide approaches toward managing the conditions upon which the Bay's living resources depend and managing the resources themselves.

The regional habitat objectives described above address the first living resources commitment--to develop and adopt, by January 1988, guidelines for protecting water quality and habitat conditions. The habitat requirements assembled by the Living Resources Task Force have been grouped by habitat regions of the Bay into habitat objectives which, if met, would improve and protect the living environment of Bay species.

The adoption of habitat requirements alone, however, will not guarantee the long-term survival of fish and wildlife in and around tidal waters of the Bay. Many of these species are subject to commercial and recreational fishing pressure and habitat modification and loss. To address these factors, the Agreement also includes commitments to coordinate the monitoring, assessment, and management of Bay species along with water quality programs and fisheries management efforts so that the Bay is treated as one system, rather than distinct jurisdictions.

The Agreement recognizes that Baywide management of living resources should include monitoring and analysis of ecologically valuable species as well as those

1987 Chesapeake Bay Agreement Living Resource Goal and Commitments

AGREEMENT GOAL: Provide for the restoration and protection of the living resources, their habitats and ecological relationships.

AGREEMENT COMMITMENTS:

- By January 1988, to develop and adopt guidelines for the protection of water quality and habitat conditions necessary to support the living resources found in the Chesapeake Bay system, and to use these guidelines in the implementation of water quality and habitat protection programs. (Commitment achieved.)
- By July 1988, to develop, adopt, and begin to implement a Baywide plan for the assessment of commercially, recreationally, and selected ecologically valuable species.
- By July 1988, to adopt a schedule for the development of Baywide resource management strategies for - commercially, recreationally, and selected ecologically valuable species.
- By July 1989, to develop, adopt and begin to implement Baywide management plans for oysters, blue crabs, and American shad. Plans for other major commercially, recreationally and ecologically valuable species should be initiated by 1990.
- By December 1990, to develop and begin to implement a Baywide policy for the protection of tidal and non-tidal wetlands.
- To provide for fish passage at dams, and remove stream blockages wherever necessary to restore passage for migratory fish.

harvested by recreational and commercial fishermen. The Chesapeake Bay Stock Assessment Committee, funded by NOAA, has begun to satisfy this commitment. It has drafted a framework for a Baywide fisheries stock assessment and has funded a project to design a Baywide adult-finish trawl survey³⁷. While the framework and survey specifically address only commercial and recreational fishery species, they will be used to develop by July 1988 a Baywide living resources stock assessment plan that includes ecologically valuable species as well as harvestable species.

Regulatory management of living resources has traditionally focused on commercial fisheries, but the Agreement contains a commitment to incorporate ecologically valuable species in fishery management plans. The LRTF habitat requirements demonstrate that there are many organisms that commercial species depend upon which are non-commercial in terms of their economic importance. The Maryland Department of Natural Resources and the Virginia Marine Resources Commission have adopted a number of fisheries management plans for individual commercial species. Like the assessment of living resources, fisheries management plans could be expanded to include ecologically valuable species.

The Baywide fisheries management plans called for by the Agreement could be framed around the regional habitat objectives described above and could act as focal points for coordinating a range of environmental plans

and regulations affecting the Chesapeake Bay, such as water quality management (monitoring, analysis, and enforcement of standards), tidal and non-tidal wetlands regulations, dredging activities, land management (nonpoint source and shoreline erosion control), threatened and endangered species plans, living resources monitoring, and fisheries regulations.

Summary

The Living Resources Task Force efforts and the 1987 Agreement provide a foundation for managing the Bay's living resources from a regional habitat perspective. A review of current state water quality standards suggests that their existing design may not protect and restore living resources, especially with respect to the control of nutrients and related levels of dissolved oxygen. The 1987 Agreement recognizes a number of mechanisms to formalize Baywide planning and management of living resources. The creation of the Chesapeake Bay Program's Living Resources Subcommittee will support the development and implementation of plans for Baywide assessment and management of living resources. This new subcommittee can also act as a bridge between monitoring, modeling, research, and regulatory efforts to improve water quality of the Bay so that these efforts are managed more directly for restoring and protecting the Bay's living resources.

Chapter 3

Approaching the Nutrients Goal

Nutrient enrichment has been identified as a major factor in the decline of the Chesapeake Bay. Nutrients--primarily nitrogen and phosphorus from wastewater and runoff from farmland--drive the process of excess productivity, decomposition, and recycling that contributes to oxygen depletion of bottom waters. Only a reduction in phosphorus and nitrogen loadings can slow this process and bring about improved water quality in the Chesapeake. To achieve this end, the 1987 Bay Agreement calls for a 40 percent reduction by the year 2000 in nitrogen and phosphorus entering the mainstem of the Bay. Reductions will be calculated from point source loads for 1985 and nonpoint loads in a year of average rainfall.

Habitat requirements for representative living resources in Bay waters were described in Chapter 2. These requirements, as well as other habitat objectives identified through the Bay Program, were used as a guide in establishing the 40 percent nutrient reduction goal.

Relationships between nutrient loadings and key water quality parameters have been evaluated through modeling. These mathematical simulations helped determine the nutrient reductions needed to achieve living resource habitat and water quality goals in the Bay. A number of abatement and control strategies were analyzed to determine their effectiveness in reducing nutrient and chlorophyll *a* concentrations, and in increasing DO levels. These control alternatives will be described later in the chapter.

The Anatomy of Decline

Nutrient enrichment has been correlated with a number of unhealthy trends in Bay resources. Significant loss of SAV is a prime example. Excess nutrients enhance algal growth on the stalks and leaves of SAV and promote water column phytoplankton production. These effects, together with turbidity from suspended particles, reduce the amount of light reaching SAV below levels needed for healthy growth.

An overabundance of phytoplankton creates other problems as well. When production exceeds the food needs of the next trophic level, the plant organisms that are not consumed settle to the bottom and decay, using up oxygen in the process. Low dissolved oxygen levels in the Bay's bottom waters during the summer can be linked to the excess algal production fueled by nutrient enrichment. Decomposition of organic matter accumulated in bottom sediment releases nutrients to the water

column. When dissolved oxygen levels are low, the rate of ammonia and phosphorus release from sediment increases. These nutrients accumulate in bottom waters until mixed by storms or tides with surface water, where they help fuel further algal production.

Nitrogen and Phosphorus

The 40 percent reduction goal applies to both nitrogen and phosphorus. These two elements are linked as the principal nutrients affecting the Bay, but they differ significantly in their chemical behavior.

Nitrogen is extremely difficult to control. Highly soluble, it is not easily removed from wastewater during treatment. For the same reason, it leaches readily from soils and animal manure to be transported to the Bay via runoff and subsurface discharges. Some nitrogen escapes to the air as a gas, complicating the task of tracking this nutrient.

Phosphorus also is water soluble, but binds readily with soil particles on land and with suspended material and sediments in water. Large amounts of phosphorus are introduced to the Bay and its tributaries from wastewater and runoff.

The persistence of nutrients within the Bay reflects the limited exchange that occurs between the Chesapeake and the Atlantic. Nutrients tend to remain in the Bay to be recycled several times before permanent burial or removal. This nutrient "trapping" has been a major factor in the Bay's high productivity over the years; unfortunately, it also amplifies the adverse effects of excessive nutrient loads.

Other Factors Influencing Transport

Geology, land use, land management practices, and weather are among the many factors that influence the transport of nutrients within the Bay watershed.

Some nutrients discharged in the watershed never reach the Bay, while others are merely delayed in their movement. Phosphorus may be trapped in the sediments of natural or man-made reservoirs; nitrogen may be converted to nitrogen gas in the absence of dissolved oxygen; either nutrient may be taken up in plant tissue. Sediments containing nutrients may be stored in reservoirs, river beds, and the soil in years of little rainfall only to be released during floods and washed to the Bay.

Above-average rainfall increases nonpoint nutrient loads to the Bay; in dry years, point sources and base flow (ground water feeding into rivers) are of relatively

greater importance as contributors of nitrogen and phosphorus to the Bay.

Seasonal and regional variations in nutrient loadings also are significant in the Bay basin. Nitrogen input rises at winter's end when melting snow and runoff from seasonal rains swell river flows. The spring freshet brings an average total nitrogen load of 70 million pounds to the Bay, about twice that of other seasons³⁸. The phosphorus loads also vary seasonally, depending in part on freshwater flow and on the impact of storms. If the bottom water becomes anoxic--as it does during the summer in parts of the Bay--phosphorus and nitrogen are released in increased amounts from sediment and reintroduced to the water column. This benthic nutrient release in summer can be many times that which occurs in other seasons.

The impact of nitrogen and phosphorus on water quality differs from one end of the Bay to the other. The Susquehanna River carries a large burden of nitrogen from agricultural lands to the upper Bay. In the lower Bay, on the other hand, the mix with nitrogen-poor oceanic waters tends to increase the significance of phosphorus.

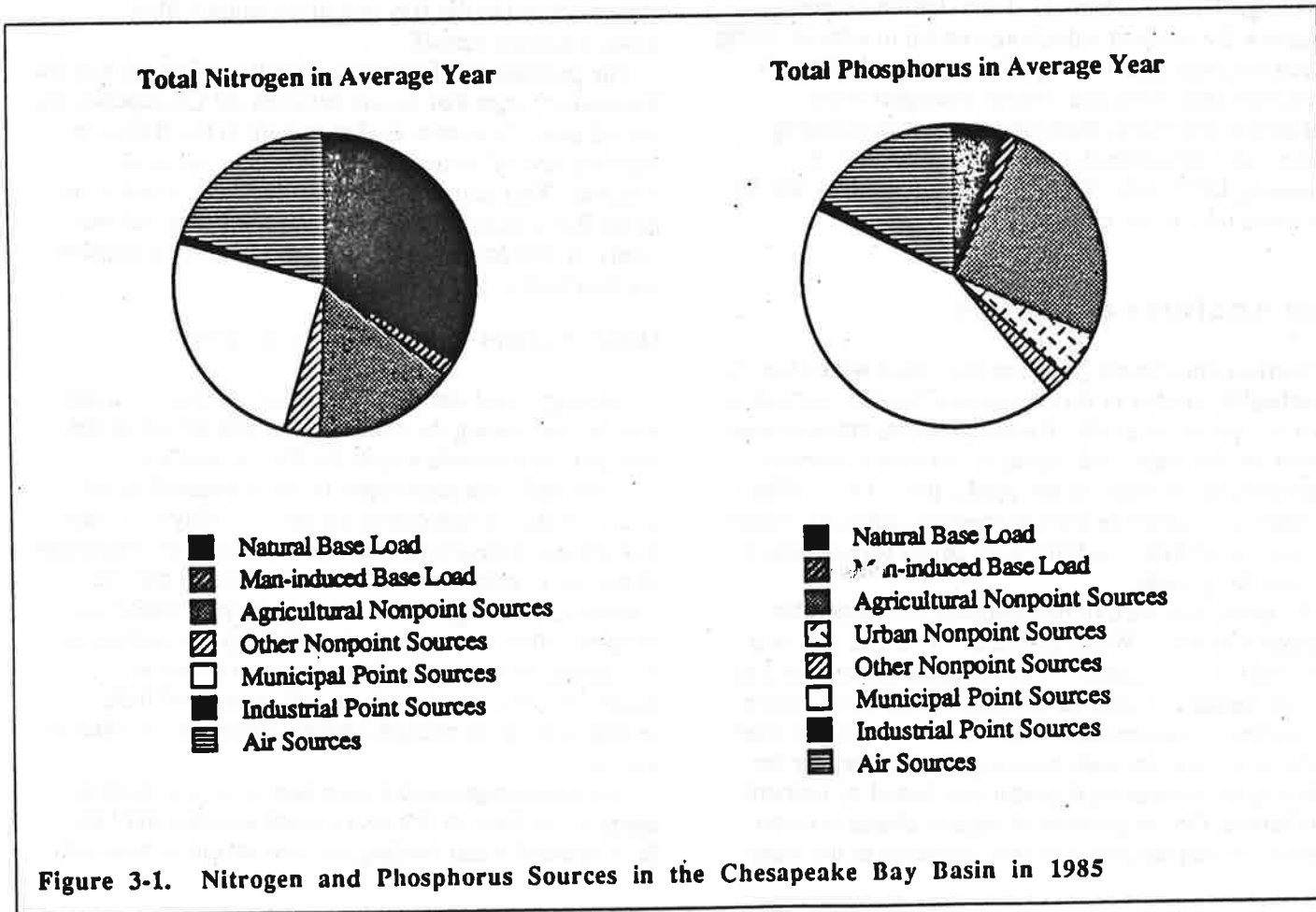
Wastewater treatment managers commonly use the "limiting nutrient concept"³⁹ to determine the most efficient nutrient control strategy. The concept is based on the principle that controlling the nutrient in least

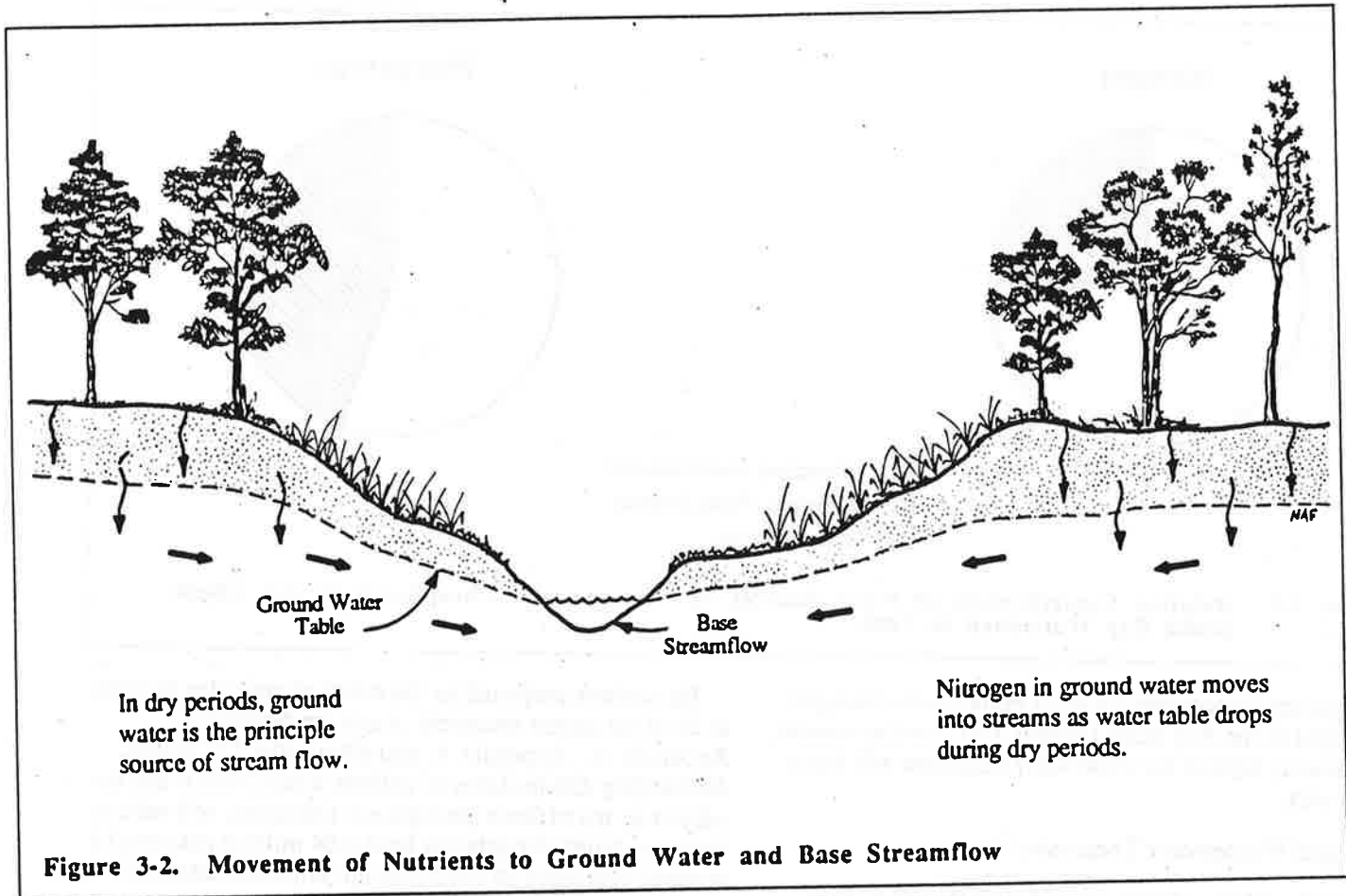
supply will effectively limit algae growth. In the Bay, however, the "limiting nutrient" changes from place to place, from season to season.

Nutrient Sources and Controls

Nutrients that reach the Bay and its tributaries originate both from point sources (municipal and industrial wastewater treatment facilities) and nonpoint sources (cropland, animal wastes, urban runoff, base flow). The 40 percent nutrient reduction goal applies to all controllable sources, both point and nonpoint. Relative magnitudes of nutrient source categories are shown in Figure 3-1, which reflects 1985 point source loads and estimates of nonpoint source contributions based on average year precipitation and 1985 land use information^{36, 40}.

Base flow (subsurface waters that recharge streams as illustrated in Figure 3-2) is the largest contributor of nitrogen--about 45 percent. It is roughly estimated on the basis of model runs, however, that as much as 95 percent of base flow nitrogen may be from natural sources. The contribution from natural sources would be present even under pristine conditions. Only the smaller percentage resulting from human activity is considered susceptible to control. The total phosphorus contribution from base





flow is much smaller (9 percent) because soil effectively adsorbs this nutrient from infiltrating surface water. About half of the phosphorus in base flow is believed to be from natural sources.

Of the total nutrient load from municipal sewage treatment plants, 42 percent of the phosphorus and 67 percent of the nitrogen is discharged by facilities located below the fall line (BFL) in the coastal plain and nearest the Bay. Since loads from these plants are not subjected to the chemical and physical degradation that occurs in transport, they have the greatest potential to impact upon Bay water quality. The plants below the fall line account for 66 percent of the total municipal wastewater flow in the watershed, another manifestation of the population distribution shown in Table 1-1.

The phosphorus load from BFL plants is low relative to total flow as the result of improvements in wastewater treatment required under regional control programs. These regional programs are described later in this chapter.

Industrial sources contribute only a small part of total point source nutrient discharges in the watershed. They account for 8 percent of the nitrogen and 2 percent of the phosphorus.

Surface runoff from agricultural activities (cropland and animal wastes) is responsible for about 29 percent of the phosphorus and 19 percent of the nitrogen discharged in the watershed. Runoff from forested lands

and urban areas contributes small amounts of the two nutrients.

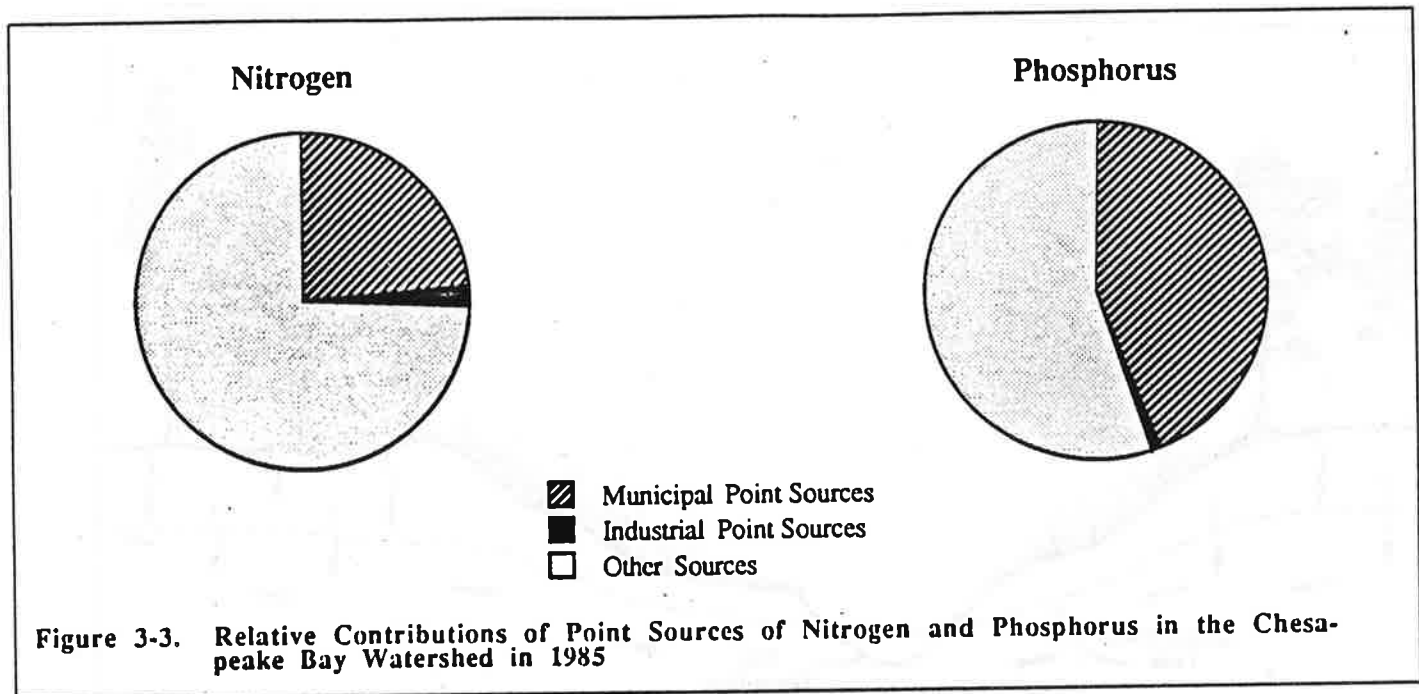
Strategies to reduce nutrient enrichment of the Bay must take into account the relative importance of the various nitrogen/phosphorus sources as well as the existing control programs described below.

Point Sources

Industries generate some nutrients in wastewater discharges, but the percentage is small compared to the contribution of municipal wastewater treatment plants. (Figure 3-3). Roughly 25 percent of the 6,000 point source dischargers in the Bay basin are municipal treatment plants. Of these, the 200 largest facilities, all municipally owned, are responsible for 95 percent of the municipal wastewater effluent volume. Fifty-eight of these large facilities discharge into tidal portions of the Bay and its tributaries.

Wastewater discharges from point sources are regulated under permits issued by the States or EPA. All permits require certain minimum levels of treatment; additional treatment may be required if necessary to protect water quality in the tributaries or the Bay.

Municipal facilities along the lower Susquehanna, the West Chesapeake (the minor tributaries of the middle and upper Bay western shore), and the Potomac and James rivers below the fall line (see map, page viii, for tributary



locations) are responsible for most point source nitrogen discharged in the Bay basin (Figure 3-4). For this reason, the following section on wastewater treatment will focus on this area.

Municipal Wastewater Treatment

The federal Clean Water Act requires that all sewage treatment works provide secondary or, in some cases, higher levels of treatment.

Construction grants provided under a federal/state cost-sharing program assist communities in building new municipal treatment plants or upgrading older facilities to meet statutory treatment requirements. Improvements funded under this program have enabled municipal sewage plants to reduce total phosphorus loads by about 60 percent from 1965 to 1985 despite increases in wastewater flow³.

Additional phosphorus reductions will result from phosphate detergent bans enacted by the District of Columbia, Maryland and Virginia. Preliminary data from the Blue Plains STP in the District of Columbia and six plants operated by the Washington Suburban Sanitation Commission indicate that the ban has reduced effluent phosphorus concentrations by 25 percent or more. Operating and maintenance costs in these plants were reduced 10 to 15 percent. The savings are achieved through decreases in chemical dosage and reduced sludge generation.

In 1985, 25 municipal dischargers below the fall line were in the process of upgrading levels of treatment to comply with secondary treatment requirements and State water quality standards. These improvements, referred to subsequently as "planned upgrades," together with phosphate detergent bans, are expected to form the core of nutrient reductions from this category of dischargers.

Reductions projected as the result of upgrades planned at 20 of the largest treatment plants are detailed in Appendix A. Appendix A also shows that 117 plants, discharging 236 millions of gallons a day (MGD) and not subject to any effluent phosphorus limitation, will reduce their combined phosphorus load 0.64 million pounds (18 percent) compared to 1985 through implementation of phosphate detergent bans.

Planned upgrades are expected to achieve significant results by the year 2000:

- 12 plants, discharging 275 MGD, will reduce their combined biochemical oxygen demand (BOD) load by 74 percent compared to 1985.
- 14 plants, discharging 293 MGD, will reduce their phosphorus load by 41 percent from the 1985 level.
- 5 plants, discharging 202 MGD, will reduce their total nitrogen load by 35 percent from 1985.

Overall, planned upgrades and current phosphate detergent bans are expected to reduce phosphorus discharges by 1.44 million pounds a year (25 percent) and nitrogen by 4.74 million pounds annually (9 percent) compared to 1985 levels. Population growth will offset these reductions, however, resulting in a net decrease in phosphorus loads of 0.8 million pounds a year (15 percent) while nitrogen loads will increase by 3.3 million pounds a year (6 percent).

In addition to improving treatment, some plants are expanding their total capacity. Table 3-1 shows 1985 municipal wastewater discharges by state, existing capacity, and discharges projected for the year 2000. In the aggregate, current or planned capacity appears adequate to treat expected flow increases, or even larger volumes. Growth greater than expected may occur in some sewer service areas, however, requiring an

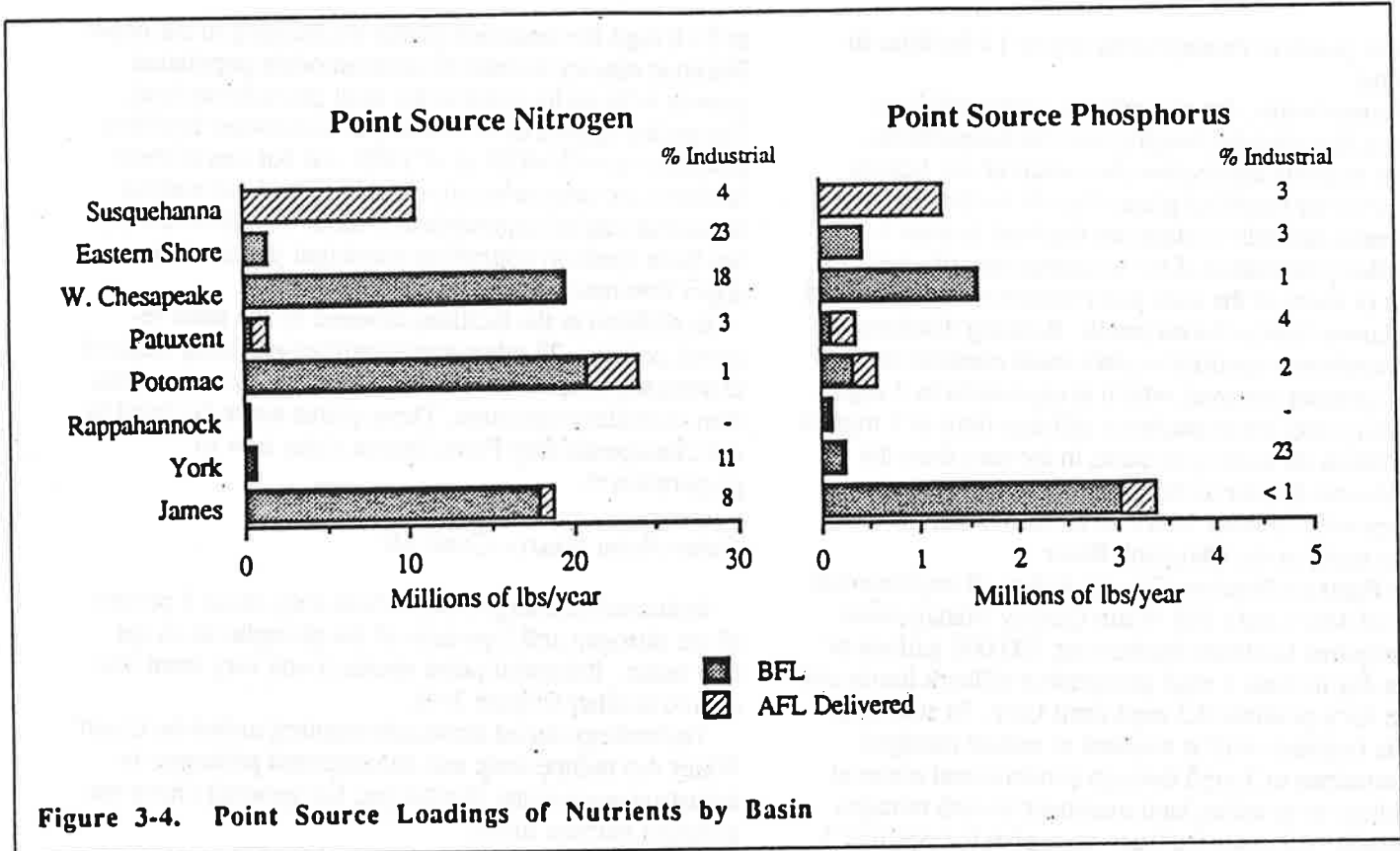


Figure 3-4. Point Source Loadings of Nutrients by Basin

expansion of capacity at individual facilities beyond that which is currently planned.

Regional Control Programs. Effluent limitations more stringent than national standards are required under three programs currently in effect in various areas of the watershed. The three are: the Upper Chesapeake Bay Phosphorus Limitation Policy, ⁴¹ the Patuxent Nutrient

Control Policy, ⁴² and the Potomac Strategy ⁴³. Overall, these programs cover 71 municipal facilities that accounted for half the municipal wastewater flow in the Bay basin in 1985.

The Upper Chesapeake Bay Phosphorus Limitation Policy, ⁴¹ initiated in 1979 to reduce nutrient enrichment of the upper Bay, was applicable in 1985 to 40 municipal

Table 3-1
Existing and Future Municipal Plant Flows (MGD) below the Fall Line

State	1985 Flow	Year 2000 (CBP) ^a		Year 2000 (states) ^b		Design capacity ^c	
		Flow	% change	Flow	% change	Flow	% change
DC	301	306	+ 1.7	352	+ 17	370	+ 23
MD ^d	291	360	+ 24	406	+ 40	423	+ 45
VA	356	389	+ 9	564	+ 58	537	+ 52
Total	948	1055	+ 11	1322	+ 39	1330	+ 40

a - CBP estimates based on state projected county population increases, and state year 2000 projections for Back River, Patapsco and Western Branch STPs.

b - Virginia estimates are based on design flow (currently planned and approved) for year 2000; other estimates on facility plans and other available information.

c - CBP estimates derived from Needs Survey and state data.

d - Includes 100 MGD of treated wastewater used as cooling water.

treatment plants in Pennsylvania and to 11 facilities in Maryland.

In Pennsylvania, the phosphorus limit applies to treatment facilities discharging into the Susquehanna River or its tributaries below the mouth of the Juniata River. New or modified plants that do not have phosphorus controls in place are required to meet a 2 mg/l effluent limitation if the discharge contributes 0.25 percent or more of the total point source phosphorus load in the Lower Susquehanna pools. Existing dischargers with phosphorus controls in place must continue to provide 80 percent removal, which is equivalent to 2 mg/l.

In Maryland, the phosphorus effluent limit of 2 mg/l is applicable to all municipal plants in the area from the Pennsylvania border to the Gunpowder River, and to facilities with flows of 10 MGD or more from the Gunpowder south to the Choptank River.

The Patuxent Nutrient Control Policy, ⁴² implemented as part of Maryland's 208 Water Quality Management Plan, requires facilities discharging 500,000 gallons or more a day to meet 1 mg/l phosphorus effluent limits and to plan for a possible 0.3 mg/l limit later. In addition, specific facilities will be required to reduce nitrogen concentrations to 3 mg/l through conventional removal technology or to utilize land treatment to curb nitrogen discharges. All other facilities must plan for possible 3 mg/l nitrogen limits. The Patuxent policy applies to 10 municipal facilities discharging 36 MGD as of 1985.

Like the Patuxent Policy, the Potomac Strategy ⁴³ also is being implemented as part of a 208 Water Quality Management Plan. The Potomac Strategy Management Committee reduced the phosphorus limit from 0.22 mg/l

to 0.18 mg/l for treatment plants discharging to the upper Potomac estuary in order to accommodate population growth with no increase in the total phosphorus load. The policy applies to 11 municipal wastewater facilities discharging 440 MGD as of 1985. All but one of these facilities are close to meeting the limit without making additional capital expenditures. About \$1 billion already has been spent on upgrading municipal plants in the upper Potomac estuary.

In addition to the facilities covered by the three regional policies, 28 other municipalities are being required to impose phosphorus and BOD controls more stringent than secondary treatment. These plants are to be listed in the Chesapeake Bay Point Source Atlas now in preparation ⁴⁴.

Other Point Source Controls

Industrial dischargers contribute only about 8 percent of the nitrogen and 2 percent of the phosphorus in the Bay basin. Industrial point source loads vary from one area to another (Figure 3-4).

Technology-based standards required under the Clean Water Act reduce toxic and conventional pollutants in industrial wastewater discharges, but generally have not included nutrient limits.

Twenty industrial dischargers in Maryland and Virginia currently are required to meet state nitrogen and/or phosphorus effluent limits.

The feasibility of developing BAT-level nutrient limitations paralleling those applicable to other pollutants may need to be investigated.

Table 3-2
Land Use in the Chesapeake Bay Watershed

Sub-basin	Sub-basin acreage	Land Uses (percent of acreage)			
		Cropland	Pasture	Forest	Urban
Susquehanna	17,443,932	20	8	64	8
Eastern Shore	2,664,759	39	2	49	10
West Chesapeake	1,089,245	22	8	41	29
Patuxent	494,478	16	6	46	32
Potomac	8,948,709	17	14	58	11
Rappahannock	1,969,984	17	11	65	7
York	1,724,448	12	5	71	13
James	6,618,064	8	9	74	10
WATERSHED TOTAL	40,991,379	18	9	63	10

Note: The above land area does not include water.

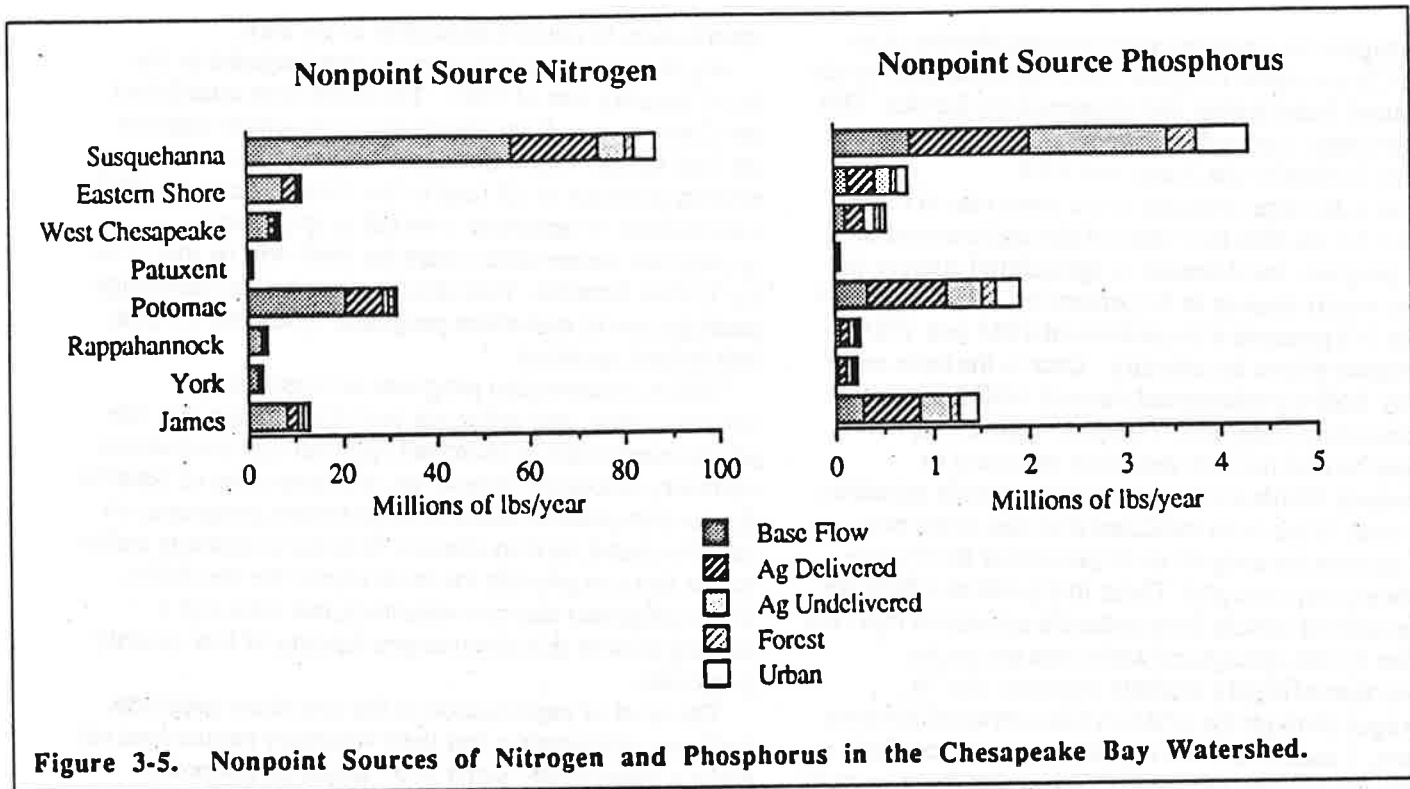


Figure 3-5. Nonpoint Sources of Nitrogen and Phosphorus in the Chesapeake Bay Watershed.

Combined sewer overflows and other periodic overflows, bypasses, and spills of raw sewage are other point sources of nutrients. Their cumulative effect on Bay waters has not been quantified, but these discharges may contribute significant concentrations of nitrogen and phosphorus to local waters.

Chesapeake Bay Program data systems focus on pollution sources located below the fall line (see Figure 1-1). This is because these sources make the largest contribution of nutrients to the Bay and they cannot be quantified unless they are individually enumerated. They are also the closest to the Bay and nutrients they discharge are the most certain to be transported to the Bay and to have negative influences on Bay water quality.

Sources that discharge above the fall line can be quantified at the fall line, which forms a convenient gate at which to measure both flows and loads. Quantified estimates of pollution loads referenced in this report will specifically note the zone they cover. Discussions of pollution control programs, however, apply equally to pollution emissions originating both above and below the fall line.

Nonpoint Sources

Nonpoint source nutrient contributions are largely a function of land use. For purposes of relating land use and nutrient loads, the nearly 38 million acres of land in the Bay basin may be characterized generally as forest, cropland, pasture, and urban areas (Table 3-2). Although cropland and pasture comprise only 27 percent of the acreage in the watershed, these agricultural operations

are the primary sources of nonpoint nutrient pollution. Nonpoint source contributions are shown, by tributary, in Figure 3-5.

Since the signing of the 1983 Bay Agreement, state and federal programs to reduce nonpoint source pollutants have focused primarily on agricultural lands through the application of a variety of the site-specific controls called best management practices⁴⁵. Only pilot-scale projects have been initiated thus far to deal with urban nonpoint nutrient sources.

Agricultural Sources and Programs

Agricultural nonpoint source nitrogen discharges range from 19 percent in years of average rainfall to about 32 percent in wet years. The phosphorus contribution ranges from 29 percent in average years to about 57 percent in wet years. Cropland erosion loss and animal waste are the principle sources of the agricultural nutrient load. In the base year of 1985, erodible soils and animal waste were about even as sources of nutrients in Pennsylvania, Maryland and for the Bay basin as a whole. Manure was relatively more significant as a nutrient source in Virginia. Figure 3-6 shows the breakdown between these two agricultural sources for each major tributary.

Since 1985, Chesapeake Bay Implementation Grants have been available to help states establish or expand agricultural cost-share programs. Among other projects, these EPA grants fund installation of BMPs. There are now more people interested in participating in these programs than current program funding can handle. USDA provides funds to implement cropland and animal waste

best management practices under the cost-sharing Agricultural Conservation Program (ACP) administered by the Agricultural Stabilization and Conservation Service. This ASCS program accomplishes many of the same goals as programs funded by the States and EPA.

If load reductions continue at the same rate as those estimated for the first two years of the Implementation Grants program, the decrease in agricultural sources of nitrogen would amount to 35 percent by the year 2000 ⁴⁵.

Table 3-3 presents a breakdown of 1985 and 1986 conservation efforts by tributary. Data in the table represent only BMPs implemented through ASCS or state/CBP cost-share programs. There are reports, however, that some landowners are installing structural or management BMPs on their own without such subsidies. In one state, it has been indicated that cost-share programs account for only 40 to 60 percent of BMPs currently being implemented. These independent efforts are an unquantified benefit from technical assistance routinely provided by the agricultural assistance programs.

Protection of highly erodible cropland also is encouraged through the USDA's Conservation Reserve Program. Landowners who qualify are compensated annually for keeping land out of production for at least 10 years. In contrast to some other areas of the nation, the program has not attracted many participants in the Chesapeake Bay area. The level of compensation is relatively low in comparison with land values in the watershed. Some landowners whose property is in the probable path of urban development also are reluctant to commit land to conservation for an entire decade. Approximately 44,000 acres are currently in conservation reserve in the watershed. Significant expansion is not considered likely at the present rate of compensation, but making this program more attractive could represent an important

contribution to nutrient reduction in the Bay.

Another conservation initiative was included in the Food Security Act of 1985. The legislation established the Conservation Compliance Program which requires the Soil Conservation Service (SCS) to evaluate the erosion potential of all land in the United States by 1990. Landowners or operators who fail to implement appropriate conservation plans by 1995 will be ineligible for USDA benefits. This deadline has helped encourage participation in cost-share programs sponsored by state and federal agencies.

USDA conservation programs are essentially voluntary now, and influence over the location and rate of implementation is exercised only through educational outreach, cost-share incentives, and restriction of benefits for noncompliance. State/EPA cost-share programs, on the other hand, tend to channel funding to counties and/or basins that can provide the most impact for the dollar. These programs also are voluntary, but most use a ranking system that discourages funding of low-priority proposals.

The level of participation in the cost-share programs has been encouraging, but their voluntary nature does not allow a disciplined "worst first" attack on nonpoint problems. Economic considerations apparently prompt some landowners to forego subsidies and other benefits rather than install BMPs. In addition, about 30 percent of the farmers who enroll as participants in a given year fail to complete BMP commitments.

Some BMPs that reduce nutrient and soil loss in runoff may have the undesirable side effect of increasing concentrations of nitrogen and pesticides in ground water. Controlling nutrient movement to ground water has not been emphasized in Bay Program implementation efforts but nutrient management ⁴⁶, which is coming into

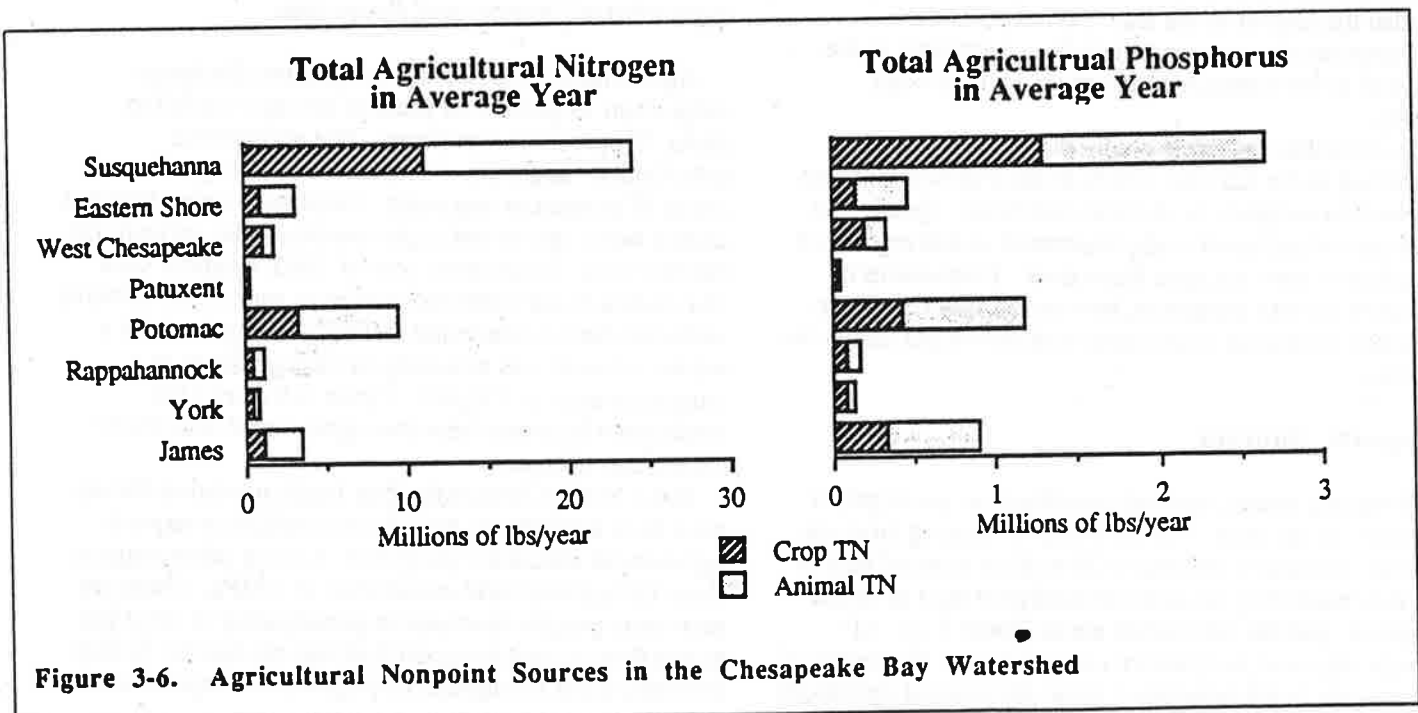


Figure 3-6. Agricultural Nonpoint Sources in the Chesapeake Bay Watershed

Table 3-3
Agricultural NPS Nutrient Reduction in Terms of Soil Saved and Manure Stored

Tributary	NITROGEN		PHOSPHORUS	
	lbs needing treatment in 1985	Percent reduced 1985-86	lbs needing treatment in 1985	Percent reduced 1985-86
Susquehanna	170,936	2.61	33,249	2.56
Eastern Shore	20,657	9.49	3,961	9.56
West Chesapeake	13,773	3.10	2,705	3.11
Patuxent	7,359	2.10	1,473	2.02
Potomac	98,807	3.25	19,011	3.29
Rappahannock	21,789	5.75	4,237	6.01
York	12,024	3.81	2,347	3.93
James	39,628	4.97	7,607	5.27
BASIN TOTAL	384,973	2.96	74,590	3.03

increasing use as a BMP, does have the effect of lowering ground water nitrogen. Nutrient management encourages greater reliance on animal wastes in place of chemical fertilizers, reducing overall use of nitrogen. Utilizing the natural filtering and nitrogen-fixing capabilities of riparian filter strips and wetlands also can reduce nitrogen levels in ground water ⁴⁷.

Nonpoint Sources

The relative contribution of other nonpoint sources of nutrients is shown in Figure 3-7. These include urban and industrial runoff and base flow carrying nutrients stemming from human activities such as fertilizer application and natural releases to ground water. The sources are grouped here because they are not well quantified except in the aggregate, and in most cases no programs exist to control them.

Urban and industrial runoff is a relatively small contributor to nutrient loads, although local effects may be damaging where discharges empty into nursery grounds and critical habitats for aquatic biota. Basin-wide, such discharges account for about 4 percent of the total nitrogen load and about 6 percent of the phosphorus.

Comprehensive efforts to apply urban runoff controls are under way along the Anacostia River. Anne Arundel County also has begun to implement a series of controls in an effort to improve water quality in its tributaries and the Bay. Local and regional agencies within the Rappahannock River drainage basin have begun development of strategies to manage urban runoff in areas which are beginning to experience intensive development.

Stormwater runoff has not been regulated as a point

source discharge previously, but Clean Water Act amendments enacted in 1987 provide for the control of these discharges from industrial sites and large urban areas under NPDES permits.

Permit requirements for industrial stormwater discharges are to be established by February 1989. Permit holders will have five years to comply, well within the timetable in the 1987 Bay Agreement.

Stormwater control requirements are to be prepared by February 1989 for urban areas with populations of 250,000 or more, and by February 1991 for areas with populations of 100,000 to 250,000. In both cases, jurisdictions will have five years to comply.

Base flow is another example of nonpoint sources which are not now well controlled. Carrying nutrients contributed by ground water moving through the soil, base flow tends to come to the surface at low points in the terrain, forming wet weather springs and eventually reaching surface streams. Since the concentration of nutrients in base flow is highly dependent on the concentration of nutrients in the soil, excess use of fertilizer results in increased levels of nutrients in base flow and larger loads to nearby streams.

Studies conducted during the research phase of the Chesapeake Bay Program in the lower Susquehanna River showed 65 percent of the nitrogen and 19 percent of the phosphorus load delivered to the fall line originated as base flow ⁴⁰. If the Susquehanna is assumed to be typical of tributaries in the watershed, it seems clear that a strategy to curtail excessive use of fertilizer is essential in order to achieve significant reductions in nutrient loads, especially nitrogen.

Acre for acre, forests are the lowest nutrient exporters

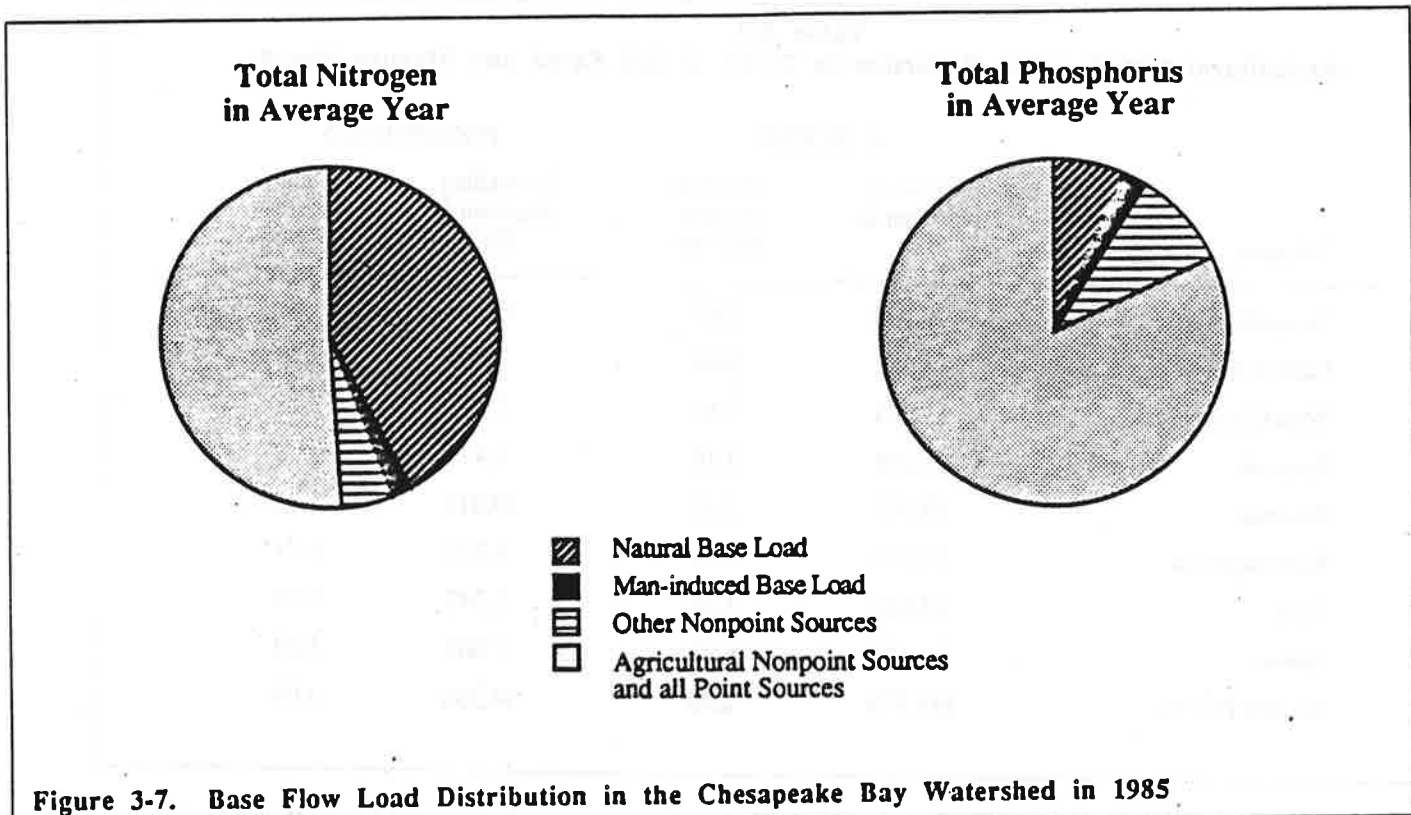


Figure 3-7. Base Flow Load Distribution in the Chesapeake Bay Watershed in 1985

in the Bay basin. Forested lands make up about 63 percent of the watershed but contribute only 2 percent of the nitrogen and about 3 percent of the phosphorus. In fact, the trees and grasses of forests and meadows actively remove nutrients, indicating the potential value of such land uses as elements in control programs. The Bay watershed's forested acreage has increased about 12 percent since 1950, according to U.S. Forest Service estimates⁴⁸, but urbanization may be reversing that trend in Maryland.

Projecting Future Bay Quality

Mathematical models are used to estimate effects on the Bay of various alternative control strategies. A model is a simplified representation of reality. Simplification is necessary to isolate and focus on key features relevant to water quality. Mathematical equations are altered to simulate the effects on Bay water quality of varying reductions in nutrient loads.

Two models were used in the preparation of this report. One was the Steady-State Model of water quality in the Bay. The other—the watershed model—simulated the production and delivery of nutrients to the Bay. (Future plans call for refining the watershed model to more accurately represent activities in the watershed. The Water Quality Model is being upgraded to simulate the Bay in greater detail and to show time-variable changes.)

Development of the Steady-State Water Quality Model of the tidal estuary and major tributaries was completed by the Chesapeake Bay Program in March 1987^{49, 50}.

The model assesses the effect of nutrient inputs on phytoplankton growth and dissolved oxygen levels. Major model inputs included fresh water flows and nutrient loads measured at the fall line, nutrient contributions from both point and nonpoint sources below the fall line, atmospheric nutrient loads, Bay bottom sediment nutrient loads, and dissolved oxygen.

The time period over which modeling results are averaged is July and August. These two months were selected because biological productivity is relatively high, fresh water flows are low, stratification of the Bay is relatively constant, and DO concentrations are most depressed.

The model was calibrated to average July/August conditions for the years 1965, 1984 and 1985. Those three years were characterized by contrasting degrees of fresh water flow, vertical stratification, and point and nonpoint nutrient inputs, and by wide differences in fresh water flow from the tributaries (Figure 3-8). In 1965, fresh water flows were extremely low; 1985 was closer to an average year, with fresh water flows slightly more than twice the level of 1965. In contrast, fresh water flow in 1984 were nearly six times higher than those of 1965. Differences in fresh water volumes have two significant effects. One is that nonpoint nutrient loads in a dry year are about half what they are in a wet year. More important, fresh water inflows overlay denser estuarine water, resulting in strong vertical stratification in wet years. Stratification retards the transfer of oxygen to bottom layers of the Bay.

A number of major conclusions were drawn from the calibration of the water quality model and subsequent sensitivity evaluations:

- The decrease in dissolved oxygen concentrations in bottom waters of the Bay from 1965 to 1985 was due to the combined effect of increased oxygen demand and nutrient fluxes from bottom sediments, together with phytoplankton respiration and bacterial oxidation.

- Phosphorus tends to be the "limiting nutrient" in the upper Bay; nitrogen is potentially more limiting in the lower Bay.

- Model calculations indicate that bottom sediments were the largest source of dissolved inorganic phosphorus (DIP) and ammonia (a form of nitrogen) in the summers of 1984 and 1985. Low dissolved oxygen in summer increases the nutrient flux of phosphorus and ammonia. If bottom dissolved oxygen levels were higher, phosphorus would remain chemically bound to metal compounds in the sediment and ammonia would be largely converted to nitrogen gas⁵¹. With current low dissolved oxygen concentrations, estimated contributions to the Bay were 65 percent of the total dissolved inorganic phosphorus load, and 45 to 57 percent of the ammonia. A methodology was developed which related projected changes in sediment oxygen demand and sediment nutrient release rates to reductions in point and nonpoint source loads. This "sediment methodology" is used in conjunction with the calibrated model to make projections of the effects of point and nonpoint sources control strategies.

- Bay water quality is controlled largely by bottom sediment oxygen demand, the rate of nutrient flux from sediments, and the degree of vertical stratification (a

function of fresh water flow). Higher flows increase stratification, which magnifies the effects of bottom sediment oxygen demand and nutrient release. The result is lower dissolved oxygen concentrations in bottom waters and more chlorophyll in surface waters.

- Neither fall line nor point source nutrient reductions have significant direct impact on main Bay water quality, but they can decrease sediment oxygen demand and nutrient release rates by reducing the amount of nutrients and organic matter deposited to bottom sediments. Nutrient reductions also can improve tributary water quality.

The Steady-State Bay model, as is the case with any model, has limitations that should be kept in mind in considering model results. Because of these limitations:

- Issues involving a time factor could not be addressed by the summer average Steady-State Model. This limitation precluded, for example, determining the effects of high flow spring runoff, looking at the impact of past events on existing water quality, or evaluating the effects of winter/spring algal blooms on summer water quality.

- Projected changes in sediment oxygen demand and sediment nutrient release rates in response to varying point and nonpoint source loads are based on a simplified "sediment methodology." This framework limits assessments to effects of regional point source strategies and tradeoffs between point and nonpoint source strategies.

- The model tends to underestimate the water quality benefits of nitrogen control strategies under 1985

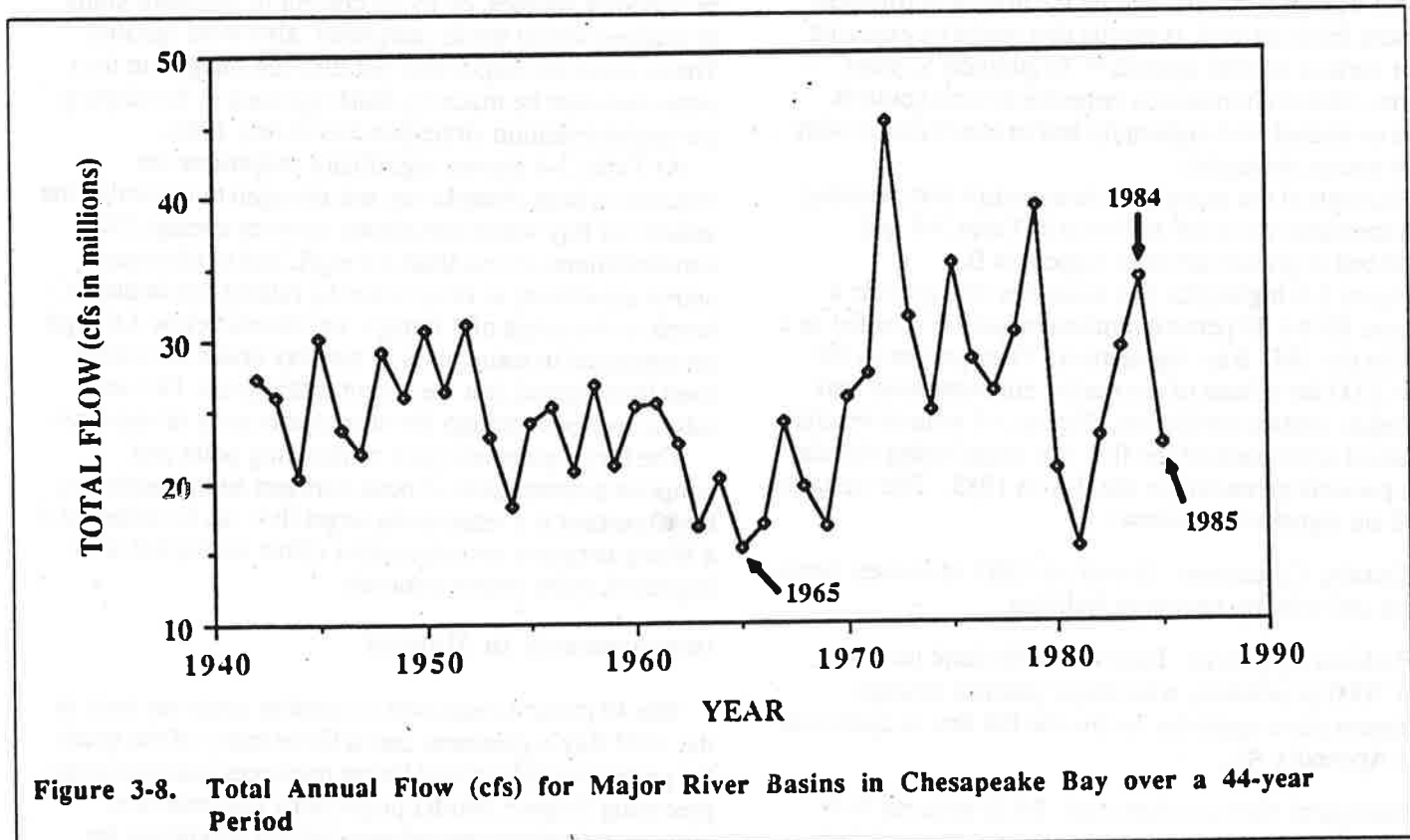


Figure 3-8. Total Annual Flow (cfs) for Major River Basins in Chesapeake Bay over a 44-year Period

circulation conditions. Model projections under 1984 circulation conditions appear to be more accurate for nitrogen, although some uncertainty remains due to the detection limits of 1984 nutrient data.

- Biological nutrient control technology (nitrification/denitrification) is most effective during summer conditions simulated by the Steady-State Model. Colder weather decreases the metabolic rates at which bacteria nitrify wastewater, making nitrogen removal more difficult. Such seasonal variations should be considered in evaluating BNR technologies. Municipal loadings shown in Appendix C assume year-round removal of nitrogen under summer conditions.

The Bay Program Modeling Subcommittee and the Model Evaluation Group (MEG), an expert advisory panel, provided guidance and carried out detailed reviews throughout the development process to ensure the quality and technical validity of the model. MEG concluded that "the water quality model calibrations are consistent with the observed data given the present model structure, the steady-state limitation, and the available data. We believe that the model can be useful in certain aspects of wastewater load allocation processes, particularly in looking at the impact of regional loads and in setting Bay water quality standards."

Evaluating Reduction Alternatives

The Chesapeake Bay Steady-State Water Quality Model was used to demonstrate the effects of different nutrient levels as well as results that might be expected from various control options⁵². In addition to point source control alternatives, nonpoint source controls were evaluated both separately and in combination with point source strategies.

Fourteen of the many pollution control and planning year scenarios modeled are listed in Table 3-4 and described in greater detail in Appendix B.

Figure 3-9 highlights five scenarios that provide a context for the 40 percent nutrient reduction selected as a goal in the 1987 Bay Agreement. They project to the year 2000 the effects of alternative environmental and pollution control conditions. Figure 3-9 reflects results obtained when each of the five was tested using circulation patterns prevailing in the Bay in 1985. The scenarios used are summarized below:

1. Existing Conditions. Based on 1985 land uses, population and existing treatment facilities.

2. Planned Upgrades. Based on 1985 land uses and year 2000 population, with major planned sewage treatment plant upgrades below the fall line in operation (see Appendix A).

3. Biological Nutrient Removal. BNR systems^{53, 54} removing both nitrogen and phosphorus at municipal

wastewater treatment plants located below the fall line (see Appendix C).

4. 40 Percent Reduction. Application of the 40 percent reduction goal to total phosphorus and total nitrogen from municipal and industrial point sources, and urban and agricultural nonpoint sources (including nutrients in stormwater and those in base flow stemming from farming activities).

5. Pristine Conditions. This scenario assumes a completely forested watershed with no urban or industrial point or nonpoint nutrient discharges.

The primary criteria used in evaluating alternatives were dissolved oxygen levels and chlorophyll concentrations. DO is the primary measure of habitat conditions for most aquatic life; chlorophyll is a better indicator of SAV habitat. Chlorophyll concentrations also provide an index to "excess" organic material, which eventually contributes to the anoxia/hypoxia problem in the Bay. Levels of dissolved inorganic nitrogen and dissolved inorganic phosphorus were used as secondary criteria for SAV habitat.

No effort was made in setting up the scenarios described in Appendix B to identify or fix responsibilities for achieving the reductions in nutrient discharges to the Bay. The 40 percent reduction strategy was applied uniformly in model runs without consideration of possible tradeoffs between different areas of the basin--between States, for example, or between locations above and below the fall line. Possible tradeoffs in controlling point or nonpoint sources, or in the control of different kinds of sources within those categories, also were ignored. These issues are important, but they are integral to decisions that must be made by State agencies in developing the implementation strategies due in July 1988.

As Table 3-4 shows, significant reductions are required in both phosphorus and nitrogen to minimize the volume of Bay water containing summer average DO concentrations of less than 2.0 mg/l, and to eliminate anoxic conditions in deep water by raising minimum DO levels to the range of 1.0 mg/l. DO levels below 2.0 mg/l are projected in some parts of the Bay under all alternatives investigated, but the extent of these low DO areas can be reduced through the stringent control of nutrients.

The Bay Agreement goal of reducing point and nonpoint source loads of both nitrogen and phosphorus by 40 percent is a reasonable target that can be achieved if a strong nonpoint source control effort is coupled with improved point source controls.

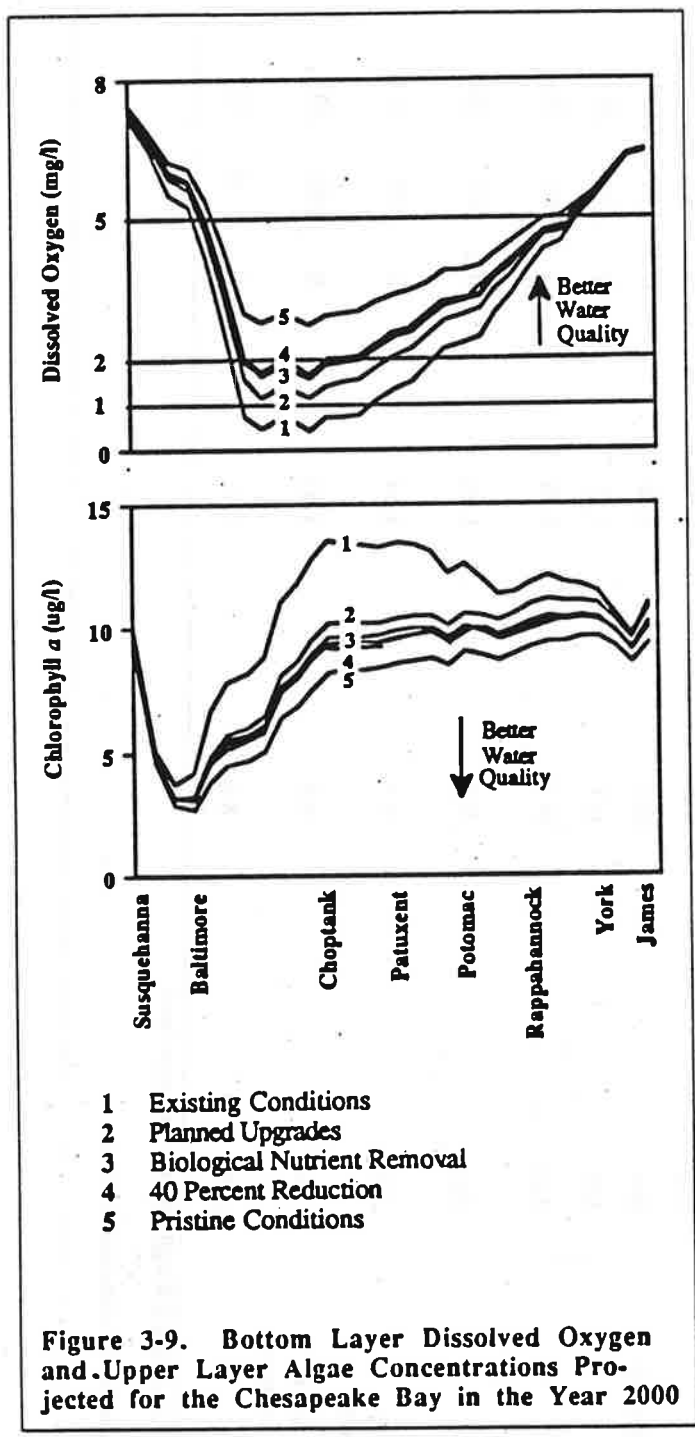
Improvements in Habitat

The 40 percent reduction in nutrient loads set forth in the 1987 Bay Agreement can achieve many of the goals for protecting habitat and living resources outlined in the preceding chapter. Model projections illustrate how nutrient reductions can enhance habitat conditions for

Table 3-4
The Effectiveness of Nutrient Reduction Scenarios Simulated by the Steady-State Model using 1985 Circulation--North-South Transect (Kilometers 148 to 187)

Scenario	CHLOROPHYLL <i>a</i>			DISSOLVED OXYGEN - DO		
	Total Mass Bay and Tributaries (10 ⁶ kg)	Peak Summer Avg. Concentration in Bay Channel (µg/l)	Lowest Summer Average Conc. in Bay Channel (mg/l)	Mainbay Volume (10 ¹⁰ m ³) with Summer Average DO Less Than (mg/l)		
				1	2	3.3*
a) Existing Calibration	.717	13.6	.43	.135	.276	.549
b) Planned Upgrades**	.619	10.4	1.10	0	.155	.454
c) Planned Upgrades**, 2000X	.663	11.2	.87	.031	.195	.464
d) Planned Upgrades** + TP=1	.581	9.8	1.28	0	.155	.417
e) Planned Upgrades** + TP=1 TN=6 (BNR Randall Est.)	.575	9.8	1.33	0	.135	.417
f) Planned Upgrades** + TP=2 TN=8 (BNR - EPA Est.)	.591	10.0	1.23	0	.135	.417
g) Limits of Technology**	.552	9.5	1.46	0	.135	.379
h) Planned Upgrades** + 2000 NPS	.604	10.0	1.40	0	.135	.417
i) TP=2, TN=8 + 2000 NPS	.577	9.7	1.53	0	.135	.357
j) Limits of Technology** + 2000 NPS	.540	9.1	1.75	0	.061	.295
k) Limit of Technology** + 40% Ag NPS	.533	9.0	1.96	0	.031	.250
l) 40% Reduction of TP for all Point and Nonpoint Sources	.596	9.7	1.54	0	.135	.357
m) 40% Reduction of TP & TN for All Point and Nonpoint Sources	.584	9.9	1.65	0	.098	.337
n) Pristine Conditions	.500	8.6	2.7	0	0	.155

* 3.3 mg/l summer average equates to 2.0 mg/l habitat requirement level.
 ** Municipal Sources
 Note: Appendix B contains the detailed scenario descriptions.



SAV and oysters, as well as raise oxygen levels in the Bay's deep central trench.

As noted in Chapter 2, SAV growth is impaired when concentrations of chlorophyll *a*, dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) exceed certain levels. Figure 2-12 depicted such high concentrations in relation to areas where SAV was present in 1985.

Figures 3-10 and 3-11 show improved conditions projected for the year 2000 following a 40 percent reduction in nitrogen and phosphorus loads. These reduced loads were simulated under the different circulation conditions of the years 1984 and 1985.

Figure 2-6 showed areas where oyster and clam habitats were impaired in 1985, a relatively good year for those species in the Bay. Figures 3-12 and 3-13 project the improved dissolved oxygen conditions a 40 percent nutrient reduction could achieve by the year 2000 in areas and at depths important to oysters and clams.

The 40 percent reduction also would improve DO levels in the deep central trench of the Bay (Figure 3-9). The trench itself is habitat for some species. In addition, winds, storms and currents at times send waters from the trench into critical habitats along the Bay's edge. DO levels in the trench, where oxygen depletion is most severe, also provide a gauge to the quality of other Bay waters.

Attaining Reduction Goals

The 1987 Bay Agreement reduction goal applies to all anthropogenic (man-induced) nutrient loads, but not "natural background" nutrient releases to the Bay. The background loads were estimated for both runoff and base flow from the "pristine" (100 percent forest cover) model run described earlier.

Model simulations and other projections suggest ways in which programs can be structured to achieve the nutrient reduction goal by the year 2000. Possible combinations differ in their impact upon tributaries, in cost, in the time required for implementation, in certainty of results, and in the equity of responsibilities placed upon the various jurisdictions. All these factors should be weighed by decision-makers in planning control programs. These future decisions also must relate to nutrient control programs planned or already in place in the Bay basin. Selection of control options is a state responsibility, with subsequent coordination to produce a Baywide nutrient management plan.

Additional Municipal Treatment

On the basis of wastewater flow projections shown in Appendix A, planned upgrades in municipal treatment plants and phosphate detergent bans will reduce phosphorus discharges 1.44 million pounds a year by the year 2000. The upgrades will reduce nitrogen discharges by nearly 4.74 million pounds per year. As noted earlier, population growth means net decreases will be smaller than those totals.

Because projected reductions will fall short of the 40 percent target, additional treatment will be needed to remove 1.2 million pounds of phosphorus and 25.5 million pounds of nitrogen annually. Technologies capable of achieving these additional (or greater) reductions are available. Two treatment systems more stringent than those now in general use--biological nutrient removal and treatments to the limits of technology--are examples of methods that can be utilized to reach the year 2000 reduction goal.

Biological nutrient removal technology could reduce effluent concentrations to 2.0 mg/l phosphorus and 8.0

Nonpoint Sources

Agricultural control programs currently under way are projected to reduce phosphorus contributions from cropland needing treatment and improperly stored animal waste by 35 percent by the year 2000⁴⁵. Nitrogen reductions are projected to be somewhat smaller.

The projected reductions will be achieved largely through the cost-share programs now employed across the region. Nutrient management and farmer participation in the USDA Conservation Reserve and other Food Security Act programs can also play a role, but reductions that might be attained in this way have not been quantified.

Nutrient runoff from urban areas can be reduced by urban marshes, detention ponds, and other controls identified and now under study as a part of the Bay Program.

Created or engineered wetlands are man-made basins designed to improve water quality. Removal processes include settling of sediment, particulate organic matter and phytoplankton, and biological uptake of soluble nutrients. The size of the pond relative to the area it drains is the most important design parameter.

Wet ponds have a moderate to high capability of removing most urban pollutants, depending on how large the volume of the permanent pool is in relation to the

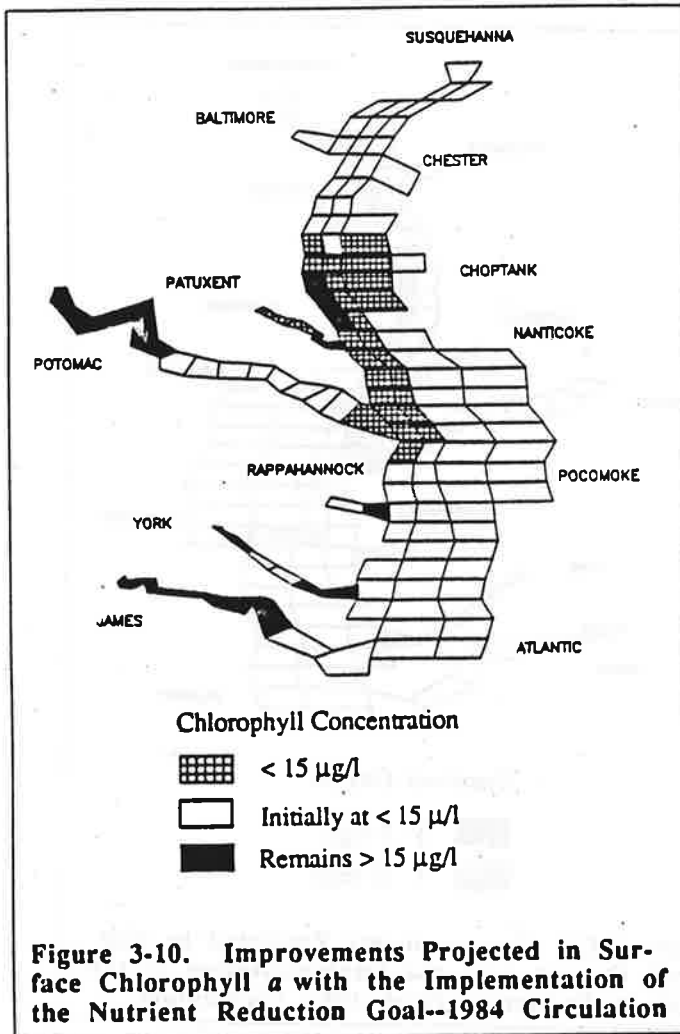


Figure 3-10. Improvements Projected in Surface Chlorophyll a with the Implementation of the Nutrient Reduction Goal--1984 Circulation

mg/l nitrogen in municipal treatment plants not treating to those levels now. Resulting discharge reductions of 54 percent for phosphorus and 45 percent for nitrogen would meet nutrient goals and accommodate projected growth as well.

Treatment to the limits of technology can produce effluent concentrations of 0.1 mg/l phosphorus and 3.0 mg/l nitrogen.

Reductions that can be achieved by employing these technologies--94 percent for phosphorus and 83 percent for nitrogen--would enable municipal plants to meet nutrient reduction goals and provide additional levels of treatment to ameliorate the impact of population growth beyond that projected for areas served by the facilities⁵³. Appendices C and D list municipal treatment plants that can be upgraded to provide these reductions and show the degree of reduction attainable using the two alternative advanced treatment technologies.

A 40 percent reduction in industrial nutrient discharges can be achieved through implementation of controls at the facilities listed in Appendix E. Together, these controls on municipal and industrial point sources reach the 40 percent nutrient reduction goal. Consideration also must be given, however, to nutrient load reductions achieved by point source dischargers prior to 1985.

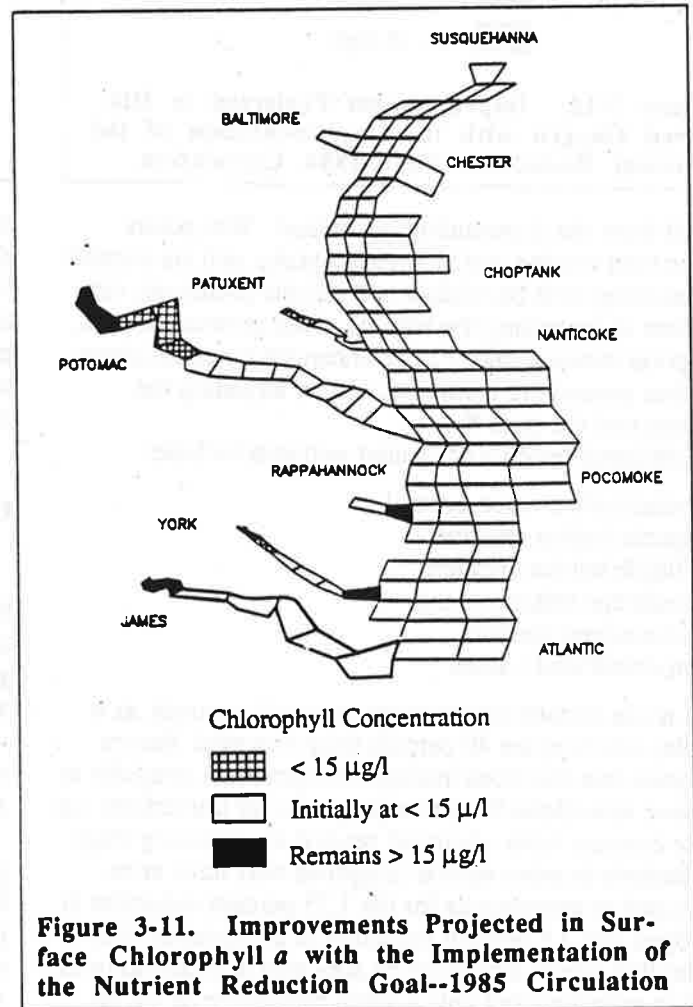
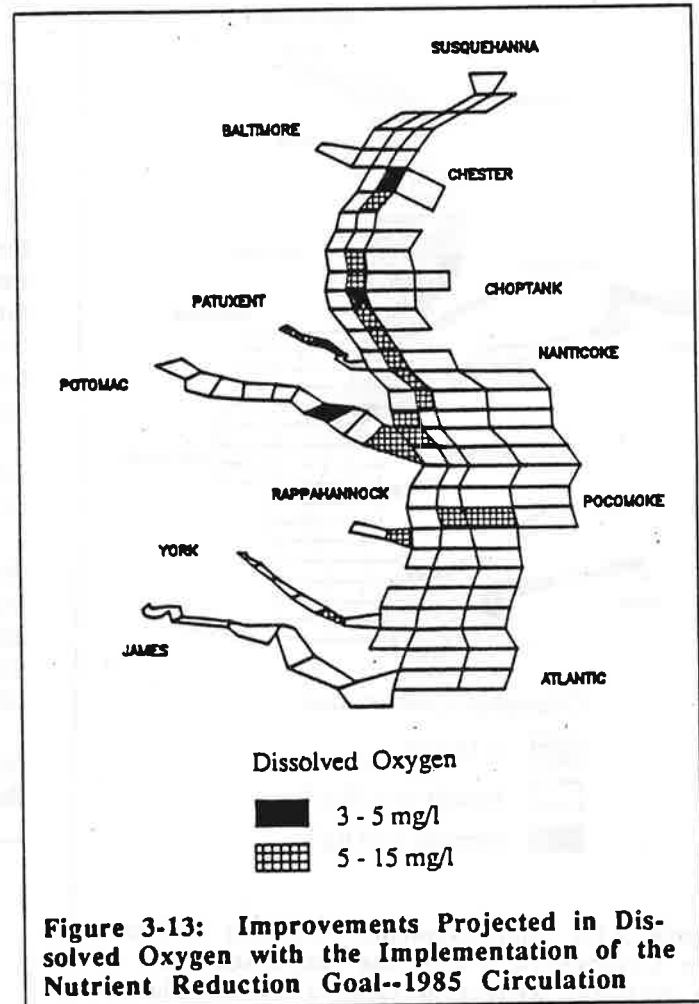
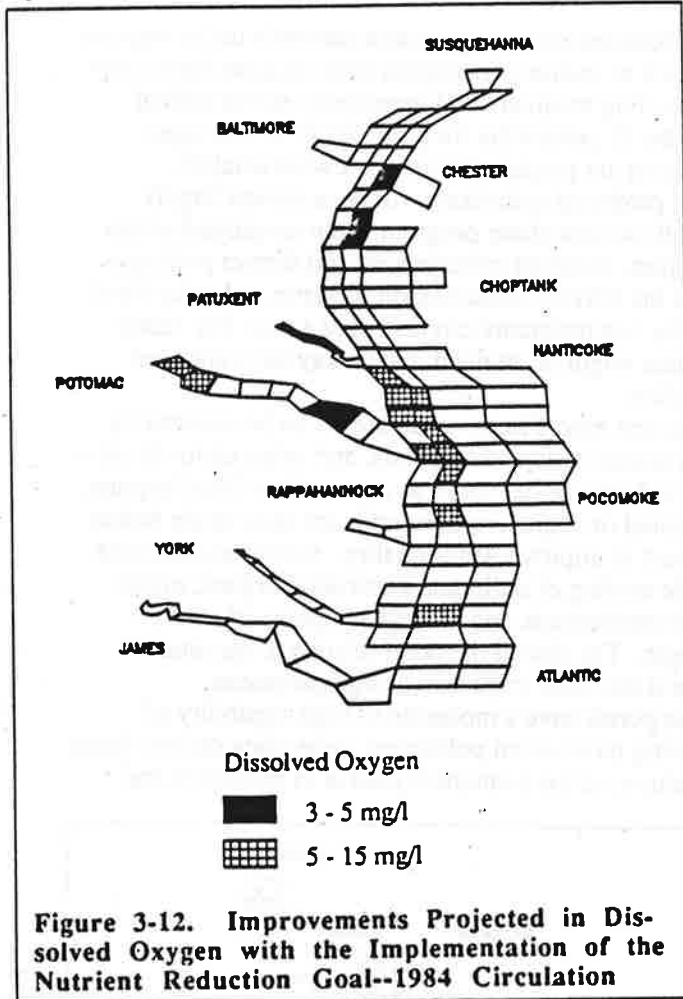


Figure 3-11. Improvements Projected in Surface Chlorophyll a with the Implementation of the Nutrient Reduction Goal--1985 Circulation



runoff from the surrounding watershed. Wet ponds utilize both settling and biological uptake, and are capable of removing both particulate and soluble pollutants. In addition to increasing the volume of the permanent pool, wet pond removal rates can be enhanced by establishing marshes around the perimeter, and by adjusting the geometry of the pool ⁴⁶.

Additional benefits of created wetlands include:

- Streambank erosion control
- Aquatic habitat creation
- Wildlife habitat creation
- Landscape enhancement
- Recreational benefits
- Improved land values

It is not certain now that urban runoff controls, as a whole, can meet the 40 percent reduction goal. Recent literature has described management practices available to achieve reductions ⁵⁵, but no programs for implementing these controls have advanced beyond the planning stage. Reductions in other source categories may have to be increased to compensate for the 1.25 percent reduction in nitrogen and 2.5 percent reduction in phosphorus (Bay-wide) that would otherwise be allocated to urban sources.

It is estimated that only a small percentage of the nitrogen in base flow to the Bay stems from farming ac-

tivity, and it is difficult to project whether current control programs can reduce these loads. For this reason, only limited reductions from base flow are included in projections of future water quality. This does not rule out the possibility that significant reductions in nutrient concentrations (particularly nitrogen) may be shown when results are more completely quantified.

Choosing Control Options

The foregoing section describes the potential capability of various programs to control major nutrient discharges and contribute to the 40 percent reduction goal. Realization of these reductions rests on several assumptions. One is that current high levels of wastewater treatment will be maintained by municipal plants and that planned upgrades will be completed to achieve additional load reductions.

Another assumption is that agricultural control programs of USDA and EPA will continue to be a major element of the Bay program, and that refinement of these programs can close the gap between the 35 percent reduction projected now and the 40 percent Bay Agreement goal.

A third planning assumption is that projected in-