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Implementation Committee

A Commitment Renewed

Restoration Progress and the Course Ahead Under the 1987 Bay Agreement

Chesapeake Bay Program

The Chesapeake Bay Program: A Commitment Renewed

Restoration Progress and the Course Ahead Under the 1987 Agreement

A Report of the
Chesapeake Implementation Committee

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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.

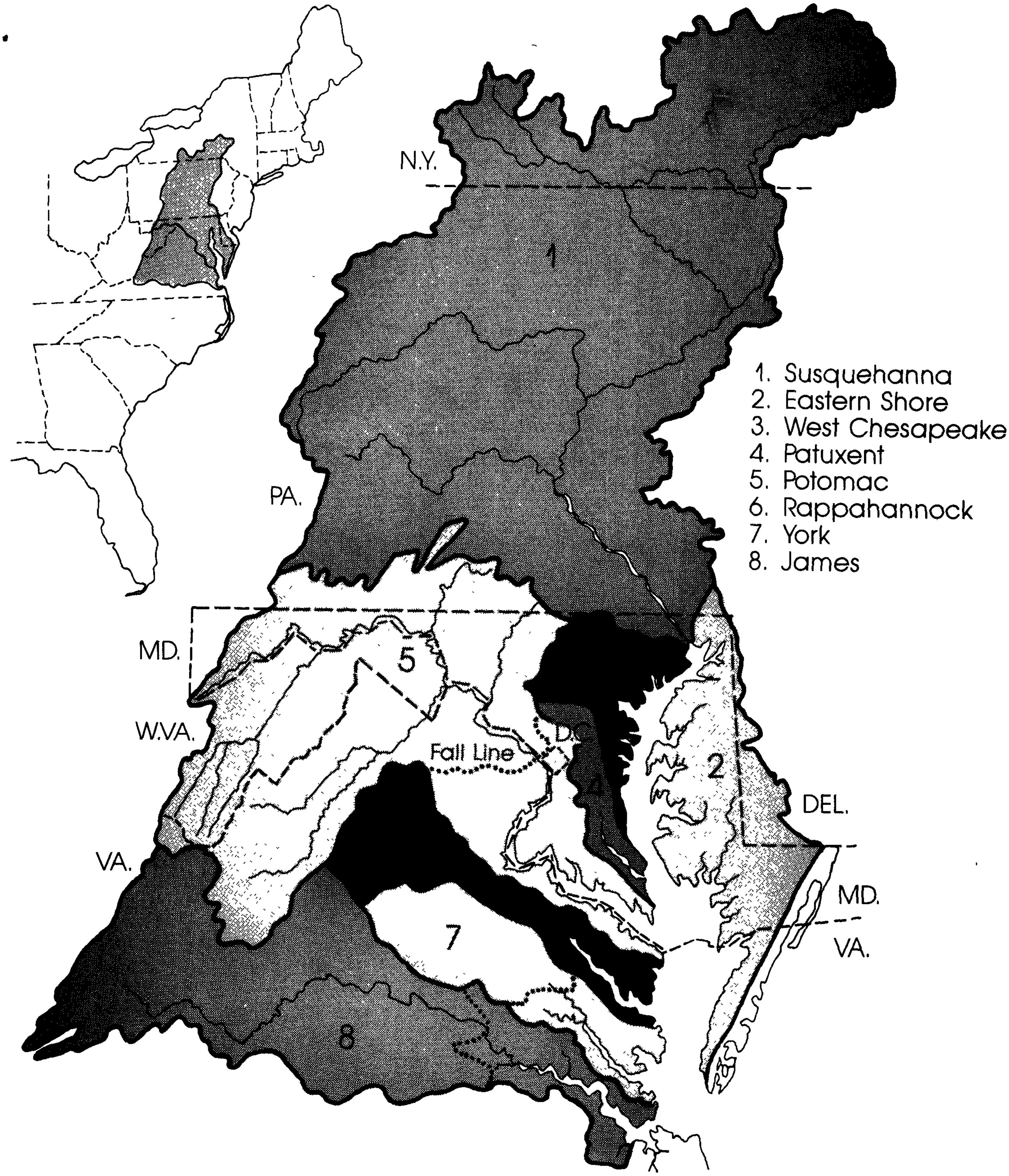
Alternative nutrient control strategies and their potential to achieve water quality conditions necessary to restore and protect living resources are presented and discussed in Chapter 3. Evaluations of strategies are based on projections made from computerized models and the best judgment of Bay region 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 1983[7]. 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 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 Bay [8] 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.

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**

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,

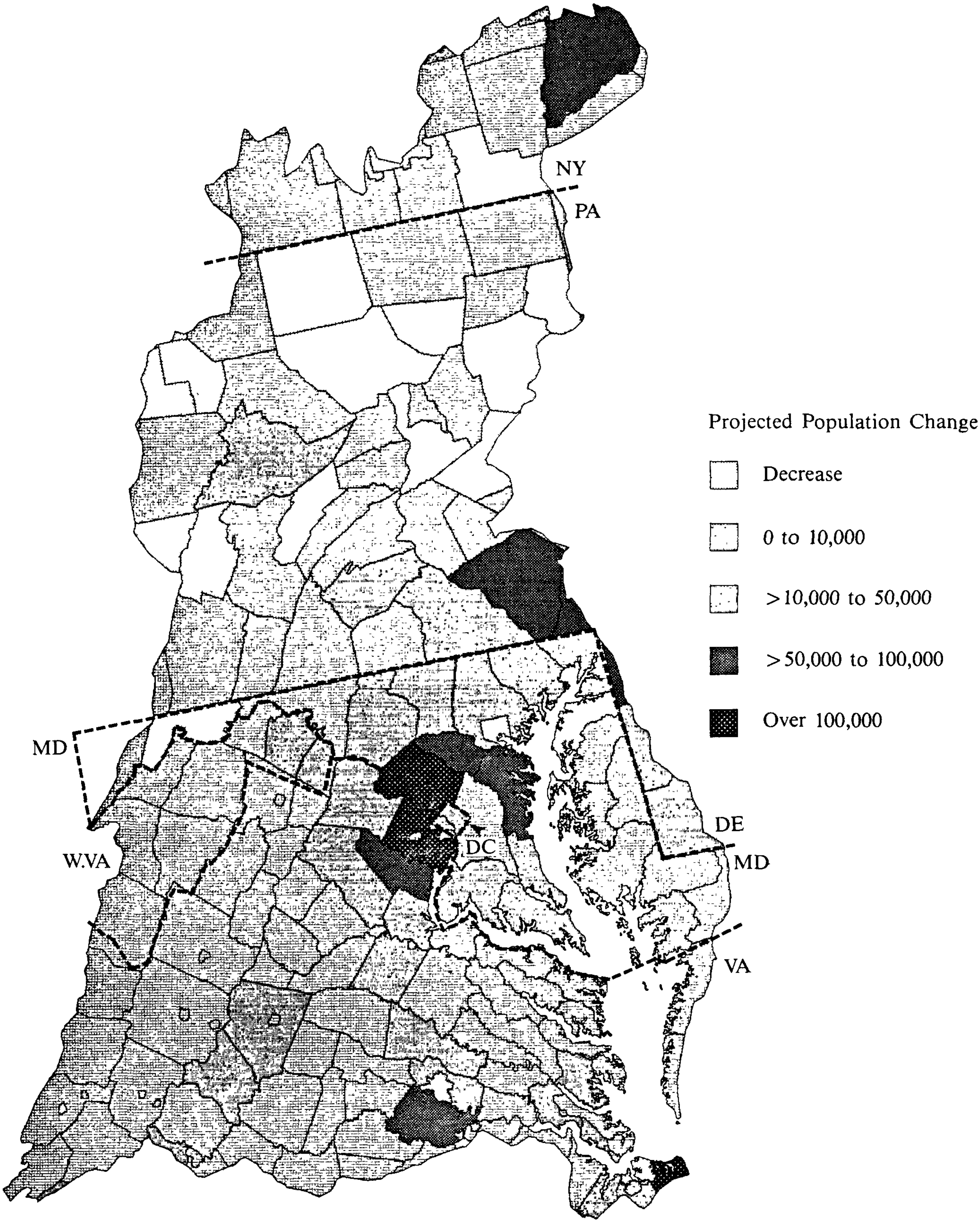


Figure 1-1. Projected Population Change in the Chesapeake Bay Watershed (1985-2000)

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 1980 [8]. 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 growth [9]. 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 persons [10].

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), 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 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.

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

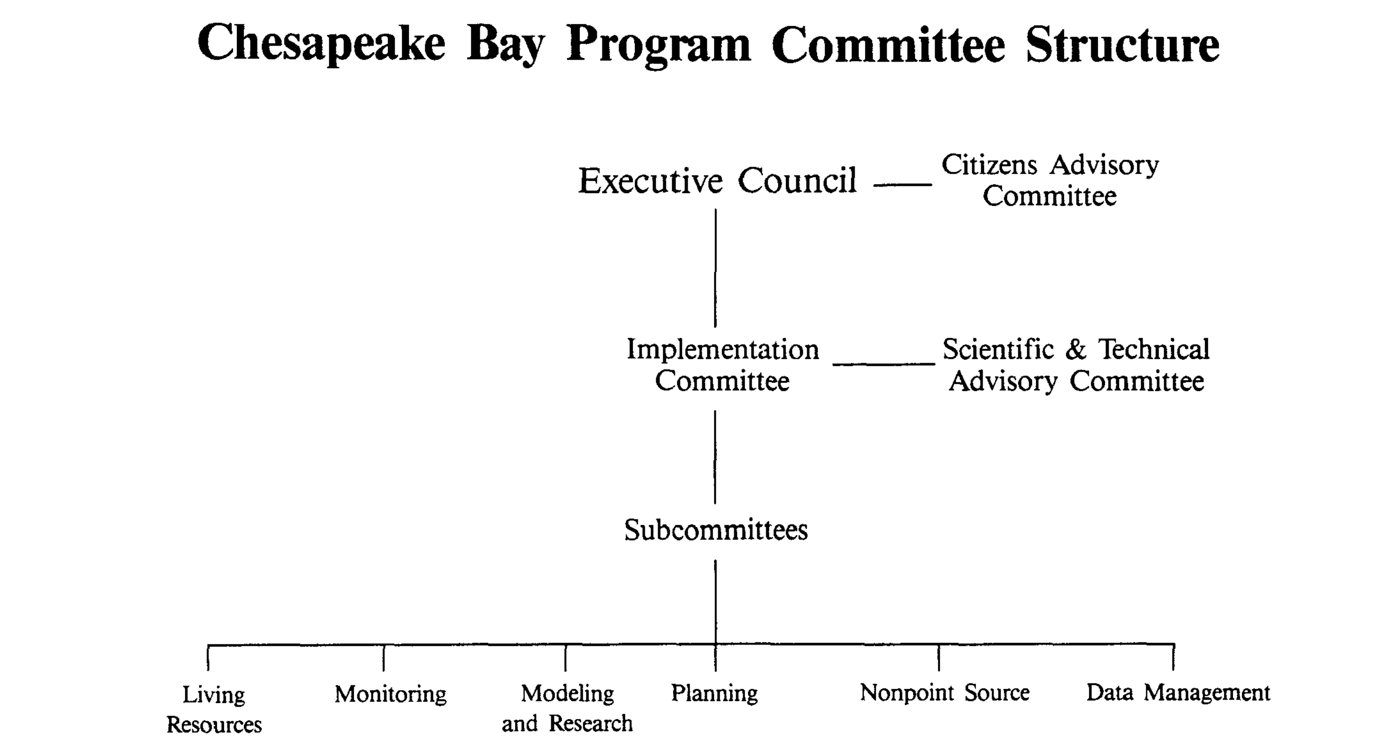


Figure 1-2. Cheapeake Bay Program Committee Structure

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].

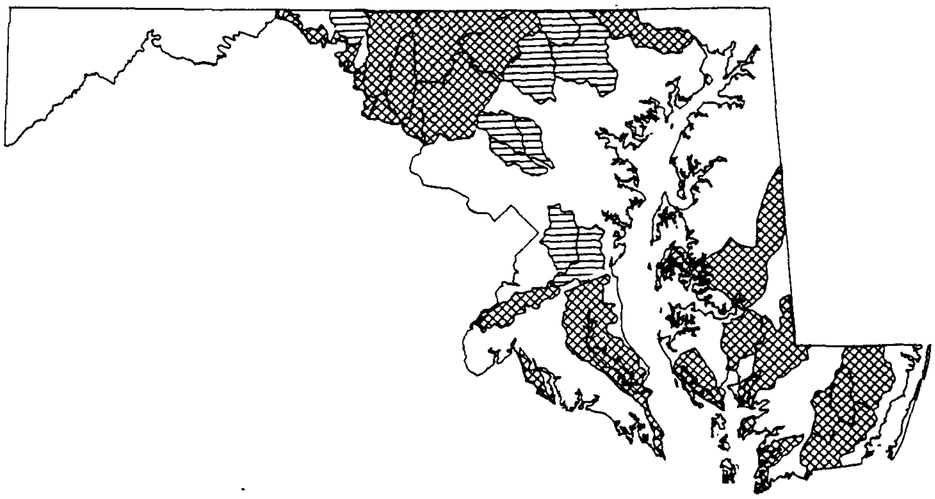
Through their leadership and participation in Agreement groups, the states have shared information on technology improvements, experiments and demonstrations, implementation of nonpoint source controls, and innovative citizen involvement and information projects. They have advocated the adoption of both 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].

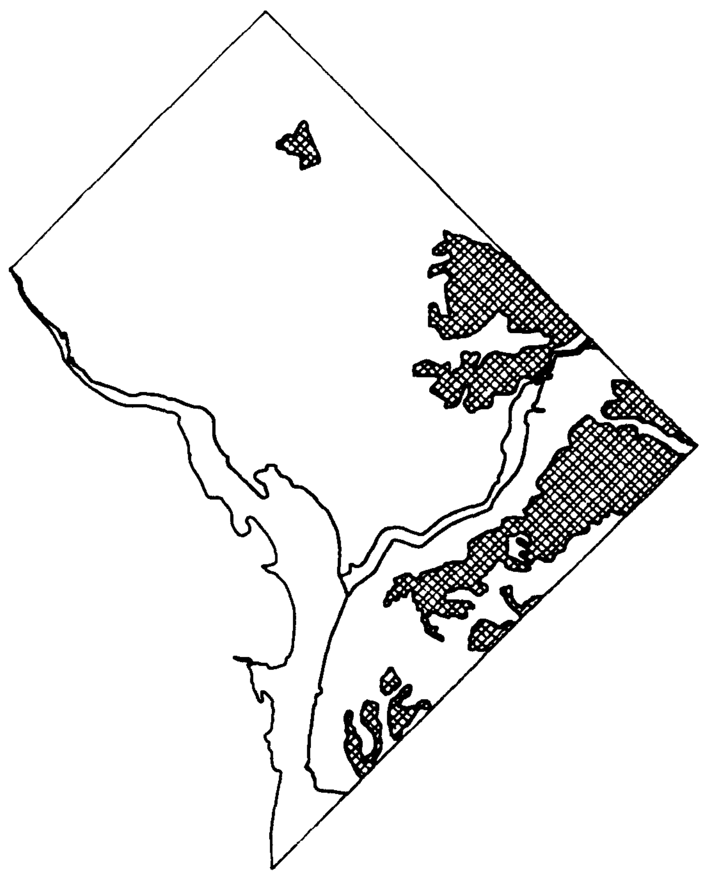
The SCS placed a coordinator in the EPA Bay office in November 1984 to ensure that its many field people in the region were closely tied to the Bay Program. Through them, SCS has reached, and helped the states to reach, many farmers with information and technical assistance to implement practices to 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



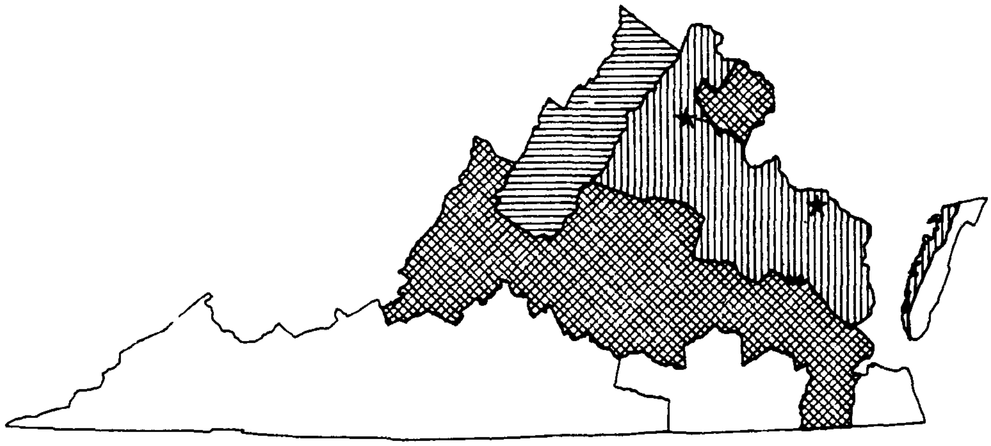
▩ Top 24 Watersheds (EPA Grant Funds Are Targeted Here)
▤ Other MACS Priority Watersheds (Funded with State and Non-EPA Monies)

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

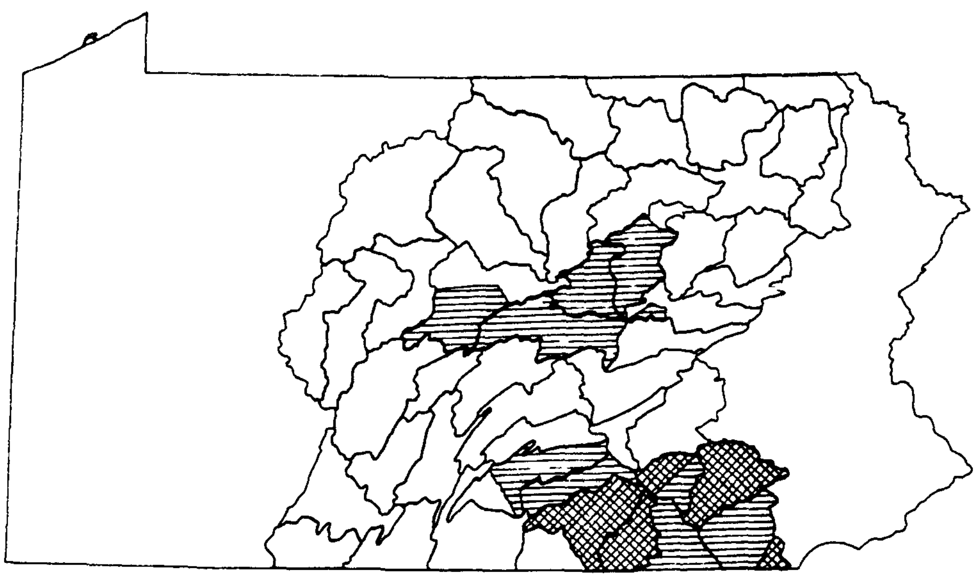
Figure 1-4. Highly Erosive Soils of the District of Columbia.
Source: *General Soil Map District of Columbia*, USDA Soil Conservation Service, U.S. DOI, National Park Service, National Capital Press, 1975.



Chesapeake Bay Program Area (Level I) (68 Counties)
Animal Waste Priority Area (Level II-A) (7 Counties)
Cropland Priority Area (Level II-C) (23 Counties)
★ Demonstration Watersheds (Level III)
Portion of Virginia not draining to the Bay (includes Virginia Program Area [29 Counties] and Chowan River Program Area [6 Counties])

Figure 1-5. Areas Targeted for Agricultural BMP Cost-Share Funds in Virginia.

Source: *1987 Virginia Agricultural BMP Cost-Share Program*, Virginia Department of Conservation and Historic Resources, Division of Soil and Water Conservation, July 1986, p.1.



Initial Watersheds Selected for Implementation
Additional Watersheds Selected for Implementation
Note: Areas on map without watershed details do not drain to the Bay.

Figure 1-6. Pennsylvania's Priority Watersheds for Agricultural BMP Implementation Under the Chesapeake Bay Program.

Source: Pennsylvania Department of Environmental Resources, Bureau of Soil and Water Conservation.

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 report[19] 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 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

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 comprehendible, 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."

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 picture [20]. 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 statute [21] 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 resources [9].

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 state [22]. 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 loads [23].

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: Marylland 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 procedures [14]. 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 1987 [24], 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 EPA [25], 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 vesesels. 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. Sampling 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 methodology 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 1986[31]. 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.

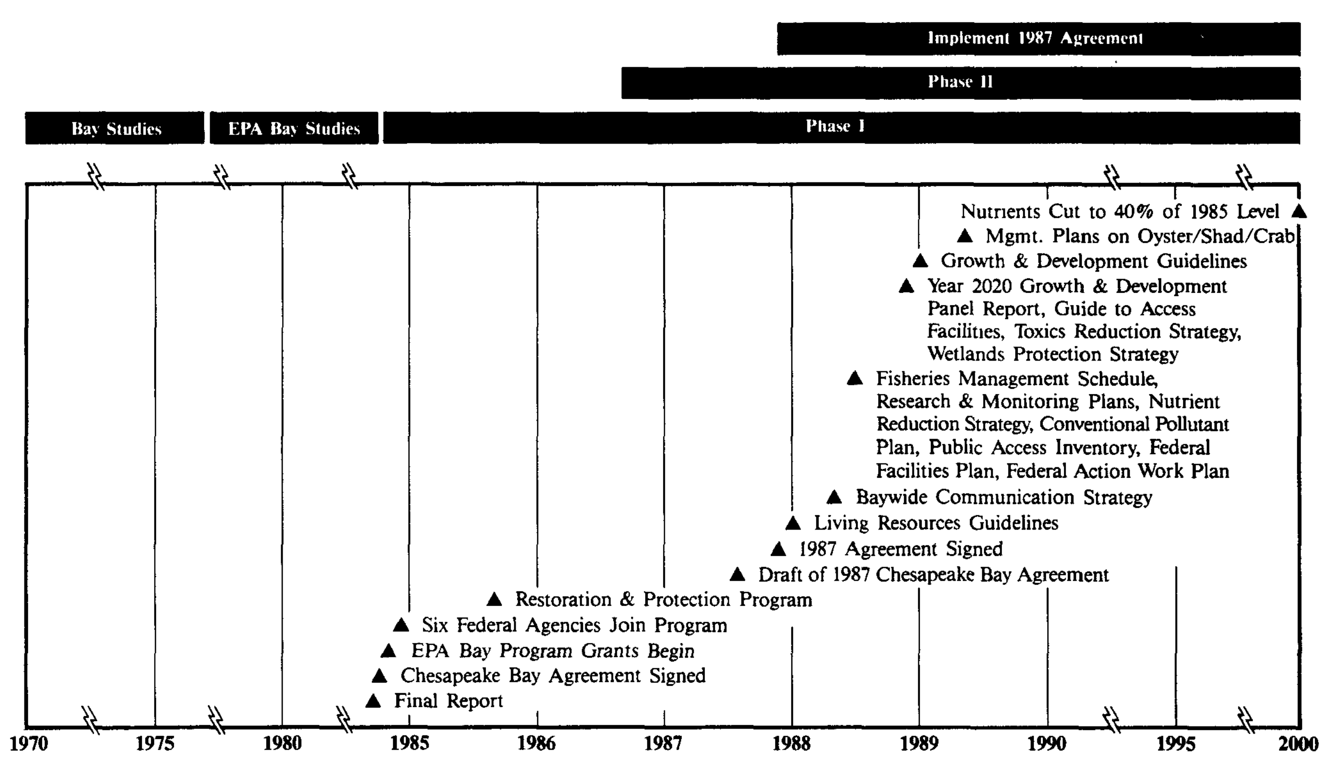


Figure 1-7. Evolution of the Chesapeake Bay Program

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

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Habitat Requirements Workshop

↓

Draft Reports and Review by Managers and Scientfic Community

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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 1987 [34]. 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.

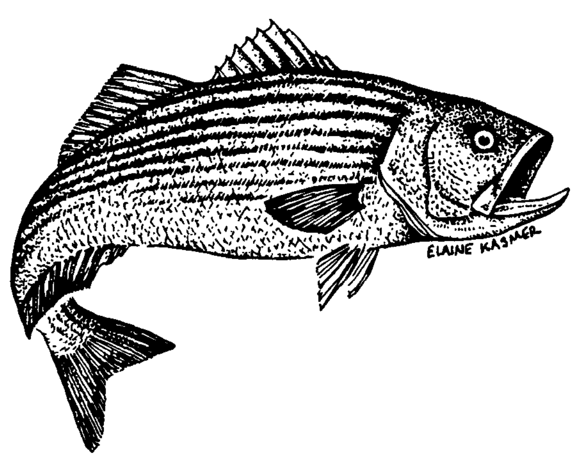
Habitat is defined in the report as the biotic and abiotic conditions upon which living resources of the Bay depend. Abiotic conditions include water quality, substrate, circulation patterns, water depths, and weather. Biotic conditions are governed by variables such as vegetative cover, quality and 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.

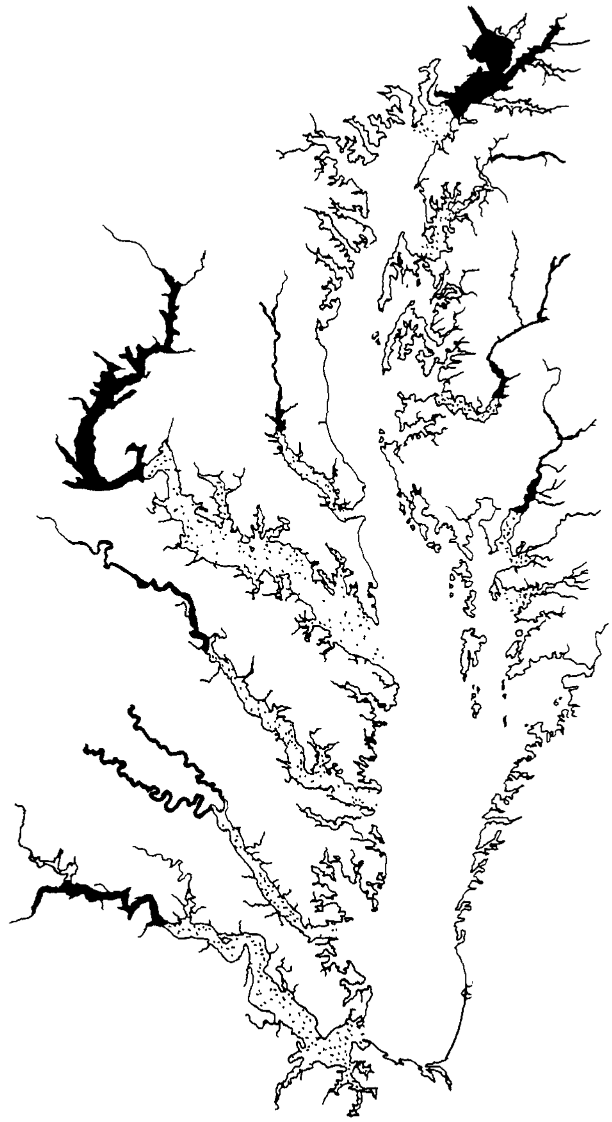
Three examples of the target species descriptions and habitat requirements presented in the LRTF report are summarized below, including an anadromous fish sensitive to tidal freshwater habitat conditions (striped bass), an immobile shellfish species which cannot escape from hypoxic waters (American oyster), 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).





■ Spawning reaches
□ Spawning rivers

Figure 2-1. Habitat Distribution of Striped Bass Spawning Reaches and Rivers (as defined by State Laws)

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

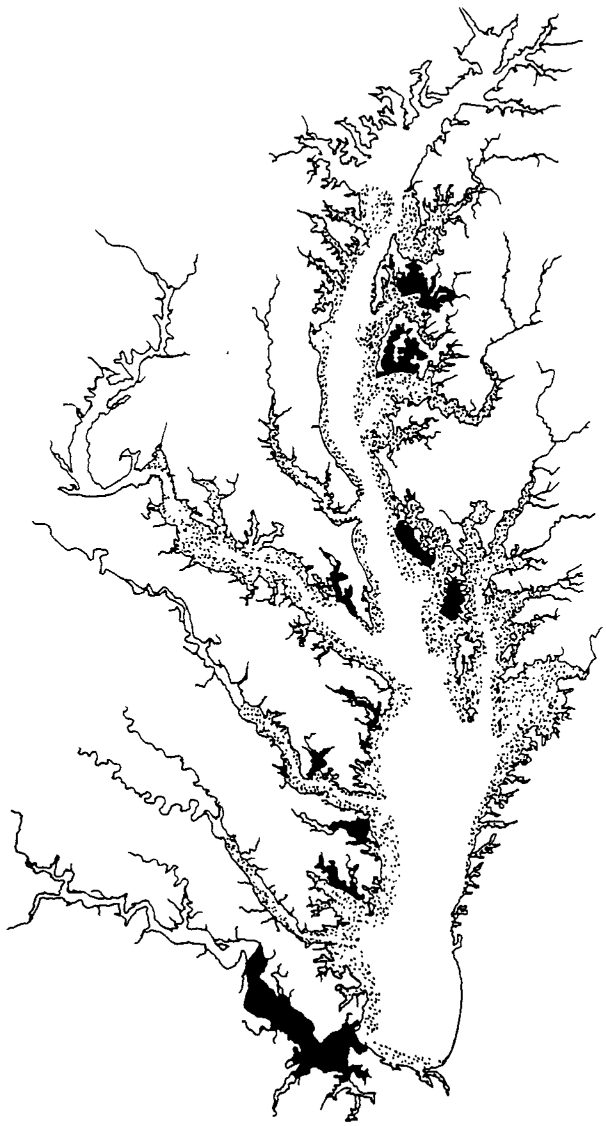


Figure 2-2. Habitat Distribution of Seed Areas and Suitable Substrate for the American Oyster

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 regions [35]. 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,

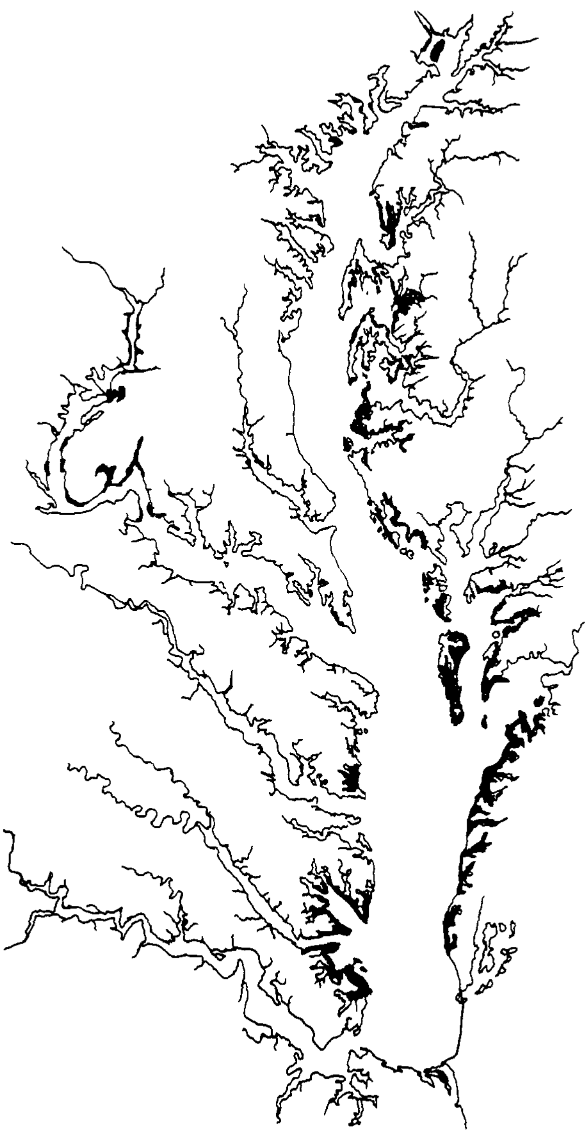


Figure 2-3. Distribution of Submerged Aquatic Vegetation

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 *a* (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

- ■ Spawning and nursery habitat for multiple targeted finfish species
- ▨ Spawning and nursery habitat for several targeted finfish species
- □ Spawning and nursery habitat for single targeted finfish species

Figure 2-4. Finfish Spawning and Nursery Habitats

Table 2-4
Finfish Spawning and Nursery Areas

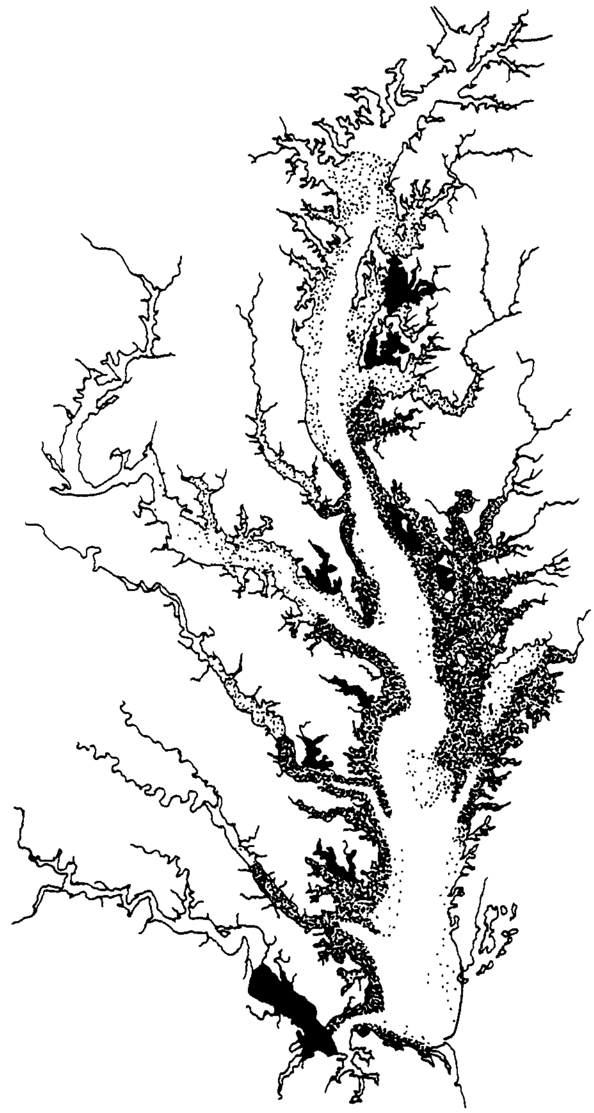
James River	Susquehanna Flats
York River	Elk River
Pamunkey River	Upper Chester River
Mattaponi River	Choptank River
Rappahannock River	Nanticoke River
Upper Patuxent River	Wicomico River
Gunpowder River	Pocomoke River
Bush River	Virginia Eastern
Upper Mainstem Bay	Shore Embayments

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,

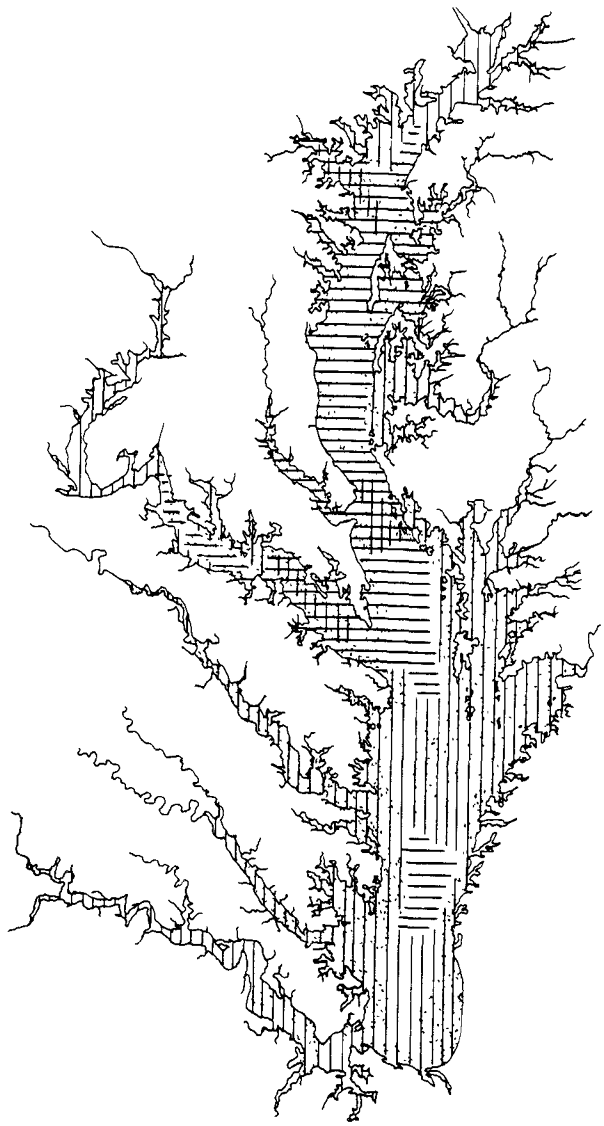


Suitable habitat for all three species
Suitable habitat for two species
Suitable habitat for only one species
Oyster seed beds

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
	Tangier Sound
Lower Potomac River	Virginia Eastern
Lower Patuxent River	Shore Embayments



- Shellfish habitat distribution (from Figure 2-5)
- Dissolved oxygen concentrations < 2 mg/l
- Dissolved oxygen concentrations 2-5 mg/l
- Dissolved oxygen concentrations > 5 mg/l

Figure 2-6. Shellfish Habitat and 1985 Summer Dissolved Oxygen at 10 meters or Bottom Depth

- Higher population densities
- Lower population densities
- Spawning area

Figure 2-7. Blue Crab Summer Habitat Distribution and Winter Spawning Areas

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 Western Shore	Eastern Bay
Upper Potomac River	Tangier Sound
Maryland Western Shore Tributaries	Virginia Eastern Shore Embayments

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 SAV [29]. 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

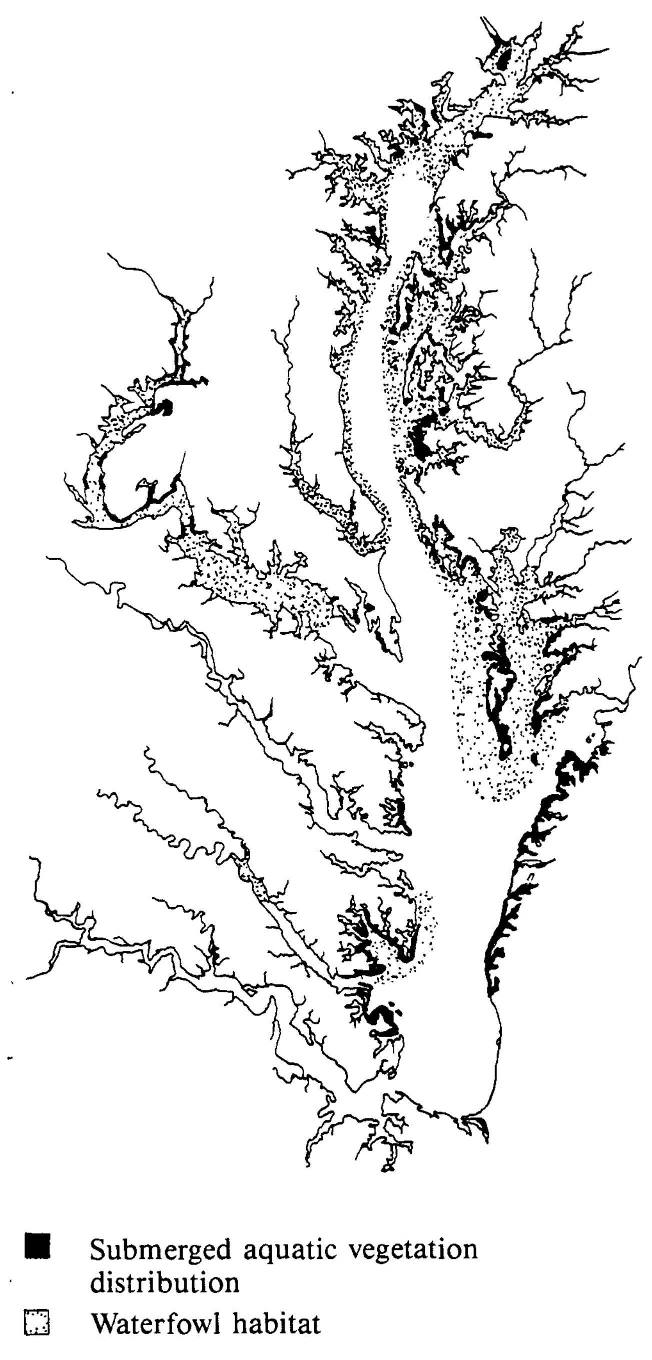
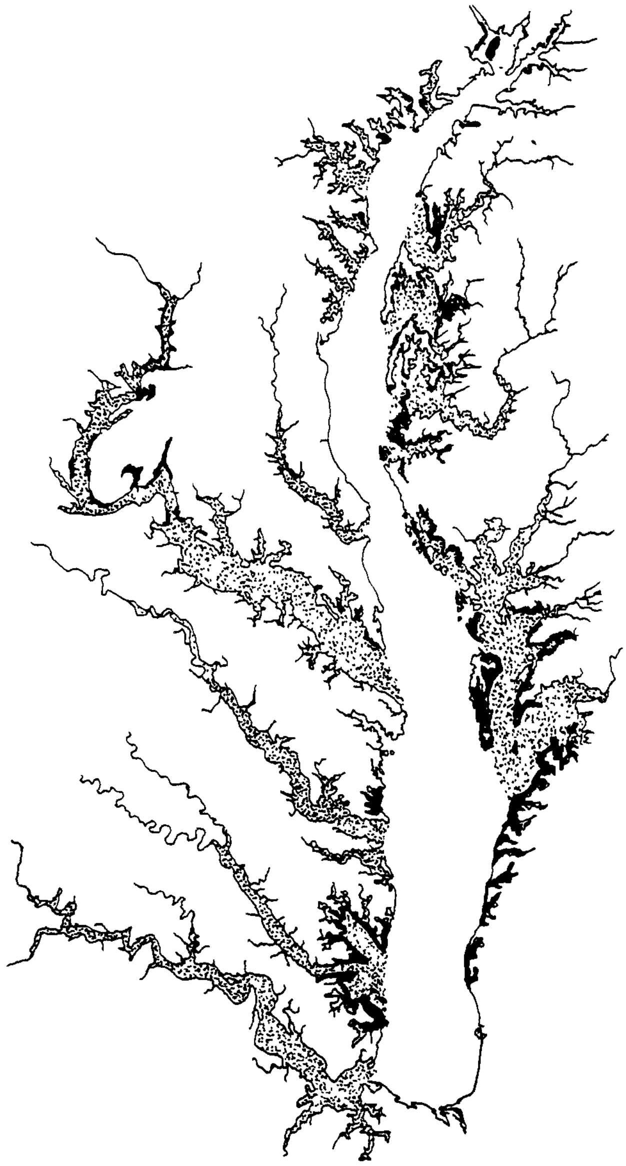


Figure 2-8. Waterfowl Habitat and 1985 Submerged Aquatic Vegetation Distribution

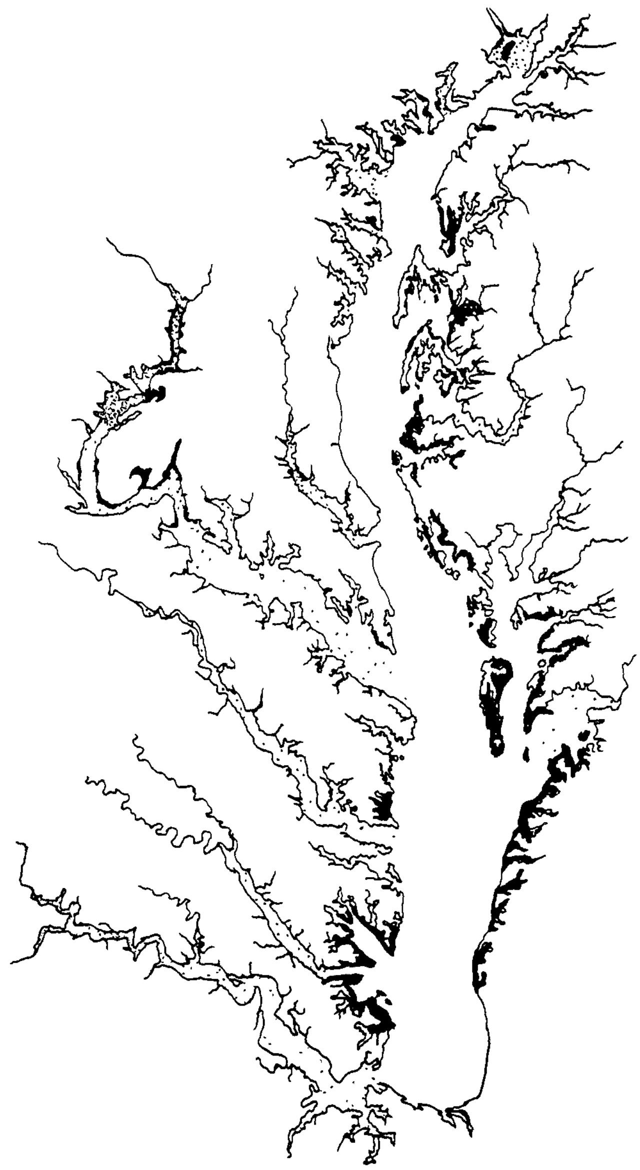


■ Submerged aquatic vegetation distribution
□ Dissolved inorganic phosphorus < 0.01 mg/l
□ Dissolved inorganic phosphorus ≥ 0.01 mg/l

Figure 2-9. 1985 Submerged Aquatic Vegetation Distribution and Summer Dissolved Inorganic Phosphorus Concentrations

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."



■ Submerged aquatic vegetation distribution
□ Dissolved inorganic nitrogen < 0.14 mg/l
□ Dissolved inorganic nitrogen > 0.14 0.7 mg/l
▩ Dissolved inorganic nitrogen > 0.7 1.4 mg/l
▨ Dissolved inorganic nitrogen ≥ 1.4 mg/l

Figure 2-10. 1985 Submerged Aquatic Vegetation Distribution and Summer Dissolved Inorganic Nitrogen Concentrations

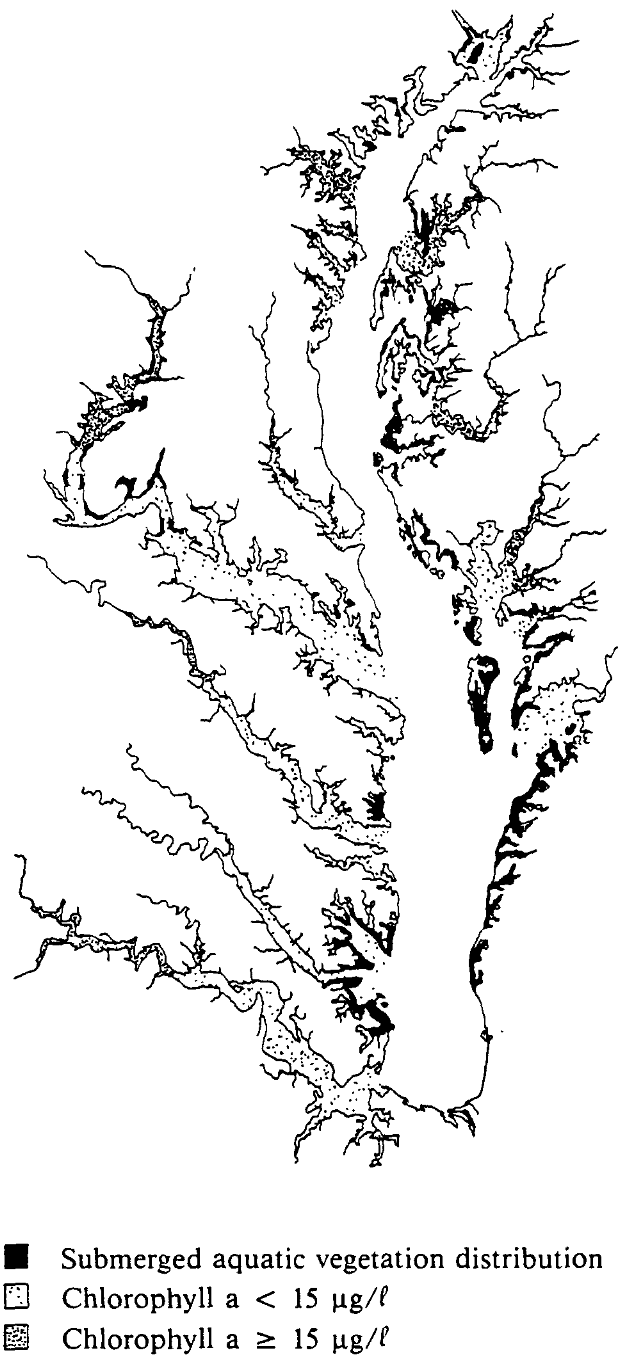


Figure 2-11. 1985 Submerged Aquatic Vegetation Distribution and Summer Chlorophyll *a* Concentrations

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 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.

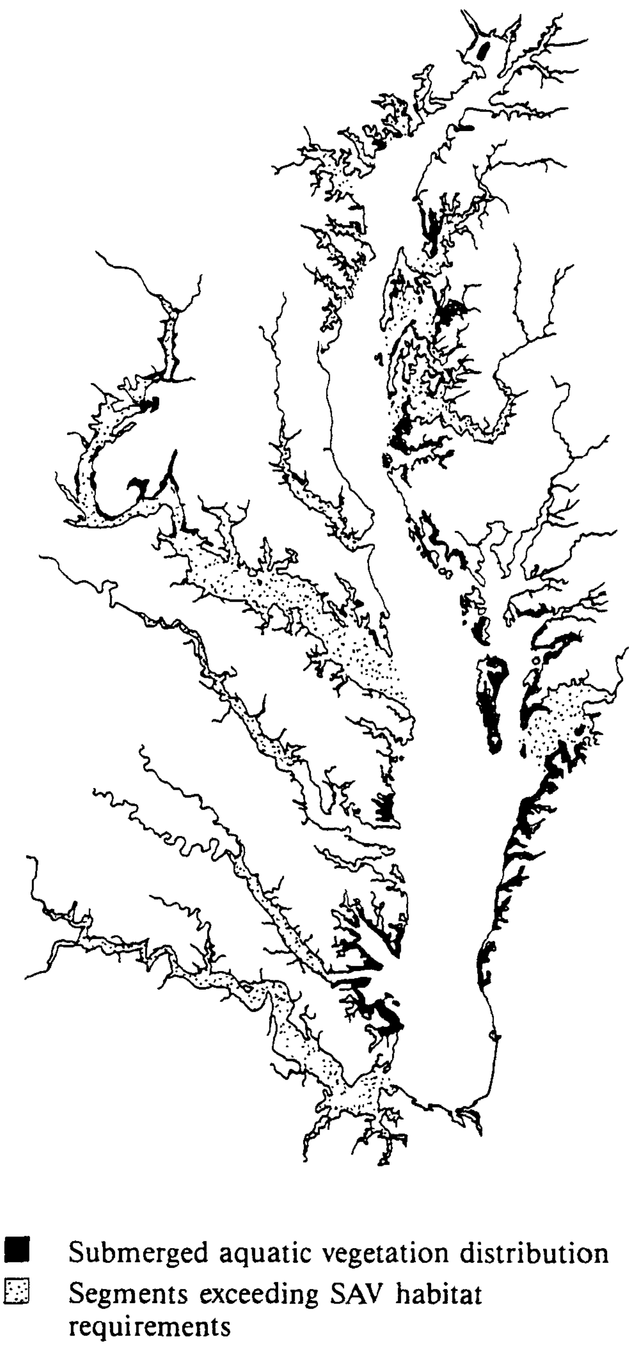
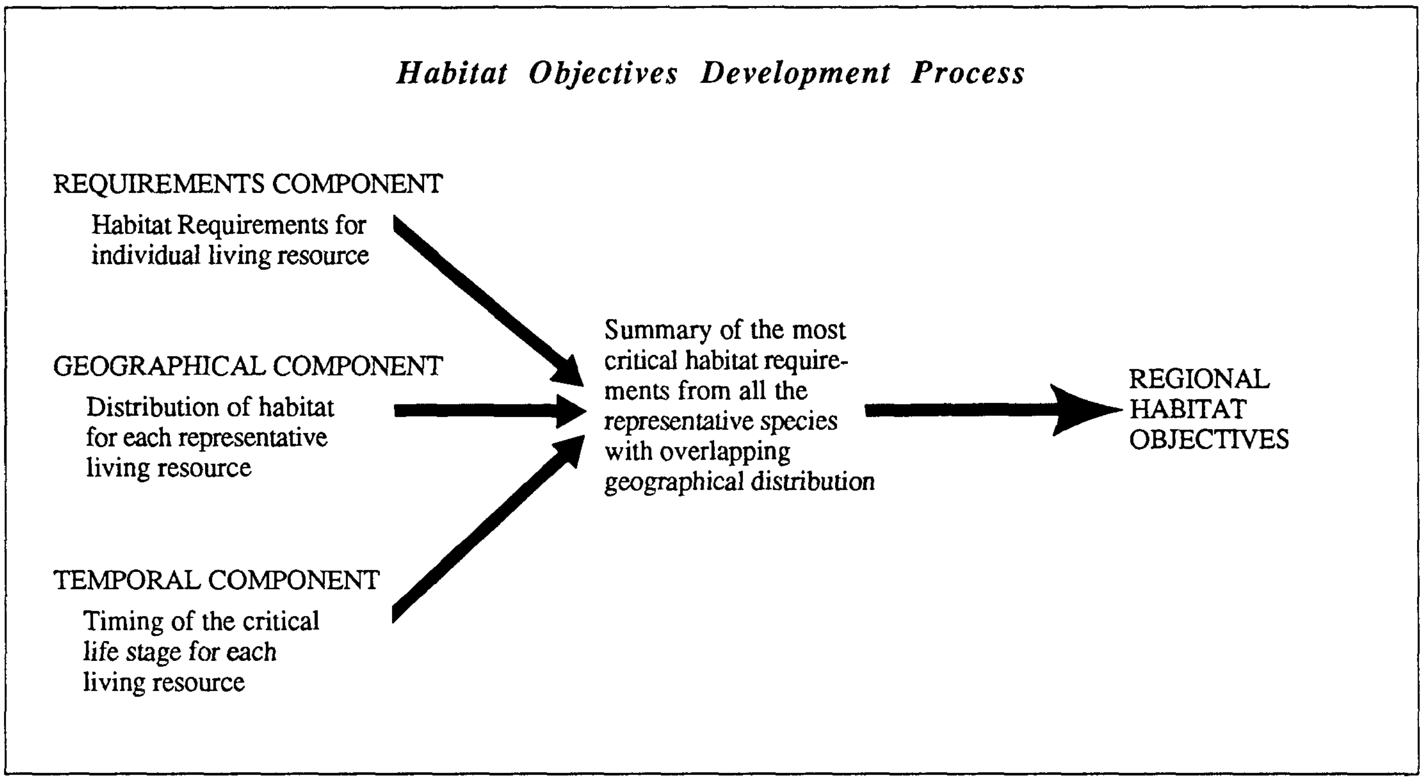


Figure 2-12. Tidal Tributary Chesapeake Bay Segments where Submerged Aquatic Vegetation Habitat Requirements are Exceeded



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 program [36]. 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

■ 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 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

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)	Cover	Flow (m/s)	Temp. (C)	pH	DO (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)	Secchi Depth (m)	Chloro-phyll *a*	Dissolved Inorganic Nitrogen (mg/l)	Dissolved Inorganic Phosphorus (mg/l)	Alkal. (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	Temp. (C)	pH	DO (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)	Secchi Depth (m)	Chloro-phyll *a* (mg/l)	Dissolved Inorganic Nitrogen (mg/l)	Dissolved Inorganic Phosphorus (mg/l)	Alkal. (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	<20	<35	1.0	<15	<0.7-0.14	<0.01	>20	0.15	*	<10	*	Zooplankton Phytoplankton (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 Phytoplankton (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 requirements [24].

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

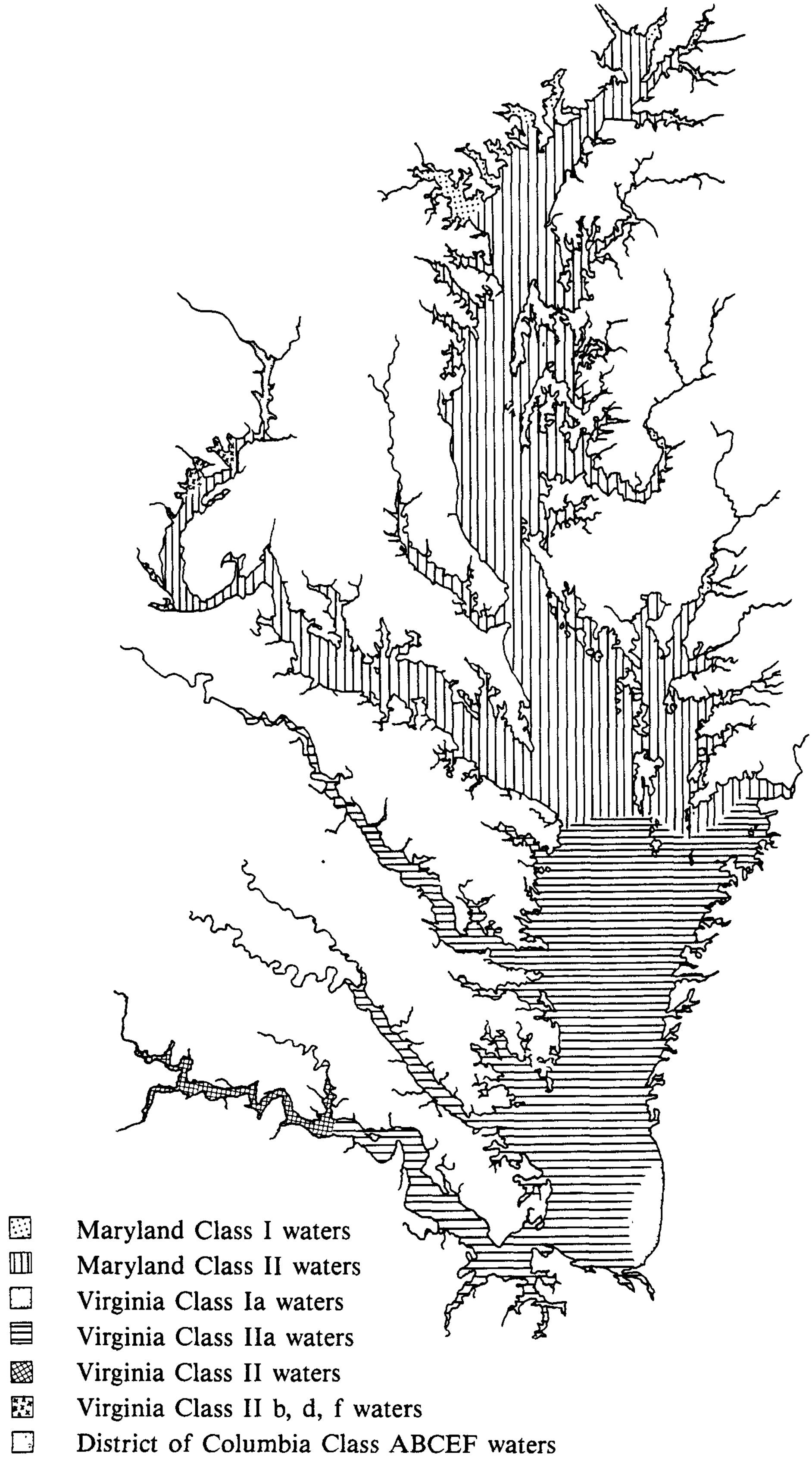


Figure 2-14. Geographic Distribution of State Standard Classification for the Tidal Chesapeake Bay Basin

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) daily Min.	Avg.	pH	Temp (F)	Fecal Coliform (max MPN/ 100 mg/l)	Turbidity (JTU)	Other Specific W.Q. Standards (ug/l)	
Maryland										
I	Water contact; recreation; aquatic life; water supply	Tidal fresh portions of tributaries	5.0	–	6.5 to 8.5	90° or ambient	200	150	Aldrin-Dieldrin Benzidine DDT Endrin PCB Toxaphene	0.003 0.1 0.001 0.004 0.001 0.005
II	Shellfish harvesting waters	Estuarine portion of tributaries and mainbay	5.0	–	6.5 to 8.5	90° or ambient	14	150	Aldrin-Dieldrin Benzidine DDT Endrin PCB Toxaphene	0.003 0.1 0.001 0.004 0.001 0.005
Virginia										
I		Open ocean	5.0	–	6.0 to 9.0	–	200	–	(1)	
II	Recreational use & wildlife	Estuarine (tidal to fall line)	4.0	5.0	6.0 to 9.0	–	200	–	(1)	
IIa	Propagation of shellfish	Estuarine	4.0	5.0	6.0 to 9.0	–	14	–	(1)	
IIb	Propagation of shellfish	Potomac embayments	4.0	5.0	6.0 to 9.0	–	14	–	(1)	
III	Public Water Supply	Estuarine	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) daily Min.	Dissolved Oxygen (mg/l) daily Avg.	pH	Temp (F)	Fecal Coliform (max MPN/ 100 mg/l)	Turbidity (JTU)	Other Specific W.Q. Standards (ug/l)
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	Susquehanna River (5)	4.0	5.0	6.0 to 9.0	87° (6)	200	–	(7)

(1) Additonal 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 Americal 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-finfish trawl survey [37]. 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 seasons [38]. 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

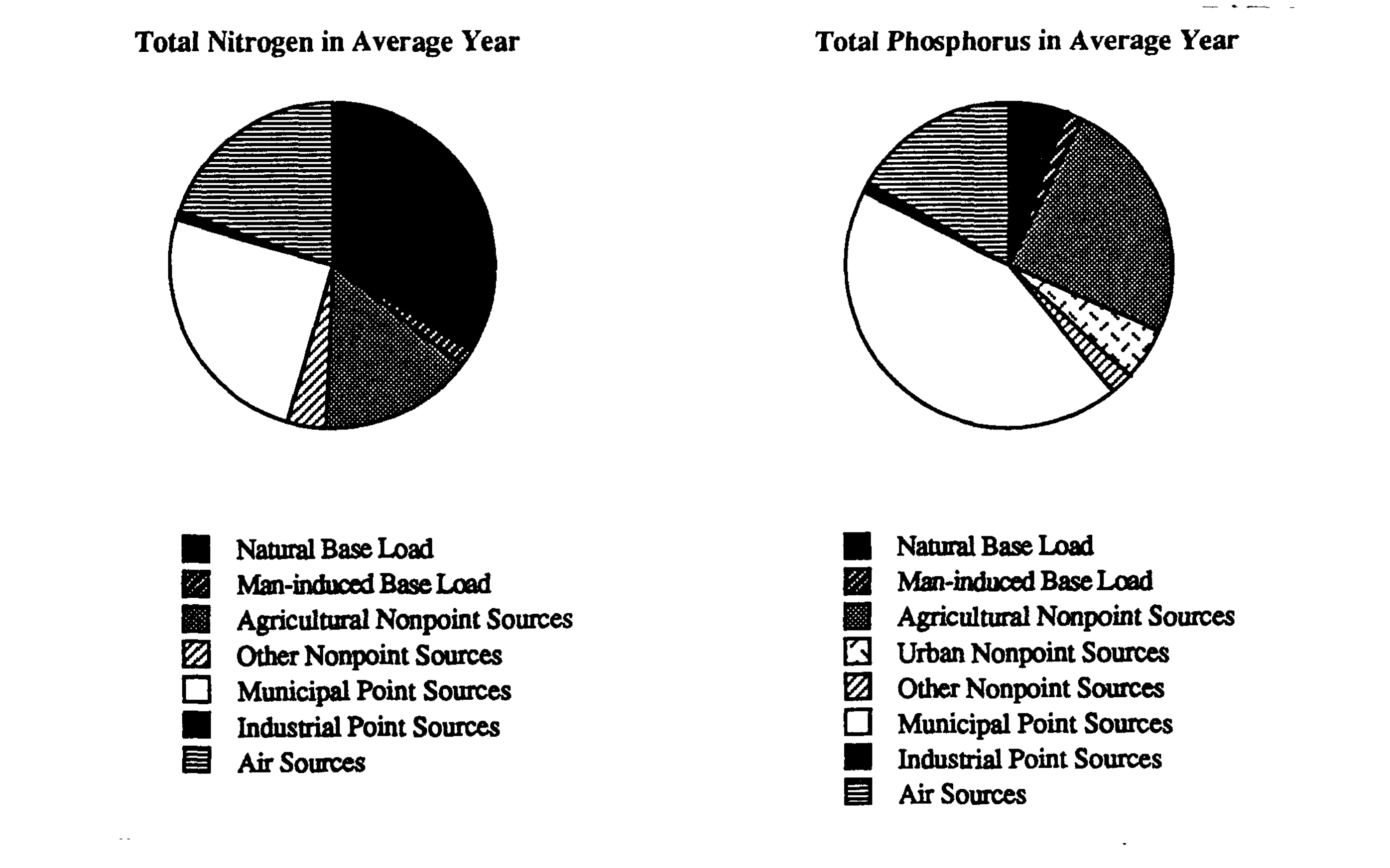


Figure 3-1. Nitrogen and Phosphorus Sources in the Chesapeake Bay Basin in 1985

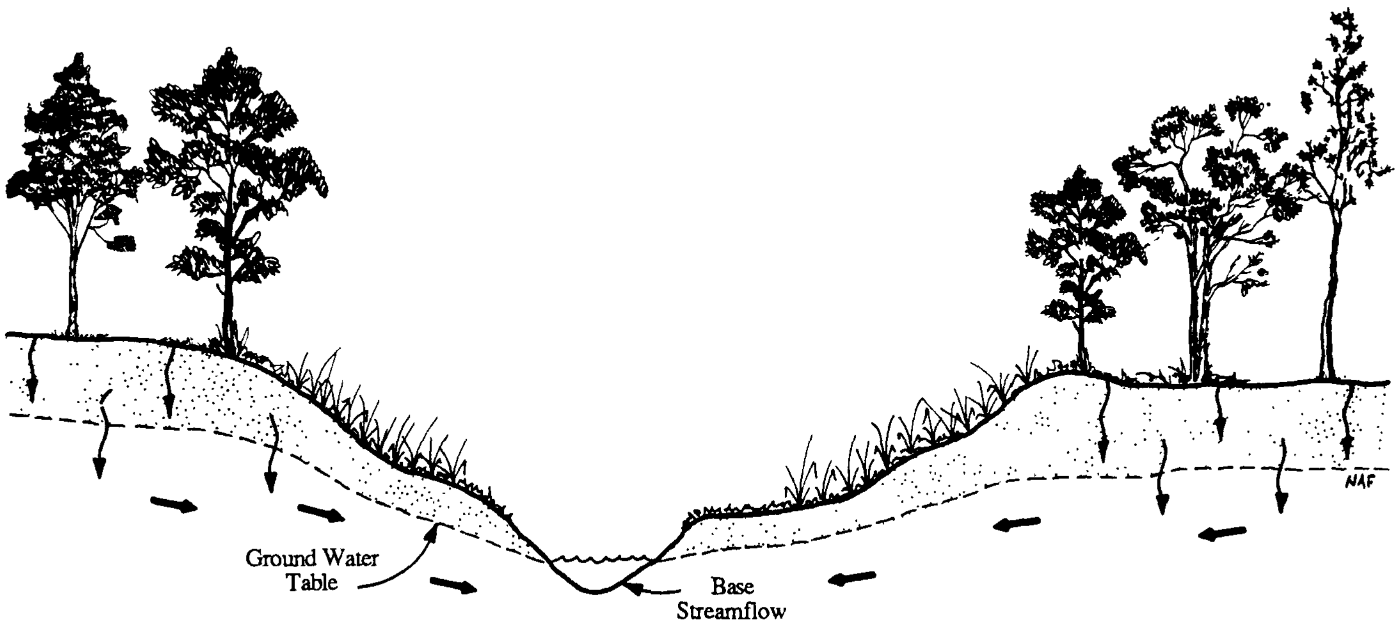


Figure 3-2. Movement of Nutrients to Ground Water and Base Streamflow

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

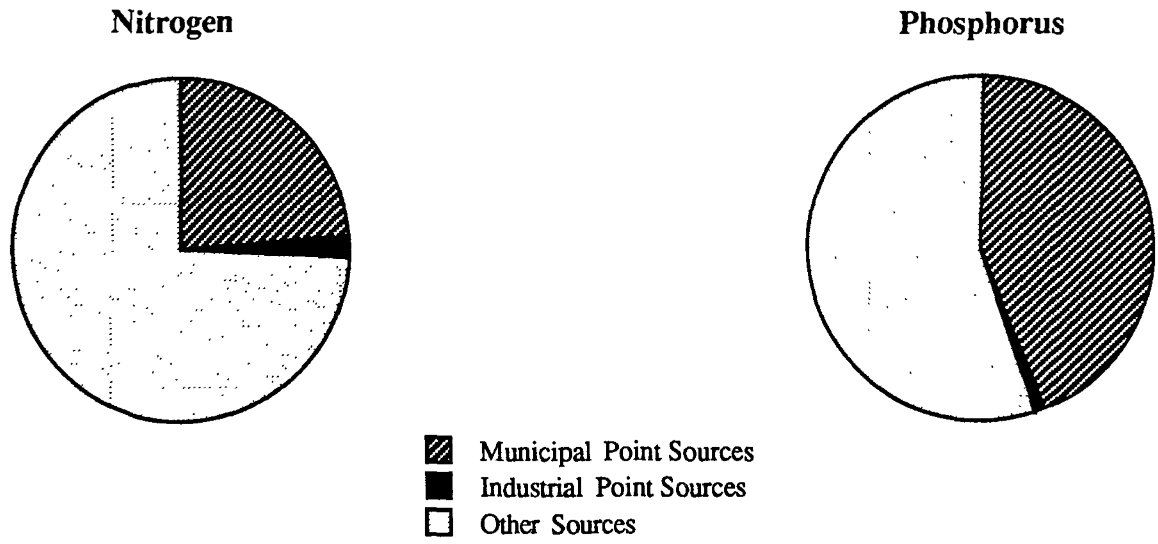


Figure 3-3. Relative Contributions of Point Sources of Nitrogen and Phosphorus in the Chesapeake Bay Watershed in 1985

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 flow[3].

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 (13 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

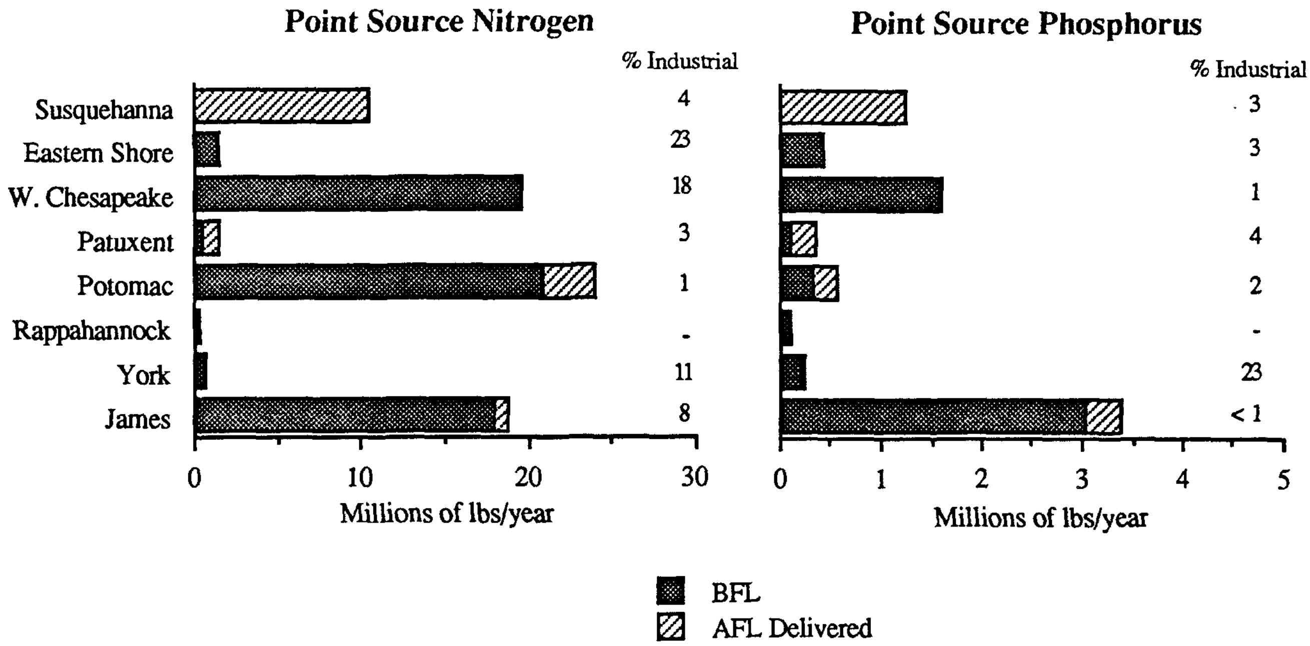


Figure 3-4. Point Source Loadings of Nutrients by Basin

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

		Year 2000 (CBP) [a]		Year 2000 (states) [b]		Design capacity [c]	
State	1985 Flow	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.

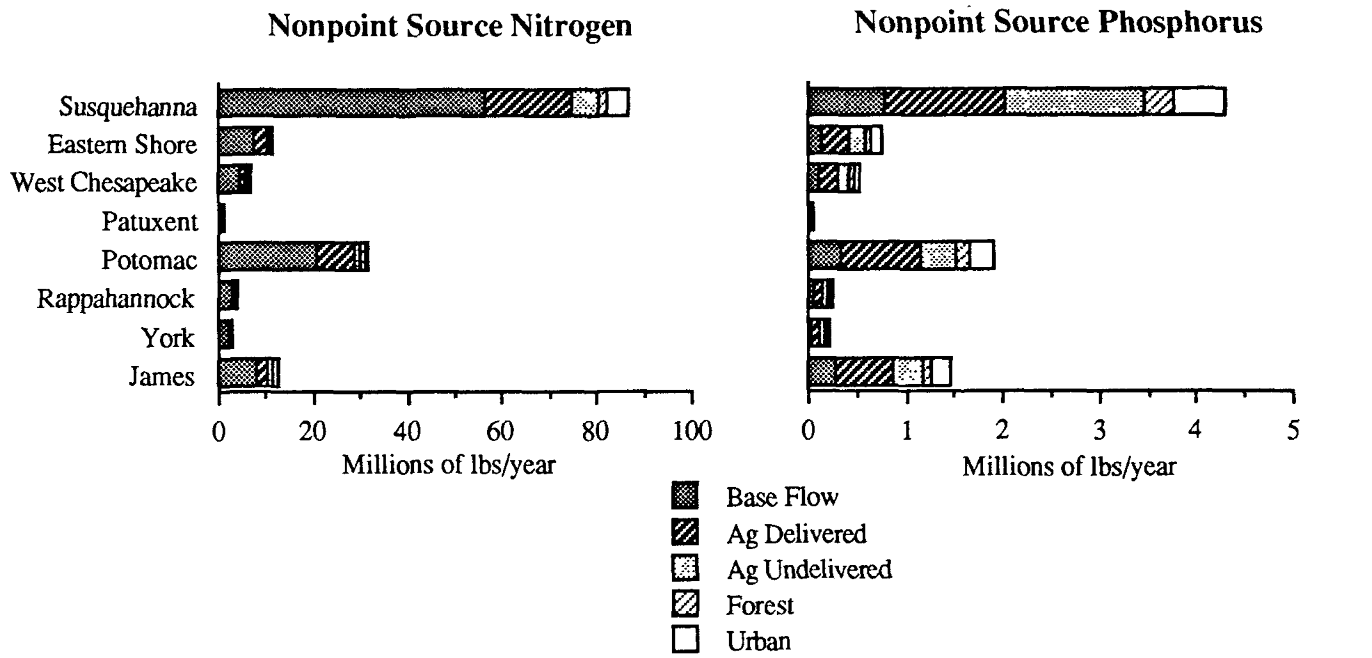


Figure 3-5. Nonpoint Sources of Nitrogen and Phosphorus in the Chesapeake Bay Watershed.

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 practices [45]. 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

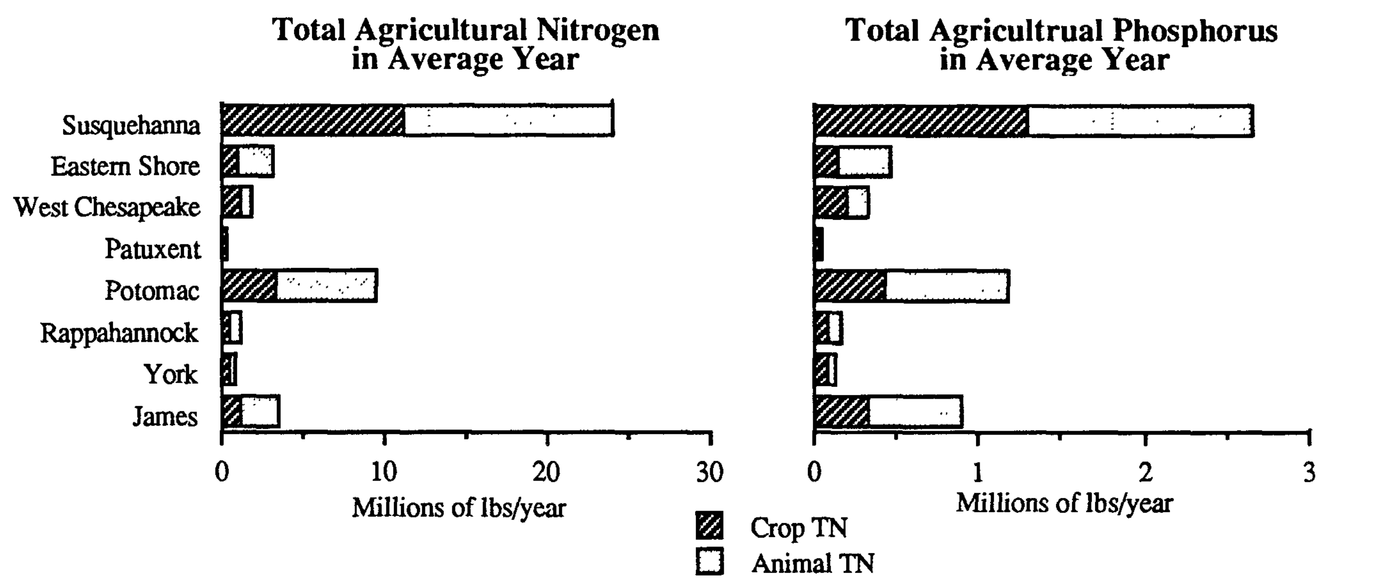


Figure 3-6. Agricultural Nonpoint Sources in the Chesapeake Bay Watershed

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

	NITROGEN		PHOSPHORUS	
Tributary	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

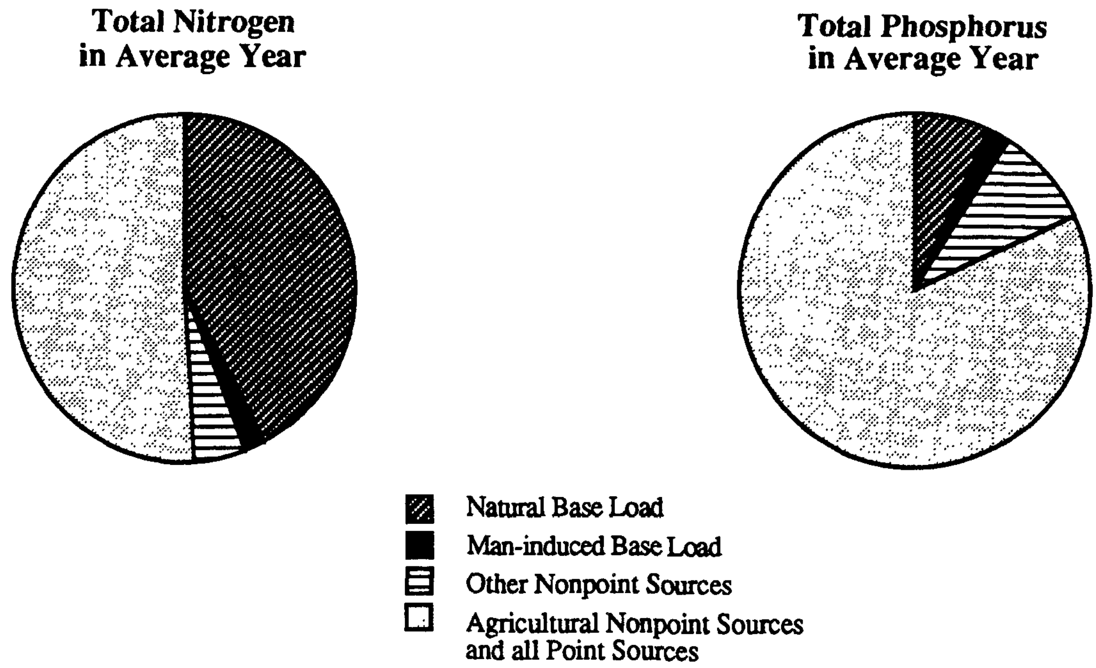


Figure 3-7. ***Base Flow Load Distribution in the Chesapeake Bay Watershed in 1985***

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 estimates [48], 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 flows 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 phosphoru (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 gas [51]. 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

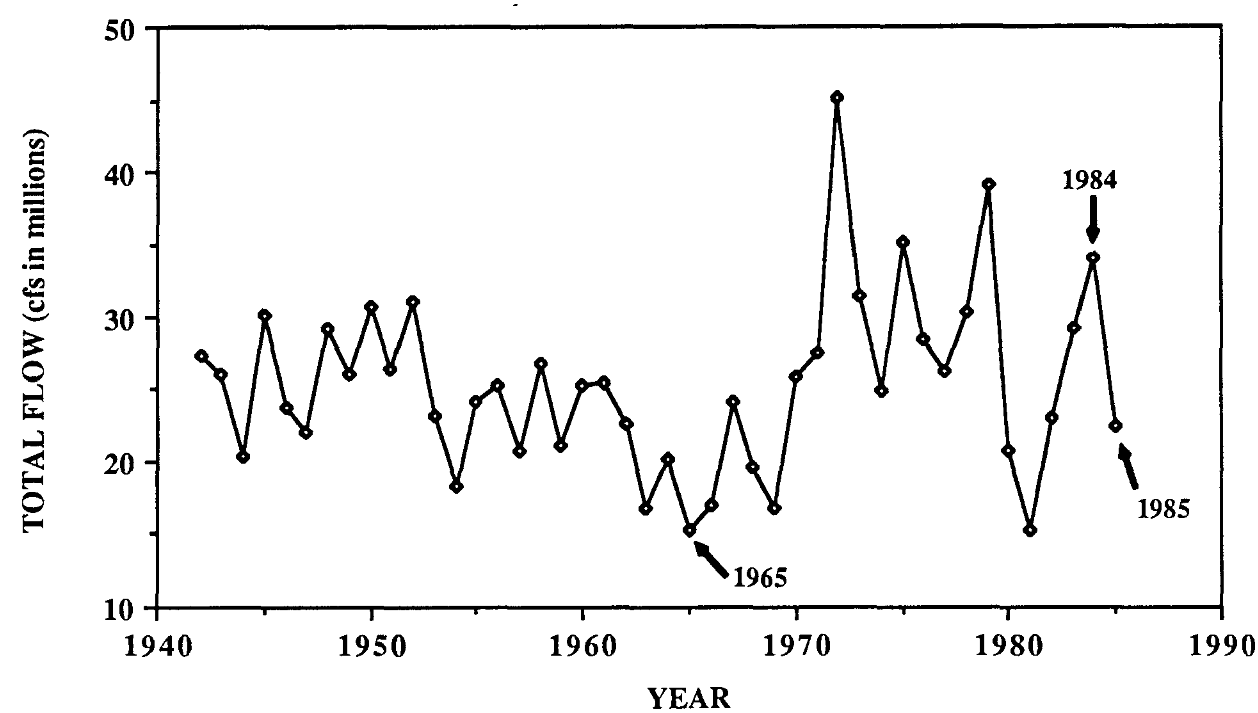


Figure 3-8. Total Annual Flow (cfs) for Major River Basins in Chesapeake Bay over a 44-year Period

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 waste-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 options [52]. 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 *a* Total Mass Bay and Tributaries (10^6 kg)	CHLOROPHYLL *a* Peak Summer Avg. Concentration in Bay Channel (µg/1)	DISSOLVED OXYGEN - DO Lowest Summer Average Conc. in Bay Channel (mg/l)	DO 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.

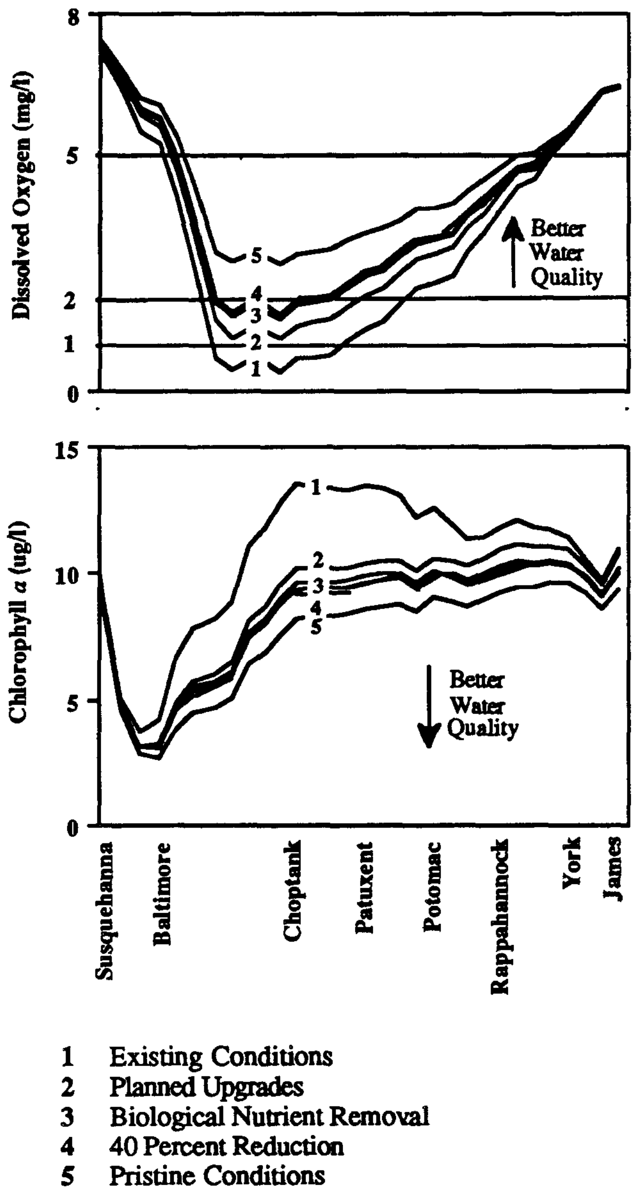


Figure 3-9. Bottom Layer Dissolved Oxygen and Upper Layer Algae Concentrations Projected for the Chesapeake Bay in the Year 2000

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

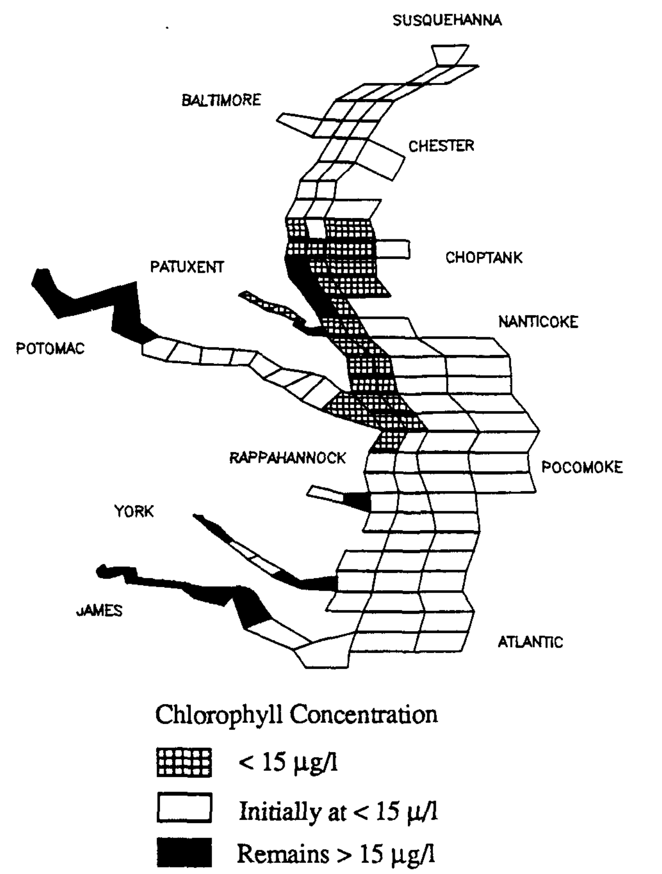


Figure 3-10. Improvements Projected in Surface Chlorophyll *a* with the Implementation of the Nutrient Reduction Goal--1984 Circulation

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 nutreint goals and accomodate 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 facilities [53]. 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.

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 2000 [45]. 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

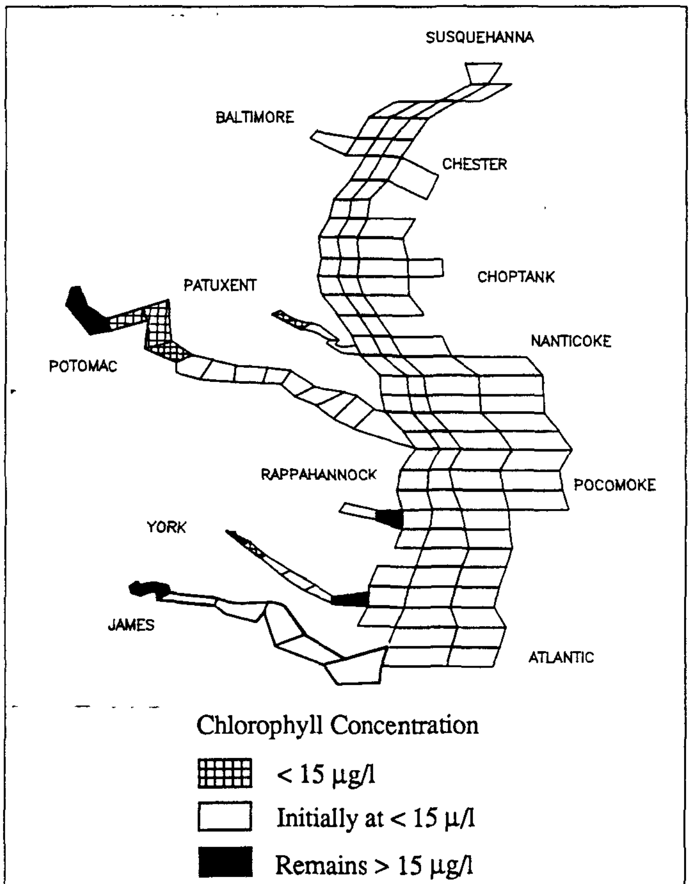


Figure 3-11. Improvements Projected in Surface Chlorophyll *a* with the Implementation of the Nutrient Reduction Goal--1985 Circulation

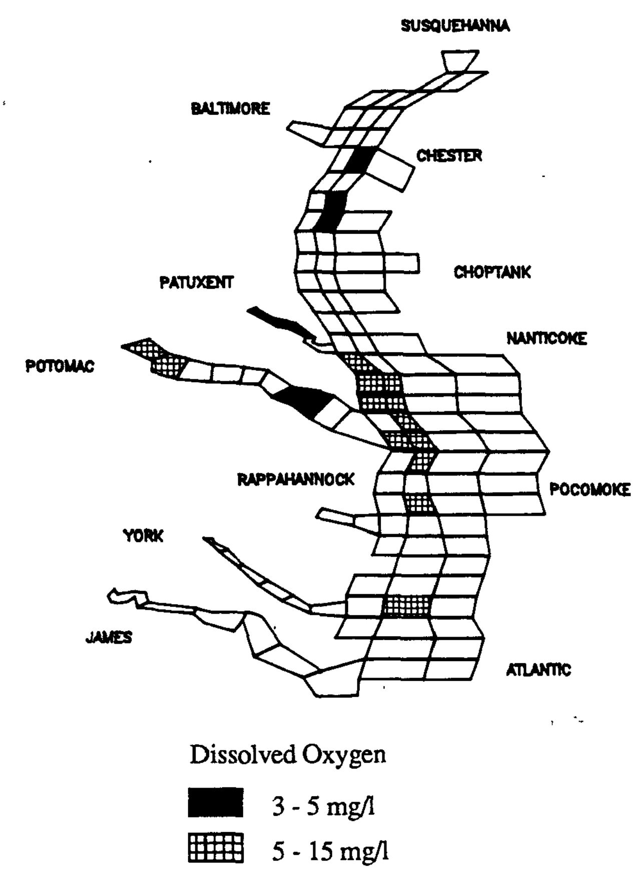


Figure 3-12. Improvements Projected in Dissolved Oxygen with the Implementation of the Nutrient Reduction Goal--1984 Circulation

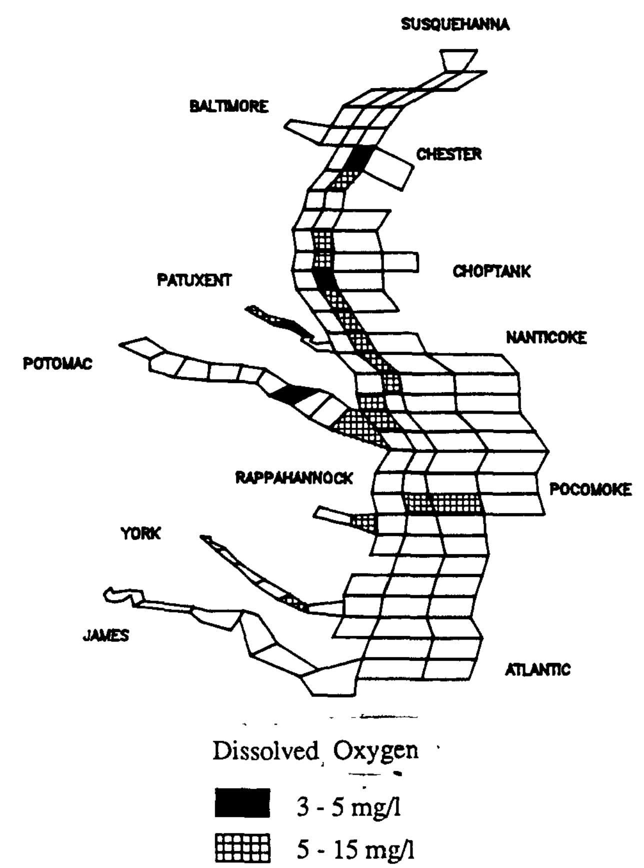


Figure 3-13: Improvements Projected in Dissolved Oxygen with the Implementation of the Nutrient Reduction Goal--1985 Circulation

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 implement-ing 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 (Baywide) 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 activity, 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 increases in population and wastewater flows are accurate overall (though variations from one area to another may put unanticipated burdens on some individual treatment plants).

Finally, to gain the flexibility needed to employ an efficient mix of control programs, planners must assume that nutrients reduced from any source have equivalent effect in achieving the overall nutrient reduction goal.

A variety of factors will influence decision-makers as they select additional controls needed to achieve the 40 percent goal. These include geographic location, the status of existing control programs, initiatives already under way, and available funding. A number of other guidelines, however, are applicable throughout the Bay basin. Some of these are outlined below.

Concerns of Equity

Jurisdictions which already treat wastewater at levels above those required to meet the nutrient reduction goal may wish to suggest ways their past efforts can be recognized in future treatment plans. Some of these jurisdictions have pointed out that any plan for a uniform rollback of nutrient discharges would be inequitable and, in some limited cases, nearly impossible to achieve.

Cost Considerations

Cost-effectiveness obviously is a critical consideration in structuring a comprehensive nutrient reduction program. The comparative cost of alternative nutrient removal programs can be derived from planning level unit costs shown in Table 3-5. The assumption that nutrient reductions from any source have equivalent effect is essential to allow consideration of control alternatives on the basis of costs.

Unit costs presented in the table demonstrate the economies of scale realized by larger facilities when additional point source treatment technologies are employed. The difference is especially significant in the case of biological nutrient removal.

The comparative cost figures show that nutrient reduction is achieved at least cost from controls on agricultural land. There are recognized limits on the effectiveness of these controls, however, and, judging from program experience, limits as well on the rate at which they can be implemented successfully.

Effectiveness of Controls

The cost of control systems must be balanced against the certainty of results in selecting a mix of programs that will most efficiently achieve the 40 percent nutrient reduction goal. There are wide differences, certainly, in the control options available to Bay basin planners.

Point source controls, for example, offer a strong degree of predictability in the results that can be expected. Mechanisms for implementing these controls are well known. They are backed by the regulatory muscle of permit provisions, monitoring and reporting requirements, and enforcement programs. Grant and loan programs are in place to assist municipalities that install needed point source controls.

Control of nutrients from nonpoint sources, on the

Table 3-5
Planning Level Unit Costs for Nutrient Removal

Control Method	Design life (years)	Cost of total N and P removed * (dollars/lb]
Agricultural BMP		
Animal Waste	25	0.44
Cropland	5	0.13
Urban Stormwater BMP		
Commercial	20	1.19
Residential	20	3.15
Point Source Treatment		
Chemical P Removal		
1 MGD	20	2.58
10 MGD	20	2.19
BNR (A20)		
1 MGD	20	2.57
10 MGD	20	0.98
Limits of Technology	20	4.67

* (53) (56) (57) (58) (59)

other hand, is beset by uncertainties. Results are weather dependent and difficult to monitor. Controls must be engineered individually for each site. Agricultural programs depend largely on the voluntary involvement of farmers. In the case of urban nonpoint sources, control technologies are available but effective implementation programs have not yet been demonstrated.

Nutrient management--the reduced use of chemical fertilizers in conjunction with the application of animal wastes--is promising but its effectiveness has not been quantified to any degree of precision. There also are uncertainties about the performance of wetlands as nutrient treatment systems, as well as the efficacy of filter strips in reducing nitrogen discharges.

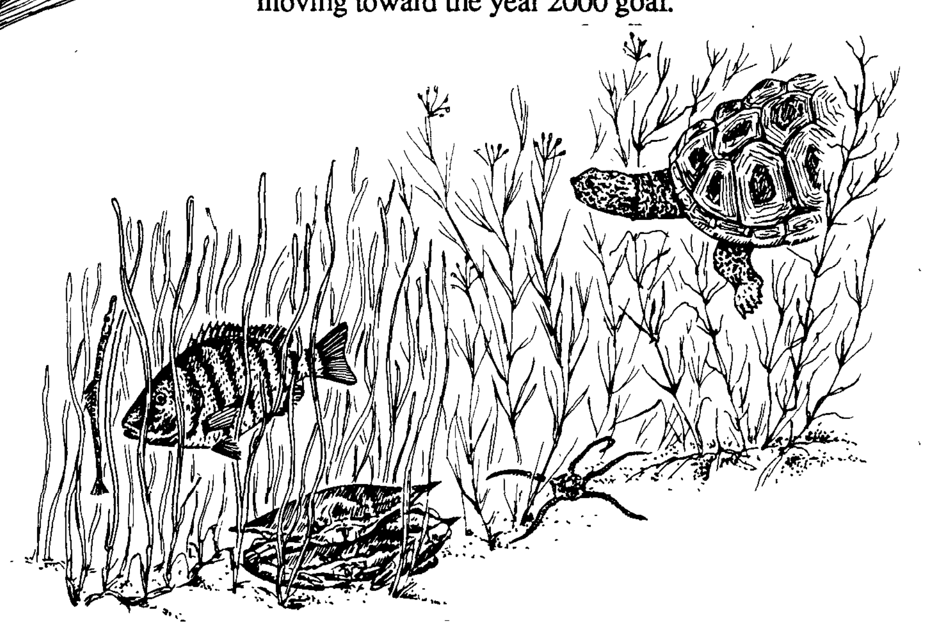
Even demonstrated reductions are uncertain in their impact if they occur some distance from the Bay. As noted earlier, not all untreated nutrients discharged in the watershed reach the Bay. A more complete understanding of delivery ratios is an objective of current work to recalibrate the watershed model with new land use data. Time-varying water quality models of the future also will help refine pollution reduction strategies. In the interim, it is safe to assume that reductions nearest the Bay and in the tidal tributaries will have greater impact on Bay water quality than controls applied elsewhere in the watershed. However, water quality in fish spawning areas of tributaries also is an important consideration that may well influence pollution control choices.

Decisions to Come

Government agencies and citizens of the Bay watershed face a series of difficult decisions in the months and years ahead as they consider options for controlling nutrient enrichment of the Bay and implement programs to attain reduction goals.

The specific water quality requirements necessary to protect living resources in each basin, as well as the efficacy and cost of available control programs, must be weighed as state and local jurisdictions decide upon nutrient management strategies.

Time is short for charting the best course to meet the year 2000 nutrient reduction goal. The 1987 Agreement requires that Bay jurisdictions develop, adopt, and begin implementation of a Basin-wide nutrient reduction plan by July 1988. The 40 percent target will be reevaluated by December 1991 on the basis of data from modeling, monitoring, and results achieved up to that time, but Bay Program participants clearly want action now to begin moving toward the year 2000 goal.



Chapter 4

Building a Strategy for Managing Toxic Pollutants

The widespread presence of toxic substances poses a potential threat to the living resources of the Chesapeake Bay and to the integrity of the ecosystem as a whole. To meet this threat the 1987 Bay Agreement commits participants to "develop, adopt, and begin implementation [by December 1988] of a basinwide strategy to achieve a reduction of toxics consistent with the Water Quality Act of 1987 which will ensure protection of human health and living resources. The strategy will cover both point and nonpoint sources, monitoring protocols, enforcement of pre-treatment regulations and methods for dealing with in-place toxic sediments where necessary."

Toxic pollutants are heavy metal or organic compounds that arise from a variety of point and nonpoint sources--industrial plants, farmland, urban areas, sewage treatment facilities, hazardous waste sites, and many others. They may be present in air, land and water. Once these pollutants enter and settle in the Bay or adjacent streams, bottom sediments become contaminated and are an in-place source of future contamination.

Along with excess nutrients, low dissolved oxygen levels, loss of habitat and other stresses, toxic substances contribute to the deterioration of the Bay. Their adverse effects, however, are not always immediately apparent. Unlike the massive "kills" that leave thousands of fish belly up in the water or decaying on shore, toxic pollutants also may overwhelm organisms in sensitive early lifestages. Many do not survive to become adult breeders, accelerating declines in stocks and continuing a downward spiral in the living resources of the Bay. Resulting smaller harvests have both ecological and economic consequences.

Research Findings

During the seven-year study that initiated the Chesapeake Bay Program, researchers found toxic metal and organic concentrations significantly higher than natural background levels in many parts of the Bay [18]. In highly industrial areas, such as the Elizabeth and Patapsco rivers, sediment metal concentrations were 100 times and more above natural levels. High levels of metal contamination were found in the Upper Potomac, Upper James, small sections of the Rappahannock and York rivers, and the upper mid-Bay. Organic compounds were found in sediments in mean concentrations of hundreds of parts per million, particularly in urban and industrial areas.

During the research phase, water quality data for the periods 1971-1975 and 1975-1980 were analyzed and exceedences of EPA water quality criteria were determined. Data for the period 1980-1985 are now being evaluated. The comparison of these latest findings with earlier data will help to define trends in the concentrations of heavy metals over time and to assess their toxic threat to living resources. Today, researchers cannot accurately describe the relationship between metal concentrations in the sediment and water column and their impact on living resources.

New sampling efforts undertaken in 1984-1985 as part of the Chesapeake Bay monitoring program will continue to expand understanding of the distribution and concentrations of toxic substances in the Bay system. A comparison of 1979 research-phase data and 1984-85 sampling results is not fully reliable because the number of sampling stations was small and their locations were not identical.

The research findings and current sampling indicate that toxic substances are accumulating primarily in urbanized areas such as the Baltimore Harbor and the Elizabeth River. With the exception of these "hot spots," Baywide concentrations of toxic substances are low, and it is difficult to determine their significance in declines in living resources. However, in highly contaminated areas, species diversity has decreased and the species mix has tilted toward pollution-tolerant organisms such as worms, indicating that living resources are stressed by the elevated levels of toxic substances [26]. Because some toxicants bioaccumulate in the tissues of fish and shellfish, contamination also can endanger human and animal health.

The report concluding the research study recommended that EPA and Bay jurisdictions develop a basin-wide plan to control toxicity from point and nonpoint sources [18]. The 1987 Bay Agreement expands upon that objective as well as establishing December 1988 as the target date for beginning implementation of the control strategy. The information presented in this chapter is intended to provide a basis for developing a strategy and to assist in identifying issues and problems that require attention.

Existing Control of Toxic Pollutants

Federal environmental legislation has spawned a number of regulatory programs that are being utilized to control toxic pollutants in the Chesapeake Bay watershed. For the most part, the authority to administer these programs has been delegated to the states with EPA maintaining oversight responsibility. Figure 4-1 summarizes these programs. The schematic shows the different sources of toxicants, legislative authority for regulation and ongoing activities in the Bay watershed. It also shows that the statutory framework to control toxic substances is in place and lists ongoing activities. In large part, the number of ongoing activities reflects the current understanding of the sources, not the toxic potential, of pollutants. Consequently, existing activities may not address the most threatening toxic sources. The comprehensive approach proposed in the Bay Agreement is needed to assess relative risks and assign priorities for the control of toxic substances from point, nonpoint and in-place sediment sources.

Regulation of point source toxicants in wastewater focused originally on technology-based controls of individual pollutants. Using toxicity and production quantity as criteria, EPA developed a list of 65 "priority pollutants" in 1976. Congress made this approach part of the Clean Water Act in amendments enacted in 1977. The new legislation directed that point sources other than municipal wastewater treatment plants utilize the "best practicable control technology" to meet effluent limitations for toxic pollutants. EPA was to establish these limits by July 1977. Industries were to move to more stringent "best available technology" (BAT) controls by July 1, 1983 (a deadline that was subsequently extended). Currently, 126 substances are listed as priority pollutants.

EPA has defined BAT controls and issued effluent guidelines for 33 major categories of industry. Controls and guidelines covering the manufacture of pesticides are being developed. The guidelines define BAT controls that can lower toxic concentrations by as much as 99 percent.

These requirements are enforceable through the National Pollutant Discharge Elimination System (NPDES) and local pretreatment requirements. NPDES permits, written by EPA or the states, are required for any industry or treatment plant that discharges wastewater directly into waterways. In addition to requiring technology-based controls, the NPDES permit can stipulate other conditions that must be met to protect waterways receiving the discharge.

Pretreatment regulations, required by federal legislation and implemented at the local level, are applicable to industries, businesses and other sources that send wastewater to municipal treatment plants. The purpose of pretreatment is to eliminate toxic concentrations that would disrupt the operation of treatment systems or pass directly through those systems to adversely affect waters receiving discharges.

EPA also has established Water Quality Criteria for 136 pollutants, some of which are priority pollutants. Each criterion lists concentrations which should not be exceeded in the water (to protect aquatic organisms) and in fish/shellfish tissue (to protect humans who ingest the seafood). These criteria may then be used by states in developing water quality standards and NPDES permit limits.

Even full compliance with chemical-specific requirements, however, does not always assure adequate protection. It is not always possible to identify all the chemical substances that may be present in complex wastewaters. Also, potentially toxic synergistic effects of compounds and their bioavailability to living organisms may not be known. For these reasons, every state has a general provision in its water quality standards stipulating that effluents must be free from pollutants in toxic amounts.

In 1983, EPA set forth a policy calling for increased use of biomonitoring to detect toxicity that might be present in effluents despite BAT or other controls[60]. If toxicity is found, the NPDES permit may require the discharger to conduct a Toxicity Reduction Evaluation (TRE) as the first step toward correcting the problem.

Nonpoint sources of toxicity--such as drainage from industrial sites, pesticide runoff, leachate from hazardous waste sites, heavy metals in urban runoff, and atmospheric deposition--are less susceptible to direct control than point sources. NPDES permits can include "good housekeeping" requirements to stem runoff from industrial plant sites. Provisions of a number of environmental statutes also bear on various aspects of nonpoint pollution. The RCRA and the Superfund programs provide protection from hazardous waste. Provisions of other laws--including the Federal Insecticide, Fungicide and Rodenticide Act; the Federal Food, Drug and Cosmetic Act, and the Toxic Substances Control Act--also offer some control of nonpoint toxic compounds through regulation of their marketing, distribution or use.

Controlling Toxicants

The control of toxic contamination of the Chesapeake Bay and its tributaries must focus on prevention, i.e. eliminating or controlling toxic pollutants at the source.

Once toxicants reach Bay waterways, they contaminate sediments which can be spread over large areas by tidal transport, natural scour, storms, or channel maintenance and other human activities. Dredging generally is the only means of removing toxic sediments. Once a toxicant is widely dispersed, however, dredging creates a new problem: how and where to dispose of what may be cubic miles of contaminated dredged material. The cost would likely be prohibitive, even if a disposal site were available. Pollutants trapped before release, even as a slurry or a sludge, can be handled as hazardous wastes at considerably smaller cost.

The Chesapeake Bay Program's approach has been to identify toxic compounds that threaten the Bay, pinpoint their sources, and develop coordinated regulatory responses to keep these pollutants out of the Bay. Implementation of this approach takes time, however,

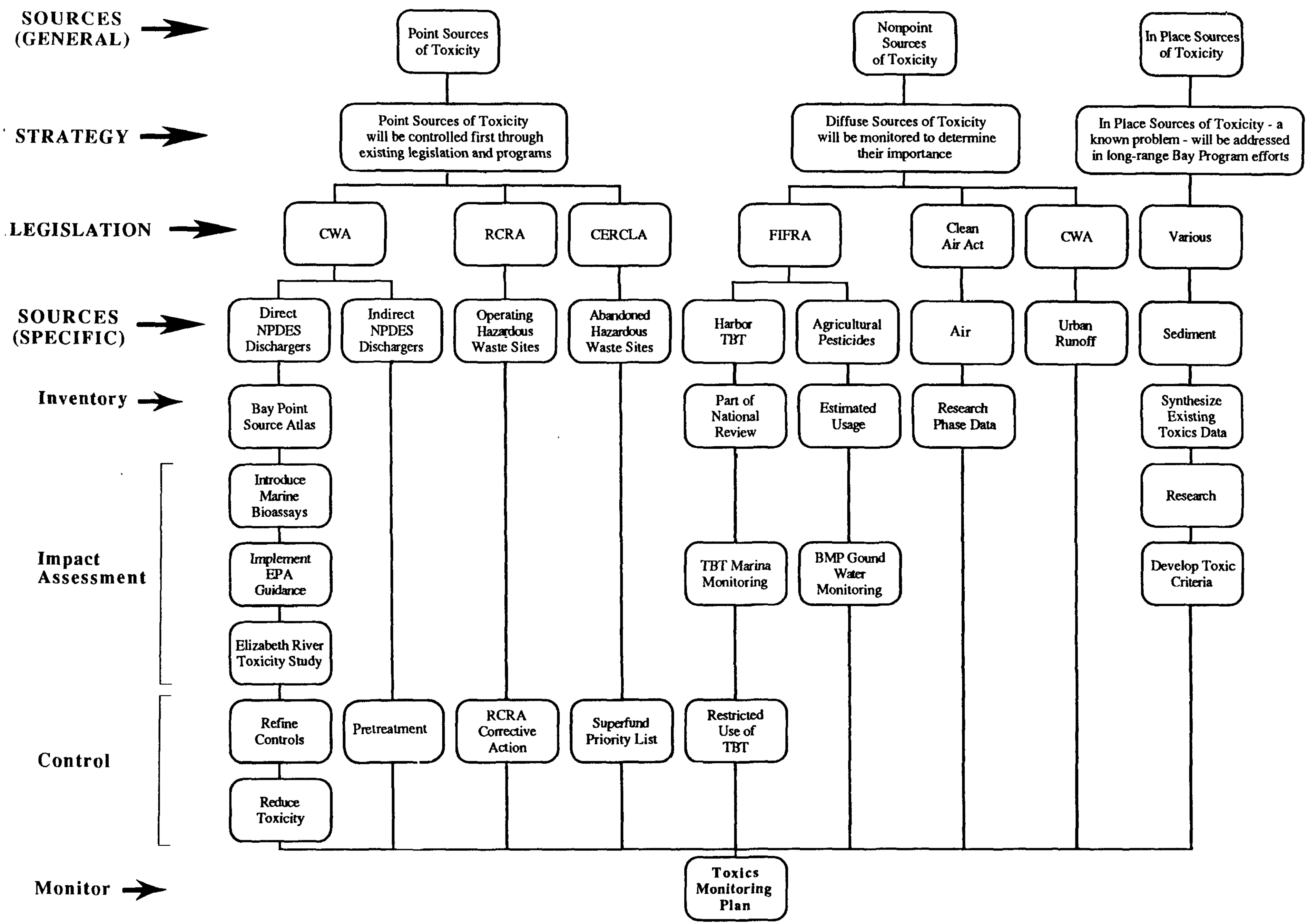


Figure 4-1. Chesapeake Bay Toxics Strategy Schematic

since the sources of toxic pollution impacting upon living resources are in many cases not known and practical means of control may not be available as yet. While pursuing this approach, program managers and scientists have to be alert to pollutants that may demand immediate action. The pesticide tributyltin (TBT), used in bottom paints for boat hulls, is a case in point. After special studies confirmed that the highly toxic TBT was a threat to living resources in the Bay, states moved quickly in 1987 to restrict its use.

Point Source Pollution

Some 6,000 industries and municipal sewage treatment plants discharge wastewater in the Chesapeake Bay watershed. The 500 different kinds of industrial activity carried out in the Basin include coal mining, seafood and poultry processing, wood preserving, ship building and ship repair. There are steel mills, organic and inorganic chemical plants, paper mills, power plants and oil refineries.

These plants discharge a variety of metal and synthetic organic compounds, many of them among the toxicants designated as "priority pollutants" by EPA. It is estimated that discharges of priority pollutants in the Chesapeake watershed total more than 14,300 pounds a day (11,600 organic; 2,700 inorganic). Of this total, 9,000 pounds (7,500 organic; 1,500 inorganic) are discharged below the fall line, where the likelihood of adversely affecting the Bay is greater. (Estimates are drawn from effluent characteristics for selected industrial point source categories. Revisions to those estimates are now being being processed and will result in reduced loadings from the organic chemical industry, a major source for these pollutants). More accurate estimates of loadings, based on measured data, are needed to establish a baseline from which the effectiveness of management programs can be evaluated. Also, these data could be used to construct sub-basin toxicant budgets which would help in assessing or compelling future improvements.

Both NPDES and pretreatment permits are chemical-specific and require controls based on the BAT. Effective control of toxic pollutants, however, requires objective, consistent and effective enforcement of permit limits. It also requires integration of biological assessments with chemical specific controls of toxicity. Biomonitoring may be an effective tool to document the effectiveness of programs to reduce toxic contaminant loadings.

Biomonitoring evaluates the total effluent, assessing the aggregate toxicity and the interaction of the compounds involved. Biological monitoring is especially well suited as a tool to help achieve the Bay Agreement goal of controlling sources of pollution to attain water quality conditions necessary to support the living resources of the Bay.

The use of biological means to assess toxicity is relatively new, but Bay jurisdictions have made a start in applying the technique, interpreting the results, and initiating control actions. Virginia introduced a biomonitoring program in 1980. It is a phased program beginning with acute toxicity tests and proceeding to chronic and bioaccumulative testing where appropriate. It also may include chemical monitoring for specific substances known to be present in the dischargers' wastewater. A toxics management regulation is currently being developed to establish monitoring and toxicity reduction requirements for Virginia dischargers. This regulation is scheduled for implementation beginning in July 1988.

Currently, biomonitoring requirements are included in the NPDES permits of more than 70 industrial plants and 20 municipal treatment facilities in Virginia. These dischargers were selected on the basis of size, a high probability of toxic discharges, or the occurrence of fish kills near their locations. Since the program began, effluent toxicity has been assessed at more than 200 dischargers. Twenty-five demonstrated toxicity and are required to conduct a Toxicity Reduction Evaluation. Ten of these TRE's have been initiated and three are completed[61].

Maryland recently initiated a biomonitoring program that uses chronic as well as acute effects as measures of toxicity. Twelve industrial and six municipal dischargers in Maryland now have, or soon will have, biomonitoring provisions in their NPDES permits, but very little information on effluent toxicity has been generated. However, as part of its' compliance monitoring program, Maryland has contracted with the Johns Hopkins University to biomonitor dischargers where effluent toxicity is suspected. To date, 25 samples have been evaluated using *Ceriodaphnia* and fathead minnow. Six dischargers showed some acute toxicity and have been notified by the state to conduct tests to confirm/ disprove toxicity. One discharger has confirmed toxicity and will be conducting a TRE to reduce toxicity [62].

Pennsylvania relies primarily on a chemical-specific approach to managing toxics in state waters. It is considering a biomonitoring program to supplement the chemical-specific approach. The District of Columbia has a biomonitoring program for the Blue Plains sewage treatment plant. Chronic testing using *Ceriodaphnia* and fathead minnow began in September 1987.

EPA Region III also conducts biological assessments of effluent toxicity, generally in response to specific requests from the Permits Branch, at facilities where effluent toxicity is suspected. In 1986 and 1987, effluent toxicity was evaluated at 72 dischargers using *Ceriodaphnia* and fathead minnow. Twenty-four effluents were not toxic to *Ceriodaphnia* and 37 were not toxic to fathead minnow. Seven of the effluents sampled showed moderate toxicity to *Ceriodaphnia* and 15 high toxicity. Seven showed moderate toxicity to fathead minnow and 14 high toxicity [63]. The states are notified of EPA results. Maryland and Virginia generally require the discharger to confirm/disprove toxicity. Pennsylvania uses the information in developing chemical-specific limits for inclusion in the dischargers' NPDES permits.

The Chesapeake Bay Program is tracking the implementation of biomonitoring at facilities considered to have a high potential to release toxic substances. Facilities where biomonitoring is required are to be identified in the Point Source Atlas [44]. Specific results at individual dischargers are not currently available but will be included. Figure 4-2 shows sites in the Bay basin where biological assessments of effluent toxicity are required in NPDES permits.

A limitation on whole-effluent toxicity can be written into an NPDES or pretreatment permit without identifying the specific compounds that must be controlled.

When overall toxicity has been demonstrated, a TRE may be necessary to identify the specific toxicant(s) in the discharge, determine the source, and evaluate control alternatives. Twelve dischargers in the Bay watershed (all but one in Virginia) had TRE projects planned or under way in mid-1987. Two of the projects are being sponsored by EPA as part of the agency's program to develop TRE guidelines for the use of municipal and industrial dischargers. EPA anticipates completing these guidance protocols in 1988.

Regulatory programs for the control of toxic discharges from point sources should soon reach their full potential. All 94 Bay-region municipal wastewater treatment facilities where pretreatment programs are required have developed plans which have been approved by the state or EPA (see Figure 4-3). All of these programs are to be fully implemented and functioning by the summer of 1988. EPA-delegated states will retain overview responsibility for ensuring proper program implementation and enforcement. BAT controls to meet effluent guidelines are to be fully operational by March 31, 1989. Enforcement of improved state water quality standards through these programs, reinforced by biological assessments, should make it possible to control point source discharges of toxic pollutants to Bay waters by the early 1990s.

Nonpoint Source Pollution

Toxic pollutants from nonpoint sources pose a more difficult challenge than point source discharges because of their diffuse nature and the difficulty of identifying responsible parties. Atmospheric deposition, runoff from city streets, leachate from hazardous waste sites, and pesticides from farms and gardens are among the diverse sources sending toxic compounds to Bay waters. Pollutant type and amount from each source need to be determined to establish control priorities.

Pollution from Hazardous Wastes

Facilities for the treatment, storage and disposal (TSD) of hazardous wastes, as well as abandoned hazardous waste sites and rubble landfills, are closely akin to point sources as pollution threats because their locations (for the most part) are known and their boundaries are limited. However, pollutant migration is heavily influenced by rainfall and therefore hazardous wastes are included in the discussion of nonpoint sources of toxic substances.

Active hazardous waste facilities are regulated under the Resource Conservation and Recovery Act (RCRA); the cleanup of abandoned sites comes under the Superfund program.

Under RCRA, TSD facilities are required to have permits specifying the technical operating standards and administrative procedures that must be observed to prevent toxic releases. There are about 300 TSD sites overall in Maryland, Virginia and Pennsylvania. Sites close to the Bay were ranked high, medium or low, based on solid waste management activities and toxic potential.

Bay managers hope to target high priority sites near the Chesapeake (below the fall line) for accelerated control action because of their potential to adversely affect living resources in Bay waters. The goal is to have the 78 facilities in this sector under permits by May 1990, 30 months before the deadline (November 1992) mandated by Congress in the Water Quality Act of 1987. Facilities without permits operate under interim status. Under interim status there are rules and regulations that must be complied with regardless of permit status. Seventy-four Bay-basin sites are included on the Superfund National Priority List (NPL); 28 of these hazardous waste locations are slated for early remedial cleanup action. Figure 4-4 shows the location of both RCRA and Superfund sites considered to have the greatest potential for polluting Bay waters. In addition, other potential NPL sites are to have preliminary assessments and follow-up site investigations completed by January 1989. Accelerated action is expected at sites that pose the greatest threat to living resources in the Bay and its tributaries.

Pesticides

Pesticides control plants, insects, animals and fungi classified as pests. They are widely used in the Bay watershed for crop production, to control weeds, as wood preservatives, and in paints. In urban areas, pesticides routinely are applied by homeowners or commercial pest control firms to control pests in lawns, trees, homes or gardens.

Some 1,400 active pesticide ingredients are registered with EPA for use in the United States. These compounds are used in more than 35,000 commercially available pesticide formulations.

Pesticide products are not intended to spread beyond areas of application, but these toxic chemicals find their way into the Bay environment through the air, in ground water, and in stormwater runoff. Pesticides were detected in sediments and biota at four of the seven stations sampled in Maryland waters in 1985. Further studies are needed to determine the extent of contamination from pesticides in the Bay basin.

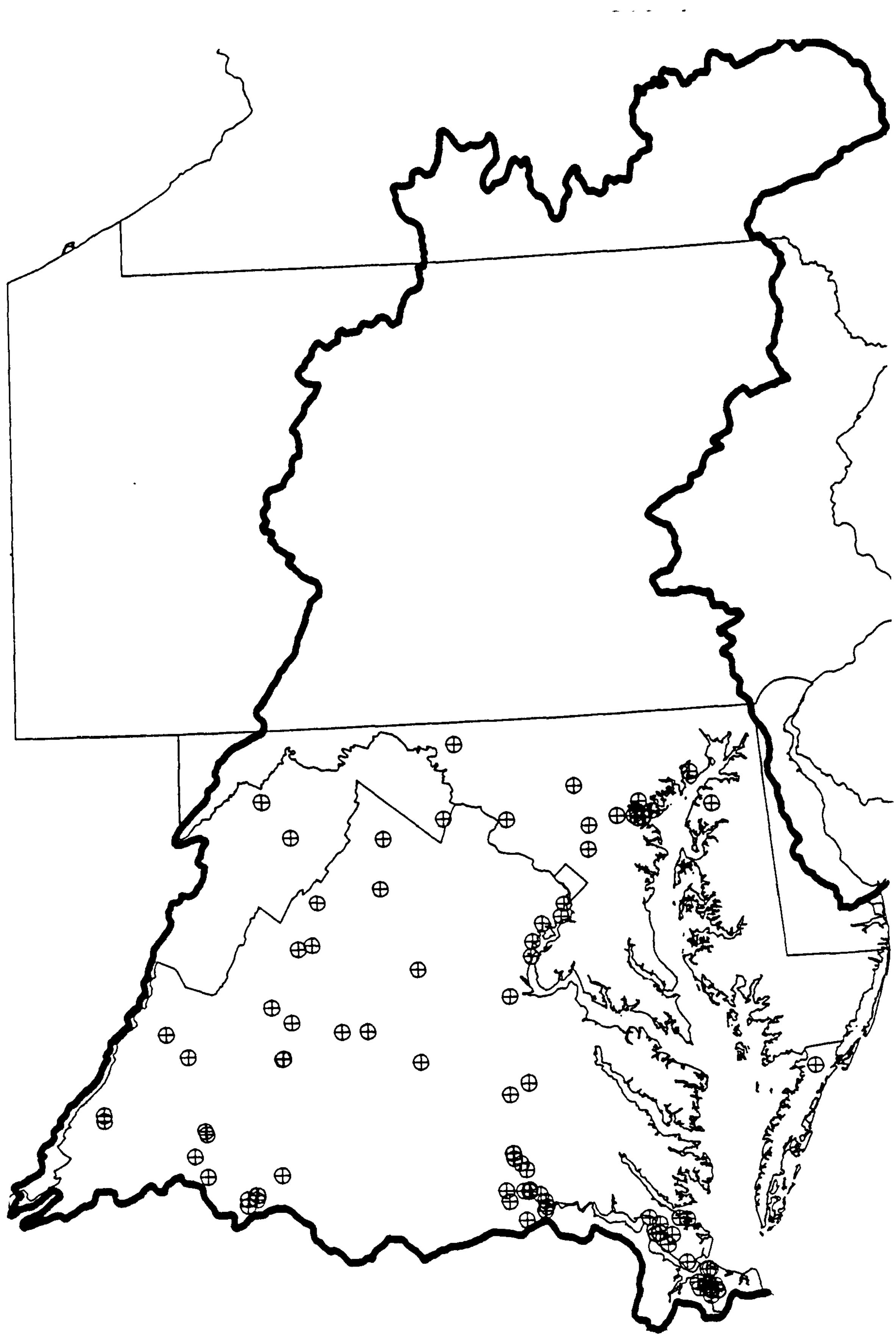


Figure 4-2. Dischargers with Biomonitoring Requirements

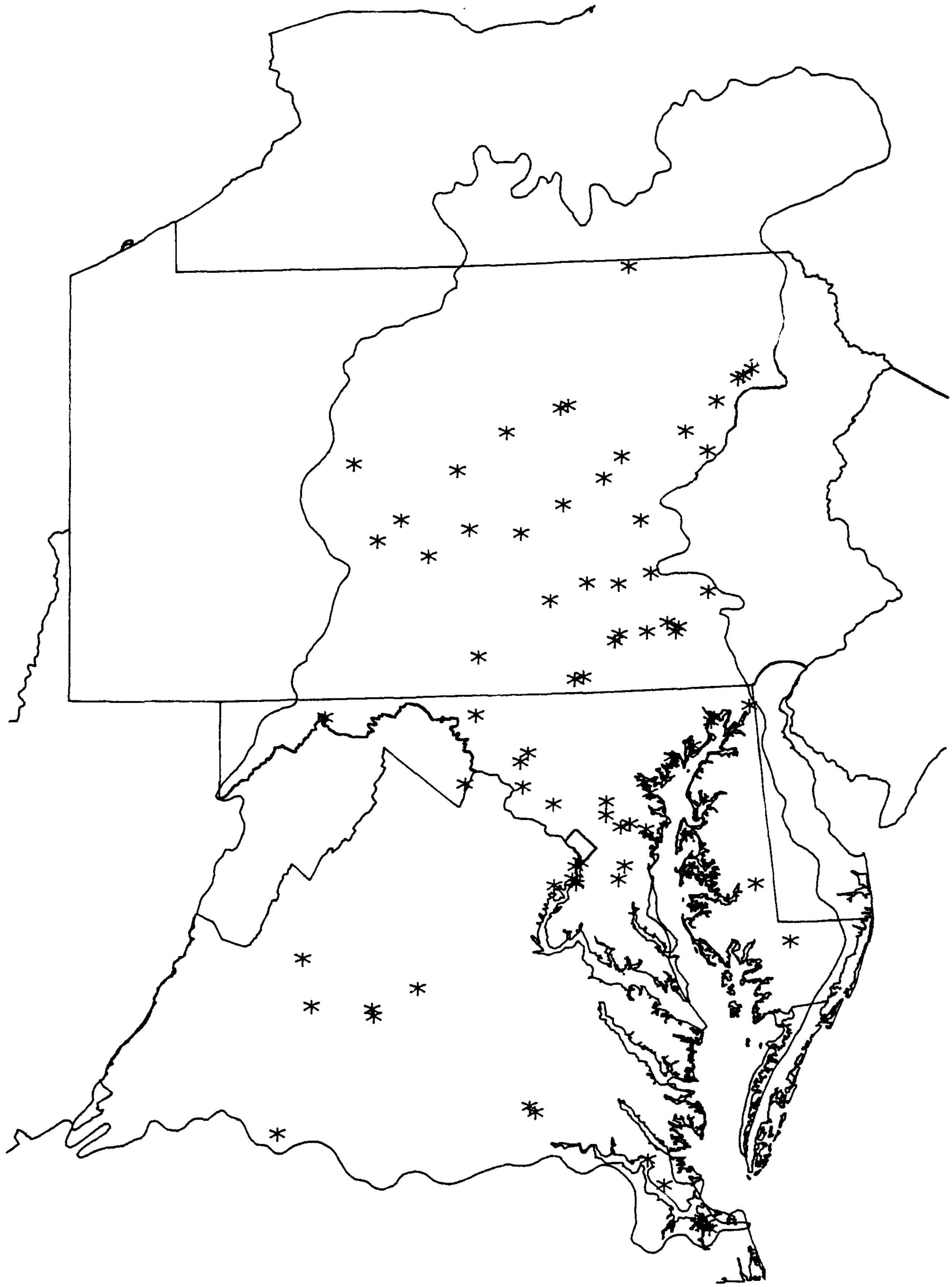


Figure 4-3. Municipal Dischargers with Pretreatment Requirements

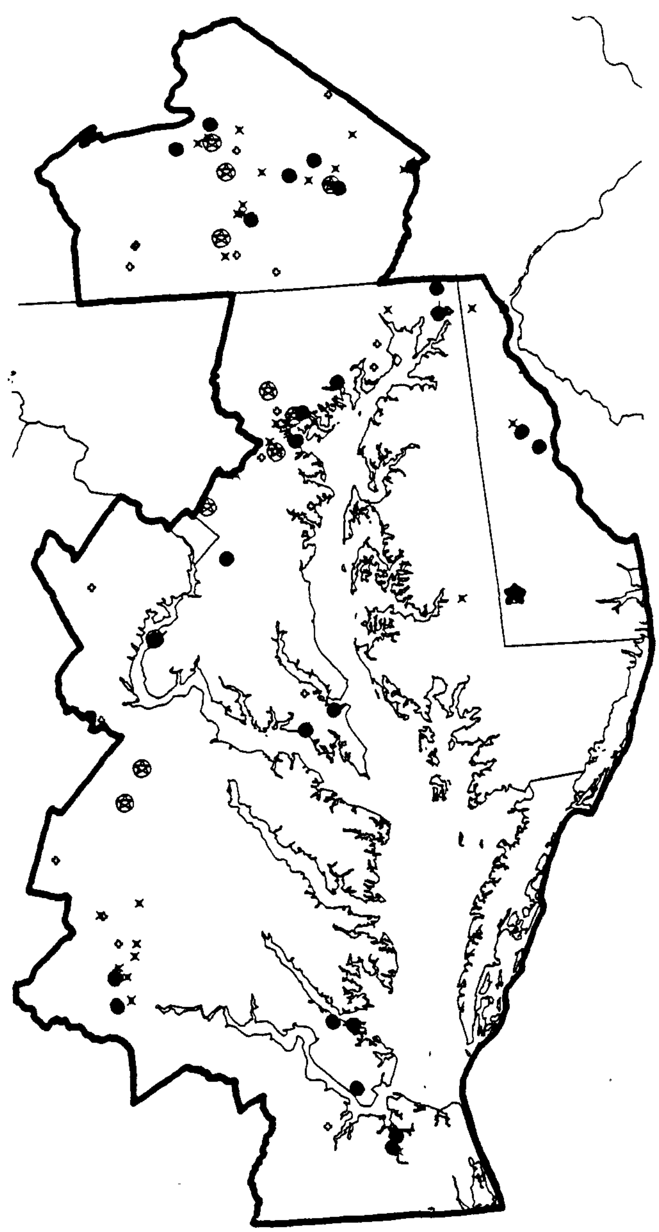


Figure 4-4: Hazardous Waste Sites in Watersheds Draining to Critical Living Resource Areas

Agricultural Use. In the Bay basin, most pesticide usage is associated with agricultural production of corn, wheat, soybeans, and alfalfa, although large amounts of chlordane are used for termite control. Figure 4-5 shows the relative intensity of pesticide usage in Maryland, Virginia and Pennsylvania; the Delmarva peninsula leads in the intensity of pesticide use. Herbicides most frequently applied to land or farms in the Bay watershed are atrazine, alachlor, metolachlor, simazine, linuron, butylate and cyanazine. Major insecticides in use include parathion, dimethoate, methoxychlor, carbofuran, and methomyl.

Best management practices (BMPs) employed on farms to control runoff and erosion generally result in greater infiltration. Pesticides and other chemicals may then percolate through the soil, eventually polluting ground water. The extent and degree of ground water pollution resulting from the use of BMPs are still unclear.

Pesticide registration and labeling requirements are intended to prevent improper use of these products. Currently, EPA is gathering up-to-date information on health and environmental effects through the "Data Call-In" program which is aimed at the proper re-registration of older pesticides. In addition, each of the states has active programs for pesticide control and management. Both EPA and the states need to focus on effective control of pesticides that pose the greatest environmental risk.

Integrated pest management (IPM), a systematic approach which combines biological, cultural, physical or mechanical techniques with chemical controls, is another means to minimize pesticide use. In certain situations, IPM can reduce the farmer's expenditures for pesticides by 40 to 70 percent, but this method does require increased technical assistance, scouting for the presence of pests, and careful attention to crop conditions, the weather, and application techniques. Use of chemicals other than pesticides also may be recommended.

Several IPM pilot programs are currently underway in the Bay basin. Two projects in progress on farms in Pennsylvania's lower Susquehanna basin combine IPM methods with progressive fertilizer management techniques. Thirty-three farms in the Maryland Double Pipe Creek watershed are under Rural Clean Water Program contracts stipulating the use of IPM and nutrient management to enhance the water quality improvement from cost-shared BMPs. IPM also is being used experimentally on peanut farms in southeast Virginia. The increased use of IPM techniques could become an important factor in reducing toxic pollution in the Chesapeake Bay region.

The Maryland Department of Agriculture has completed an inventory of pesticide usage by agricultural producers, certified private applicators of restricted-use pesticides, commercially licensed businesses and public agencies for 1985. Such an accurate inventory, rather than estimates of pesticides applied in the Bay watershed, will help to better characterize pesticide usage patterns, guide environmental fate monitoring, help target applicator training sessions and IPM programs, assist in regulatory decision making, construct toxicant budgets and achieve a better understanding of how agricultural chemicals affect ground water quality.

Marine Use. Pesticides are used in marine paints as an antifoulant to keep hulls free of organisms that slow boat

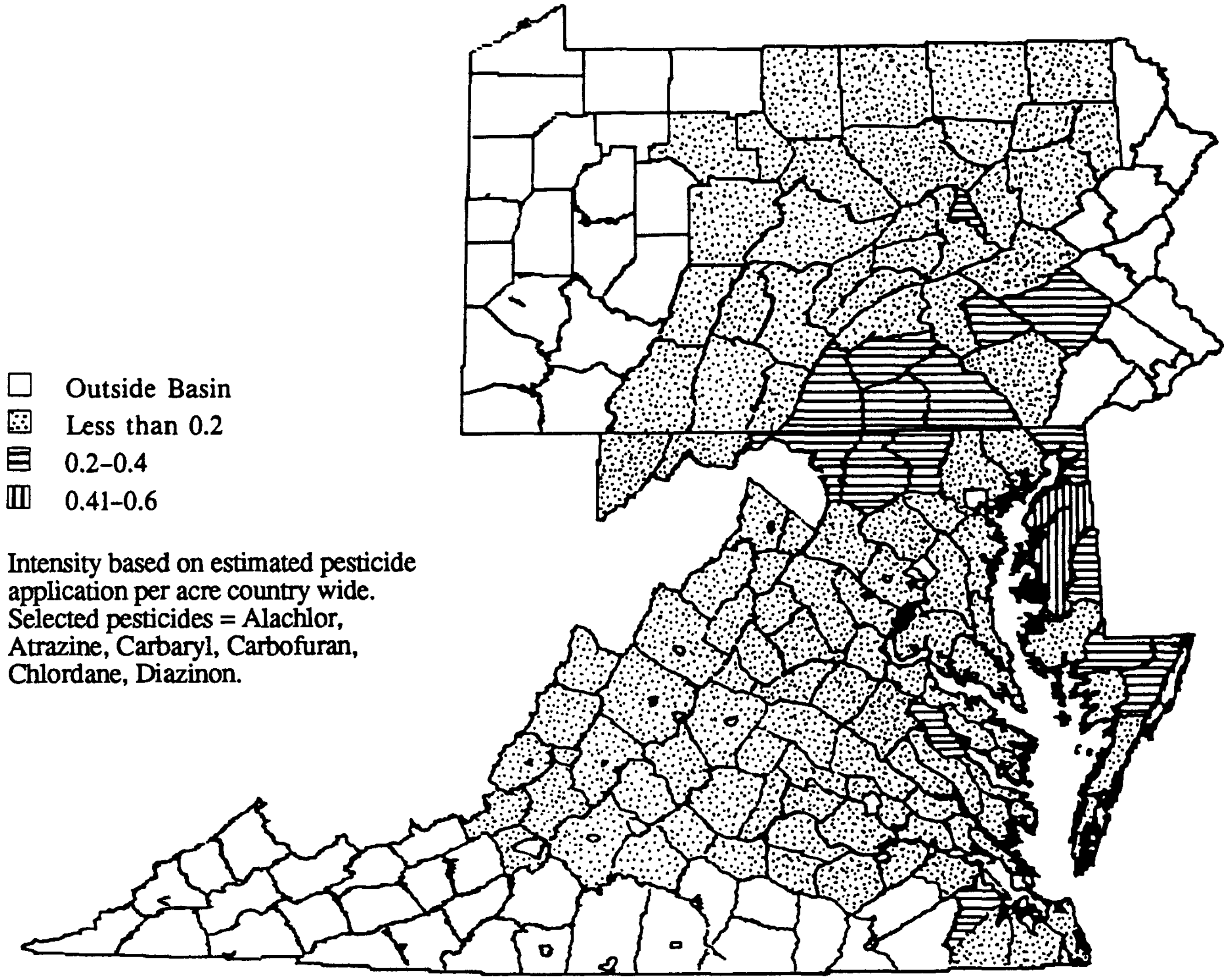


Figure 4-5. MD, PA, and VA Application Intensity of Selected Pesticides

speed and increase fuel consumption. Copper and copper compounds have been used as antifoulants since the 17th century. In recent years, there has been increased use of organotin compounds, such as TBT, which are two to three times more toxic to biota than the copper-based paints.

TBT came into use as an antifouling additive in the 1960s. Bottom paints containing TBT quickly grew in popularity because of the compound's effectiveness. Little information was available, however, on its broader toxic effects and ambient levels in the environment.

The potential adverse impact of TBT became a matter of major concern to the Chesapeake Bay Program in 1985 and federal and state agencies moved swiftly to assess the impact of its use. Maryland and Virginia joined with EPA and the U.S. Navy in sponsoring scientific investigations of TBT concentrations in the Bay and the potential impact upon living resources.

Environmental levels of TBT at harbor sites in the upper Bay were measured monthly from July 1985 to June 1986 by Maryland and Johns Hopkins University. Johns Hopkins and the Navy continued intensive monitoring at one of these sites throughout the summer of 1986. Testing to determine TBT toxicity to resident Bay species was part of the Navy-Hopkins project.

Virginia and the Navy supported work at the Virginia Institute of Marine Sciences to monitor TBT levels in the lower Bay and to perform acute and chronic toxicity tests with oysters. EPA's Chesapeake Bay Program staff carried out a sampling survey to measure TBT concentrations on a weekly basis at four harbors in the upper Bay [25].

These investigations confirmed the potential threat of TBT in the Bay. Concentrations as high as 1171 nanograms per liter (ng/l) were found in the surface microlayer where air and water meet. Levels in the water column ranged up to 998 ng/l. Chronic toxic effects have been documented in laboratory studies with species of marine snails and other molluscs and shellfish at concentrations as low as 10 to 20 ng/l.

Urged by the Chesapeake Bay Commission (CBC), Virginia and Maryland responded with legislation barring the use of TBT on recreational craft (except for aluminum boats) and on commercial vessels under 25 meters in length. The Bay study results also were funnelled to EPA's Office of Pesticide Programs for consideration in a special review of TBT initiated in January 1986. The U.S. Senate conducted a hearing in April 1987 on federal legislation to restrict use of the toxic compound. The concerted action of Bay jurisdictions, the CBC and the Chesapeake Bay Program on the use of TBT was a clear demonstration of the value of coordinated efforts to deal with a toxic threat and protect estuarine living resources.

Nonpoint Urban Sources

Stormwater runoff from roofs, lawns, streets, construction sites, parking lots, industrial sites and other paved and unpaved areas washes a variety of toxic pollutants into waterways of the Bay basin. Hydrocarbons and heavy metals such as lead, iron, copper, chromium and cadmium are common constituents of urban runoff. Washington, Baltimore, and Hampton Roads are major sources of these metals in the Chesapeake watershed.

In 1980, the Chesapeake Bay Program estimated that urban runoff is the source of 19 percent of the lead and six percent of the cadmium reaching the Bay [18]. High concentrations of these and other metals were found in sediments associated with the Baltimore industrialized areas in 1984-1985 sampling data. The relationships between sediment/metal and biota/metal concentrations were not consistent. For example, metals such as zinc and copper tended to be higher in clam tissue than in sediments. On the other hand, lead and chromium were higher in sediments than in tissue.

Toxicants in urban runoff probably have a greater effect on local receiving waters than on the Bay itself, but these areas may include critical habitat for species in the Bay food chain. These pollutants may be one of several factors contributing to the decline both in juvenile populations and in landings of finfish that spawn in the Bay's tributaries.

Although Maryland, Virginia, Pennsylvania and the District of Columbia have laws and regulations to control sediment and erosion at construction sites, the control of urban runoff is not as well advanced in the Bay basin or elsewhere. Maryland's stormwater law is a national model that goes beyond flood prevention and requires water quality and flow to match as nearly as possible predevelopment levels. Maryland also is providing funding for stormwater management programs initiated by local governments. Recently developed stormwater management regulations for the District of Columbia contain a provision to control not only runoff from landfill sites, but to periodically test leachates from such sites for toxic substances and provide for corrective measures if higher than average levels are found [64]. EPA provided funding for the newly established "Stormwater Management Program" in the District of Columbia and is continuing to do so to ensure that the program maintains a solid foundation and meets its mandated goals.

In-Place Toxic Pollutants

In-place sediments are sources of toxicity to the water column and to benthic life in the Bay. High levels of toxic chemicals have been detected in Bay sediments, but more information is needed to define their potential impact on the Bay and its living resources.

Sediments serve as a "sink" drawing materials from the aquatic environment. Many toxic metals are incorporated into the structure of sediments and some organic pollutants are subject to biological degradation over time. Other toxic substances leach back into the water from sediments, however, prolonging their impact on the Bay. Toxicants in sediments also are ingested directly by bottom feeding organisms, initiating accumulation in the food chain.

The Chesapeake Bay Program is planning a coordinated environmental monitoring program to provide data on concentrations of toxic compounds in living resources and in sediments. This information will help target specific substances to be controlled. Special emphasis will be given to developing techniques to access and measure toxic concentrations in the surface microlayer.

Maryland and Virginia have embarked upon a joint program utilizing biomonitoring techniques to assess the toxicity of ambient waters and sediments of Chesapeake Bay. Although past research efforts have included many measurements of specific chemicals in water, sediment and tissue, little is known about the relationship between pollutant concentrations in sediment or water and body burdens of organisms. Toxicants may react synergistically and their effect on living resources may be sub-lethal, rather than causing immediate mortality. The interstate cooperative effort will focus in part on the development of stress indices for commercially and ecologically important Bay organisms. NOAA is supporting this pilot project under section 309 of the Coastal Zone Management Act. In Pennsylvania, the Susquehanna River Basin Commission is sampling bottom sediments in the Susquehanna and its tributaries in another project funded by NOAA.

EPA is currently developing sediment criteria for toxic pollutants. These criteria could be used to set sediment standards, providing another regulatory tool to be utilized in the Bay basin, but a rulemaking proposal is probably a year or more away.

The Task Ahead

Clean Water Act amendments enacted in January 1987 reinforce the 1987 Agreement's commitment to develop a Basinwide plan to control toxic pollution [24]. The new legislation gives states two years to propose additional control strategies for reducing the discharge of toxicants into waterways if effluent limitations and other measures already in force do not adequately protect water quality. The amendments also require identification of specific point sources impairing water quality and a determination of the amount of each toxic pollutant discharged.

Implementation of these provisions will help in pinpointing and controlling specific substances that threaten living resources of the Bay because of their high toxicity, widespread usage, or bioaccumulation in food chain organisms.

"Fingerprinting," a technique developed during the Bay Program research phase, also may prove to be a valuable tool in tracking back to their sources known and unknown organic compounds found in sediments and the tissue of organisms in the Bay. This analytical technique is currently in use in a Virginia pilot project.

The 1987 legislation endorses the use of effluent limitations based on biological monitoring or assessments. It directs EPA to develop and disseminate further information on these techniques over the next two years.

Standardized biological tests for assessing effluent and ambient water toxicity have been developed for several freshwater species and high salinity marine species. Tests using species representative of estuarine water (salinity ranges of 2 to 25 parts per thousand) are not yet available. Species for this range are now being evaluated and EPA research laboratories are developing methodology. These tests, applicable to the Chesapeake Bay, should be available in 1988. More sensitive biomonitoring techniques, such as enzymatic inhibition and in vitro genetic tests, also are needed to supplement current testing methods.

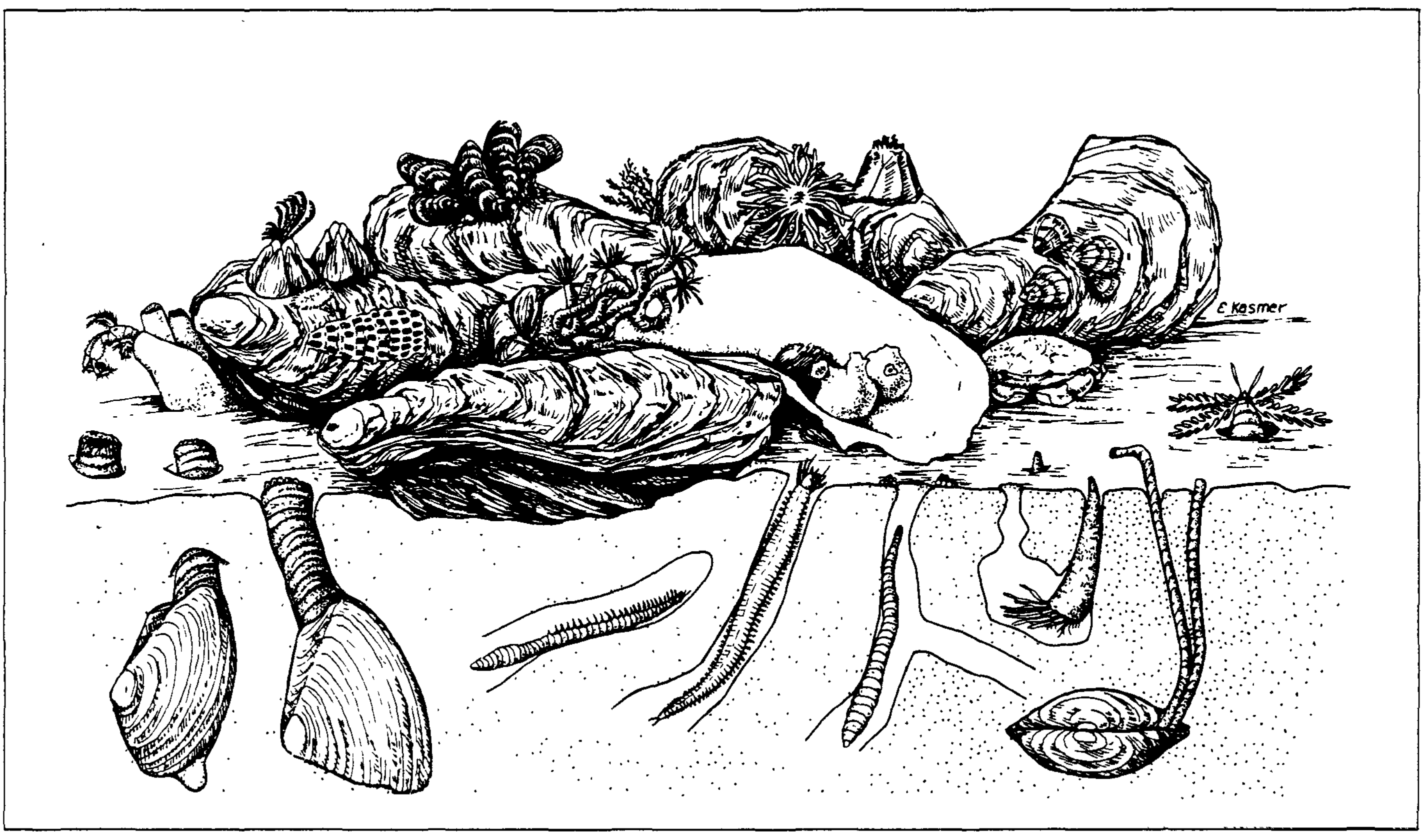
An expanded monitoring program to provide data on concentrations of toxic pollutants in sediments and living resources, coupled with ambient water biomonitoring, would aid in identifying specific substances that should be targeted for control. The Chesapeake Bay Program monitoring network, existing state toxics monitoring programs and the National Shellfish Monitoring Program offer a ready-made infrastructure for obtaining these additional data.

The Chesapeake Bay Program also will be seeking additional data on pesticide usage in the Bay basin and the possible impact on ground water. Some state ground water monitoring programs now in progress might be enhanced at relatively small cost to include concentrations of pesticides found in the sampling.

Assessing the magnitude and impact of atmospheric deposition of toxic substances in the Bay watershed also is necessary to provide a complete picture of the threat posed by these pollutants.

Although additional data will help to focus and refine protection measures in the future, promptly implementing and vigorously enforcing control programs already begun will bring significant progress in reducing toxic contamination of the Bay and its tributaries.

These efforts, in concert with the basinwide toxic control strategy, will provide the management framework to reduce and control toxic materials entering the Chesapeake Bay and enable managers to provide for the restoration and protection of living resources of the Chesapeake Bay.



Chapter 5

Research Needs

The Chesapeake Bay, the largest estuary in the United States, is a complex and productive system. The research needs of the Chesapeake Bay are as complex as the estuary itself, and often reflect its problems: excessive nutrient enrichment, high concentrations of toxic chemicals, and reduced distribution and abundance of many living resources.

Much is known about Chesapeake Bay, enough to make a confident start on a restoration and protection program. Much more, however, remains to be learned. As management options become more costly and complex, additional information will be needed to assure that the best possible decisions are made. The research community has a key role in the Bay restoration by providing this new information which will contribute to better answers for Bay management questions.

The Chesapeake Bay Program recognizes that an effective management plan must contain an integrated research component. Research priorities should be set, based on information needed to attain the goals, objectives and commitments established by the 1987 Chesapeake Bay Agreement.

The signatories of the 1987 Chesapeake Bay Agreement have committed "by July 1988, to develop and adopt a comprehensive research plan to address the technical needs of the Chesapeake Bay Program..." The Scientific and Technical Advisory Committee will coordinate this effort.

For research to be effectively incorporated into the Chesapeake Bay restoration and protection program, it is important that Bay scientists understand the goals and objectives established for the program and the information needs of managers attempting to meet these goals and objectives. It is equally important that managers understand the limits of present scientific and technical knowledge of the Bay. Finally, scientists and managers must work together to develop programs needed to supplement present knowledge.

Research needs to support improved management of Chesapeake Bay have been detailed in a number of reports. Some have focused on specific issues such as fisheries while others have attempted to cover a broad range of topics [65-70]. A number of national estuarine research needs surveys, which reflect problems identified in the Chesapeake Bay, have also been developed [71-73].

The research needs identified in this chapter were prepared by Bay Program participants and CBLO staff. The research needs presented have not been endorsed by the States, the Implementation Committee or its Subcommittees. The chapter has been reviewed by Implementation Committee Members and the Scientific and Technical Advisory Committee. The inventory is presented as a reminder of the magnitude of unanswered questions that must be addressed. It also underscores the need for managers and researchers to coordinate closely to make most efficient use of limited research funds. The chapter organizes research needs into the following categories:

- Enhancement of Modeling Capabilities;
- Living Resources Research;
- Toxic Substances; and,
- Economics.

Modeling Capabilities

The Bay Program has undertaken an ambitious estuarine modeling effort. Recent and historical data gathered for many purposes have been used to produce working models of the system, including a steady-state hydrodynamic/water quality model of the mainstem. The next step in the modeling effort is the development of a time-variable, hydrodynamic/ water quality model of the mainstem. Preliminary guidance from operation of the Steady-State Model has indicated the presence of gaps in data coverage and inadequate knowledge of some processes, particularly the effect of sediment processes on water quality.

Initial runs of the Steady-State Model have indicated the significant role that sediments may play in determining the levels of nutrients found in Bay waters. Sediment studies have been done previously, but they were too variable in place, time and purpose to form an adequate base of information required by the Time-Variable model.

Sediment Submodel. A sediment submodel is an essential component of the Time-Variable Model. The Chesapeake Bay Program's Steady-State Model has demonstrated the importance of sediment/water column interactions in determining Bay water quality. A state-of-the-art Sediment Submodel must be developed to enable the Chesapeake Bay Time-Variable Model to reach its full potential for evaluating management options.

There are three component parts to the sediment submodel: net deposition, diagenesis, and flux.

- Net deposition simulates the input of inorganic and organic matter to the sediments.
- Diagenesis, the process in which deposited nutrient-bearing organic matter (like plankton) is transformed to

inorganic nutrients through biological and chemical processes, provides the link between organic inputs and inorganic nutrient flux.

• The flux component of the model completes the sediment cycle by returning the inorganic nutrients to the water column.

The various subtasks necessary to develop a sediment submodel constitute an expansion of the existing monitoring program into the area of sediments. Additional data are necessary for each component. This expanded program will be needed for one year.

Assessment of Agricultural BMPs. In response to watershed model projections of the amounts of nutrients entering the Bay from rural and agricultural lands, extensive programs for nutrient control have been established in some sections of the watershed. The effectiveness of BMPs is principally estimated in terms of their value for erosion control and reductions in sediment production. While this allows some estimate of the reduction in phosphorus, the methodology for assessment of BMPs for nitrogen control has severe weaknesses. Studies are needed to quantify the effectiveness of nutrient and pesticide BMPs on water quality so better estimates can be made of the reductions that are being achieved. Studies also should be conducted to improve techniques for identifying areas with the highest potential for the release of nitrogen and phosphorus (targetting).

Mainstem/Tributary Exchange Rates. Tributaries have been characterized as traps for nutrients, toxicants, and sediments that would otherwise enter the mainstem of the Bay. The effectiveness of tributaries in trapping materials has been estimated at 95 percent. If the tributaries are more effective, or less effective, in trapping materials, or regional/seasonal variations exist, the impacts to the Bay could be significant, and management scenarios may need to be revised. Additional studies should be conducted to address and quantify the exchange of materials between the major Eastern and Western shore tributaries and the Chesapeake Bay mainstem.

Living Resources Research

Research is needed to broaden understanding of the linkages between water quality, habitat, and living resources. Water quality or habitat can impact living resources either directly or indirectly. Direct impacts include toxicity, physical habitat loss, stimulation of growth/ survival by nutrients (algae), light (SAV), habitat enhancements, and harvest. Indirect impacts include food chain effects over trophic levels, and effects on predators. The effects of nutrient enrichment and elevated levels of toxic contaminants throughout the food web need clarification. To aid in future decision making, managers also require a clearer understanding of the relationships between habitat conditions and shifts in species composition, distribution and abundance.

Research is also needed to develop methods and techniques to improve assessments of the health, distribution and abundance of critical species' habitats. It must be noted, however, that living resource and habitat information will always be influenced by natural variability. This variability can be understood and quantified through research so the effects of harvest, climate and pollution pressures on rates of recruitment and mortality can be partitioned.

Research and monitoring of living resource processes and habitat is vital to management of stocks. Otherwise, problems may be fully recognized only when specific species or populations are drastically reduced. It is not known whether individuals or populations are declining or improving, or even whether existing habitat conditions can support the desired population. Further, scientists are generally not able to differentiate between species' shifts caused by natural variations and those which are anthropogenic in origin.

Although the Bay is a unified system and must be viewed as such, individual components of the system may respond on different time scales and in various ways. These variations can impact stocks differently in the tributaries. Since the abundance and health of a species may vary by tributary, managers should consider regional or tributary specific strategies for restoring or protecting the stock. However, Baywide success or failure in stock recruitment can be linked to failures in key tributaries. Resource managers need a clearer picture of the dynamics of the stocks of a given species in the different parts of its range. Are breeding populations in each tributary self-contained, constituting separate subpopulations? What is the extent of intertributary mixing of breeding populations? Do populations possess genetic characteristics that select for better survival in one tributary as opposed to another? What are the differences in bioaccumulation among species and what does it mean? What are the biological mechanisms for detoxification?

These are important questions that must be answered when undertaking restoration activities in areas where stocks may not return on their own, or in establishing regulatory approaches which may enable stocks to restore themselves. Modern genetic techniques must be refined for specific species, then applied to aid in restoring or protecting living resources.

The following research tasks are considered essential to more closely relate management decision-making to living resources goals:

Effects of Nutrients. Relationships between nutrients and economically valuable marine resources have long been implied, but not quantified. Research is needed to develop the hypothetical basis for using the results of monitoring and stock assessment programs to further understand the effects of nutrient enrichment on fish production. An initial step is to determine the effect of excess nutrients on phytoplankton population composition and to determine how phytoplankton production is partitioned among alternative plankton food chains and between benthic and pelagic communities. Second, a similar study is needed on the impact of predators on lower trophic levels. Studies on diet, feeding behavior, prey selectivity, and impact of environmental factors on feeding strategies should be supported concurrently. The goal is to understand the functional relationships involved in the cycling of nutrients and indirect impacts through the food chain on top trophic production.

Periodic Components in Natural Processes. To best manage populations, information is needed on all critical life stages: feeding and elimination rates at each stage; critical habitat requirements (including food and physical/chemical tolerances); mortality from aging, disease and predation; harvest; individual and social behavior; and, intra- and inter-trophic level interactions. Many natural processes also have periodic components, and observations and conclusions will be distorted unless studies are conducted on appropriate time scales.

Analysis of Trophic Relationships. A coordinated research program should focus on analyzing trophic relationships among key species, and between trophic levels.

Influence of Contaminants and Disease. New assessment technologies must be developed to further our understanding of the impact of contaminants and disease on living resource populations and community structure. Scientists cannot determine in many instances whether a population decline is caused by pollution stress, disease (or a synergistic interaction of the two), or natural climatic/environmental factors. This inability to relate cause to effect could, in some circumstances, generate pressures for unnecessary expenditures of funds to correct a situation that does not need correction.

Planktonic-Microbial Food Webs. Studies are needed to determine the factors controlling the ultimate fate of phytoplankton within the Bay food web. Under various environmental conditions, the microbial food web (including bacteria, cyanobacteria, microalgae and protozoa) may act as either a sink for this primary production or as an important source of detrital material to higher trophic levels. Further understanding of these controlling factors must be gained. Additionally, the amount of these primary producers utilized by water column heterotrophic processes versus that transported to the sediments must be determined.

All forms of the microbial food web, particularly cyanobacteria which is the dominant component of the Bay phytoplankton community, need to be better understood. Is their presence in the Bay related to nutrient enrichment? What is their contribution to primary production? How does their presence influence the nature and rates of secondary production of living resources?

Toxic Substances

The initial phase of the Chesapeake Bay Program developed baseline information on toxic substances within the Bay. Recent activities monitor specific toxicants in the system (e.g. TBT) and examine the accumulation of toxic compounds in biota. During 1988, the Chesapeake Bay Program will be focusing on developing and beginning to implement a strategy to reduce toxic pollution. To carry out this strategy, managers will require more information on toxic pollutants, including their fate, transport, and effects on the living resource populations.

Toxic materials in the Chesapeake Bay rarely have directly observable impacts. They do not cause major fish kills unless there is a large release of a toxic material from a spill or improper application of agricultural pesticides. When the impact of toxicants in the Bay is coupled with increased sediment/turbidity, increased nutrients and lowered dissolved oxygen, the presence of toxicants adds one more dimension of stress affecting the reproduction and viability of all species.

It is technologically possible (albeit expensive) to control the majority of toxicants entering the Bay through point sources, and through alternative technologies and recycling to reduce usage of the most toxic compounds. It is also possible to mitigate the adverse impacts of toxicants already in Bay sediments by removal (dredging) or capping. With additional research, managers will be provided with the tools needed to establish and implement policies to reduce these additional stresses to the living resources of the Chesapeake Bay. The following studies will enable Bay scientists to better understand the role of concentrations of toxic chemicals on the Bay's living resources:

Point and Nonpoint Source Discharges. Materials become toxic primarily from man's refining and manufacturing processes for industry and agriculture. After industrial and agricultural use, many materials remain toxic with a potential to damage the environment. Programs exist to reduce the impact of industrial effluents, including pretreatment and NPDES and RCRA requirements. Even with these programs, toxic compounds still enter the environment from both point and nonpoint sources. Although there are options to manage toxic materials from point sources after they reach tributary waters or the Bay, the preferred solution is to control toxic pollutants prior to their discharge.

Scientific and economic studies should be conducted to evaluate the costs to society of implementing policies to minimize toxic discharges from point and nonpoint sources.

Ground Water Contamination. A variety of BMPs have been developed to reduce levels of nutrients and other agricultural chemicals reaching surface waters which flow into Chesapeake Bay. A valid question has been raised as to whether such reductions result in increased amounts of these same materials entering ground water. A study of the impact of selected BMPs on ground water would give managers the answers they need regarding possible adverse effects.

Surface Microlayer of Bay Waters. Toxicants can concentrate in the top microlayer of Bay waters in amounts up to 1000 times normal background levels. These concentrations can be a source of toxic contamination during mixing events, and directly impact neuston (surface layer plankton), thereby altering the food web. Studies are needed to identify the sources, including aerial deposition, of these microlayer concentrations, and to quantify the impact on living resources. These concentrations can also affect larval stages of fish which inhabit the microlayer environment. Approaches needed include: development of sampling techniques and protocols; studies to increase understanding of the importance of the microlayer as habitat for Bay living resources; surveys of microlayer toxicant levels at selected sites; and bioassays of microlayer waters.

Desorption of Toxic Pollutants. High concentrations of heavy metals have been found in the sediments of Baltimore Harbor, the Elizabeth River and in some isolated portions of the Central Bay. High sediment polyaromatic hydrocarbon levels have also been identified in certain Bay locations. Heavy metals and other pollutants have a tendency to sorb to fine grained sediments.

When these sediments are disturbed--either by anthropogenic activities, such as dredging, or natural events, such as storms--fine grained sediments can be resuspended. The resuspension of these contaminated sediments may result in the desorption of significant quantities of toxic contaminants. Research is needed to determine the extent and rate of desorption for both heavy metals and toxic organic chemicals. The bioavailability of sorbed pollutants to both filter and deposit feeders is an important consideration. With such information, managers can better understand the impacts of anthropogenically disturbed sediments and can reduce the impact of the re-released toxicants. Research is also needed to quantify the release of toxicants under hypoxic and anoxic conditions.

Cellular Level Effects of Toxicants. Very little is understood about the effects toxic chemicals can have at the cellular level of complex organisms such as finfish and oysters. There is increasing evidence that exposure to toxicants alters the response of the cellular immune system in fish, thus presumably affecting the relative resistance of fish to disease-causing agents. Immunological assays of the cellular immune (macrophage) function can be used to assess the degree of exposure to environmental stress and to monitor the health of fish.

Determination of enzymatic inhibition of specific constituents may also provide valuable insight into sublethal effects at the cellular level. Research and monitoring must be conducted to provide information on the first reactions of cells to chronic exposure to toxicants. Only when these reactions are understood can the overall impact of chronic exposure of living resources to toxicants be fully assessed.

Chronic Bioassay Tests. Organisms presently being used to conduct chronic bioassay tests are either freshwater or marine species. Chronic bioassay tests should be developed for estuarine species to determine realistic responses of Chesapeake Bay organisms to long-term exposure to toxicants.

Airborne Toxic Contaminants. Airborne toxicants are attached primarily to particulates from emissions. The contribution of these materials to the Bay is unknown, but could be estimated from aerial transport models. The toxicity of these materials in Bay water also is not known. Research is needed to determine both the toxicity of these airborne materials and the risk they pose to living resources of the Bay and its tributaries.

Economics

Thousands of jobs and millions of dollars worth of goods and services depend upon the Chesapeake Bay. A primary example is the seafood industry. Commercial fishing is a major component of the economic base of the Bay. The goods and services bought by the industry from other industries, as well as the household goods purchased with wages earned in the seafood industry, multiply the dockside value several times. Yet, the impact of the decline of living resources on local and state economies has not been adequately evaluated.

Research on the Bay will help managers identify alternative strategies to restore the Bay's living resources. The selection of a strategy or strategies will be based upon a variety of considerations, including the expected benefits to living resources. One measure of the benefit of the restored resources will be their monetary value, and the multiplier effect on the region's economy.

The direct financial benefits to be gained from pollution control decisions aimed at restoring living resources are poorly understood or, at best, ambiguous. As a consequence, ability to address cost/benefit questions is limited. In summary, there is insufficient knowledge of the economic value of the Bay. A fuller understanding of its worth will enable managers to estimate the real value of resource restoration. Recognition of the benefits will place the costs of restoring the Bay in better perspective.

Looking Ahead

The research needs outlined in this chapter were selected to help guide Chesapeake Bay management actions on nutrient processes, living resources and toxic chemicals. Answers to the nutrient process questions will be used to help refine the Time-Variable Model of the Bay. In turn, the model will provide guidance in the selection of cost-efficient management strategies. Answers to the living resource questions will, in time, help managers and scientists assess the effectiveness of those strategies. Toxics research will be used to develop and implement a Baywide toxics strategy.

Many different approaches (specific projects) can be pursued to fill the knowledge gaps identified. This chapter is not a research plan; it is a listing of concepts and process questions that scientists and Bay managers must explore together as they evaluate the complex and expensive Bay restoration and protection strategies.

To determine funding priorities among research needs will require a major cooperative effort among the research/technical, management, and political communities and the public as a whole in the Bay basin. With the cooperation of these entities, a successful research plan can be developed, funded and implemented.

Appendices

Appendix A - Below-the-Fall Line Municipal Nutrient and BOD5 Loads for Year 1985 with Existing Treatment and for Year 2000 with Planned Upgrades and the Imposition of Phosphate Detergent Bans

Appendix B - Modeled Scenario Results

Appendix C - Below-the-Fall Line Municipal Nutrient Loads for Year 1985 with Existing Treatment and for Year 2000 with High Level BNR Treatment

Appendix D - Below-the-Fall Line Municipal Nutrient Loads for Year 1985 with Existing Treatment and for Year 2000 with Limits of Technology Treatment

Appendix E - Below-the-Fall Line 1985 Industrial Nutrient Loads

APPENDIX A

BELOW-THE-FALL-LINE MUNICIPAL NUTRIENT AND BOD5 LOADS FOR YEAR 1985 WITH EXISTING TREATMENT AND FOR YEAR 2000 WITH PLANNED UPGRADES AND THE IMPOSITION OF PHOSPHATE DETERGENT BANS

				1985				2000			
BASIN	FACILITY NAME	STATE	NPDES	FLOW	PHOSPH	NITROGEN	BOD5	FLOW	PHOSPH	NITROGEN	BOD5
E SHORE	EASTON WASTE STABIL. LAG	MD	20273	1.40	.	.	163109	1.49	.	.	136489
E SHORE	ELKTON STP	MD	22641	0.78	6415	.	106615	0.89	5451	.	81772
E SHORE	HURLOCK, TOWN OF	MD	22730	0.50	.	.	90807	0.51	.	.	46582
E SHORE	SALISBURY CITY WWTR TP	MD	21571	4.60	98079	.	.	5.18	15768	.	.
E SHORE	PHOSPHATE BAN IMPACT (45 PLANTS)			10.97	272860	.	.	12.17	225382	.	.
E SHORE	BASIN TOTAL				377354	.	360531		246601	.	264843
W CHESAP	AA COUNTY BROADNECK	MD	21644	3.20	68229	.	.	3.70	22514	.	.
W CHESAP	BACKRIVER	MD	21555	63.00	312786	4029759	4797332	65.60*	39963	2997282	1996350
W CHESAP	BETH STEEL (BACK R STP)	MD	1201	100.50	355094	7316160	15458831	100.00*	243623	4568886	3248054
W CHESAP	HAVRE DE GRACE WWTR TP	MD	21750	1.50	31982	.	968033	1.72	10480	.	157061
W CHESAP	PATAPSCO	MD	21601	43.00	458412	.	.	85.50*	520875	.	.
W CHESAP	PHOSPHATE BAN IMPACT (23 PLANTS)			13.40	265713	.	.	15.20	228068	.	.
W CHESAP	BASIN TOTAL				1492216	11345919	21224196		1065523	7566168	5401465
PATUXENT	WESTERN BRANCH	MD	21741	10.80	108557	473702	.	23.60*	71879	215635	.
PATUXENT	BASIN TOTAL				108557	473702	.		71879	215635	.
POTOMAC	ALEXANDRIA CITY SAN AUTH	VA	25160	35.60	.	.	1355436	37.55	.	.	343123
POTOMAC	ARLINGTON	VA	24143	26.56	45304	.	.	27.00	14802	.	.
POTOMAC	CHAS CO SAN DIST MATTAWOM	MD	21865	4.40	52268	.	.	5.98	3278	.	.
POTOMAC	DALE SERV. CORP. PLT # 8	VA	24678	0.84	694	.	.	1.23	676	.	.
POTOMAC	FAIRFAX CO-LITTLE HNTG CR	VA	25372	3.82	2135	.	.	4.50	2467	.	.
POTOMAC	LOWER POTOMAC	VA	25364	32.96	.	.	602362	38.81	.	.	350068
POTOMAC	U.S. M.C. BASE-MAINSID	VA	28363	1.45	.	.	25174	2.12	.	.	18581
POTOMAC	PHOSPHATE BAN IMPACT (17 PLANTS)			5.44	115989	.	.	6.10	96509	.	.
POTOMAC	BASIN TOTAL				216390	.	1982972		117732	.	711772
RAPP	PHOSPHATE BAN IMPACT (9 PLANTS)			5.40	104506	.	.	6.60	96668	.	.
RAPP	BASIN TOTAL				104506	.	.		96668	.	.
YORK	PHOSPHATE BAN IMPACT (6 PLANTS)			7.90	162907	.	.	9.80	147919	.	.
YORK	BASIN TOTAL				162907	.	.		147919	.	.
JAMES	HRSD - LAMBERTS POINT	VA	25259	19.97	200730	1338197	6151143	29.58	180239	1165736	2773315
JAMES	PETERSBURG WWTR TP	VA	25437	8.48	.	.	571590	8.29	.	.	509540
JAMES	PORTSMOUTH CTY-PINNERS PT	VA	25003	9.31	181488	530286	6791636	(Flow diverted to HRSD-Lamberts Pt)			
JAMES	PHOSPHATE BAN IMPACT (17 PLANTS)			189.40	2646543	.	.	198.64	2127258	.	.
JAMES	BASIN TOTAL				3028761	1868483	13514369		2307497	1165736	3282855
	ALL BASINS TOTAL (PLANNED UPGRADES)				1922173	13688104	37082068		1132015	8947539	9660935
	ALL BASINS TOTAL (PHOSPHORUS BAN)				3568518	.	.		2921804	.	.
	ALL BASINS TOTAL (UPGRADES AND BAN)				5490691	13688104	37082068		4053819	8947539	9660935

Flow in millions of gallons per day (MGD)
Loads in pounds per year
The impact of phosphate detergent bans was calculated from treatment plants without phosphorus effluent limits regardless of size by reducing the 1985 effluent phosphorus concentration 25 percent
Treatment plants specifically listed are those with capacity greater than 0.5 MGD and upgrading level of treatment
'.' indicates loads unaffected by planned upgrades
* Year 2000 flow based on state projection, other year 2000 flow based on forecasted population growth

Appendix B

Modeled Scenario Results

Table 3-5 in Chapter 3 and Table B-1 in this appendix present the results of different scenarios run on the Steady-State Chesapeake Bay Model under 1985 (slightly dryer than average) and 1984 (wet year) conditions.

The first two columns of data present total mass and peak chlorophyll *a* concentrations determined for the middle of the Bay. The living resource criterion for peak chlorophyll *a* is 15 ug/l. Although no criterion exists for mass chlorophyll, it is an indicator of the organic carbon being generated by nutrients in the Bay. The chlorophyll *a* peak criterion is not exceeded in 1985, but it is exceeded in 1984, the wetter year, and mass concentrations are significantly higher.

The other four columns in the tables deal with dissolved oxygen. The first of these presents the lowest DO concentrations calculated, which occur on the bottom in the middle of the Bay. A summer average concentration less than 1 mg/l represents anoxic conditions, which cause undesirable anaerobic biochemical reactions resulting in the emission of pollutants from the bottom sediment into the overlaying water column. Levels projected to summer average minimums less than 3.3 mg/l equate to instantaneous minimums of 2.0 mg/l or less. This is important because the acute toxic concentration is 2 mg/l for finfish and 2.4 mg/l for crabs. Though neither live on the bottom in the deep water of the Bay mainstem, tide and wind conditions can force waters with the low concentrations of dissolved oxygen from the deep main channel into shallow shoreline areas, with resulting destruction to fish and shellfish that cannot tolerate these levels. Volumes of Bay waters in the next three columns, projected to reflect different levels of dissolved oxygen, are indicative of the relative effectiveness of each scenario.

Scenario "a" represents existing conditions determined in using the model after it was calibrated against data collected in July-August 1985, reflecting water quality conditions which existed at the time.

Scenarios "b" through "g" are variations of different strategies for reducing nutrient loads from municipal point sources with no change in nonpoint source nutrient loads. Planned upgrades are those abatement and control actions planned or in progress at 25 municipal treatment plants. These improvements will result in reduced nutrient and carbonaceous BOD loads to the Bay. Load reductions were based on estimates of year 2000 plant flows, reflecting expected population growth. Scenario "c" is the same as "b" but with all plant flows at 100 percent of plant capacity, including planned expansions. This is projected to occur at some point in the future--the year "2000 and X"--due to population growth. Scenarios "d," "e" and "f" used the same populations, flows, and nonpoint source assumptions as "b," with the application of increased levels of municipal treatment for total phosphorus (TP) and total nitrogen (TN).

The last municipal point source treatment scenario is "g," which assumes use of the best treatment system available for removal of nutrients, achieving an effluent of 0.1 mg/l for phosphorus and 3 mg/l for nitrogen at all municipal plants.

The 2000 NPS term in scenarios "i" and "j" represents the expected NPS program accomplishments at the present level of funding through the year 2000. These reductions in phosphorus and nitrogen under the current program are only effective in agricultural areas and do not reflect any possible reductions in urban NPS nutrients. Point source nutrient reductions in "i" and "j" are the same as those in scenarios "b," "f" and "g." Scenario "k" assumes an 40 percent reduction in agricultural nutrient loads by the year 2000 in addition to the limit of technolgy reductions assumed in scenario "g."

Scenarios "l" and "m" assign a 40 percent reduction in phosphorus only ("l") and in both phosphorus and nitrogen ("m") to all sources without allowance for expected population growth in the municipal point source loads. The pristine scenario was run by assigning all land areas in the calculations performed by the model the nutrient source terms associated with forest. The hydrology assumed in the pristine scenario, however, was the same as that used in the others.

Scenario "m" in Table 3-5, representing a year slightly dryer than average, exceeds the living resource chlorophyll *a* criterion and the objective of eliminating anoxic conditions in the mainstem deep water, and comes close to eliminating the need for dilution of bottom waters from the main Bay depths when it is forced by tide and wind into shallow portions of the Bay. Controlling only phosphorus, as in scenario "l," accomplishes almost the same level of water quality. However, in Table B-1, representing relatively wet 1984, there is a significant difference between the control of phosphorus only and the control of both phosphorus and nitrogen, as observed in comparing scenarios "l" and "m."

Even when both nutrients are controlled, the chlorophyll *a* criterion is barely met, and anoxic conditions, much less acute toxic conditions, are not eliminated in the mainstem deep water. However, the volume of water under 1 mg/l has been reduced by 80 percent, and the peak dissolved oxygen concentration on the bottom in main Bay deep water has increased six-fold compared to existing conditions under scenario "a." Considering the precision and accuracy of the model, however, these improvements are too close to the stated water quality objectives to conclude that the objectives will not be achieved.

Table B-1. The Effectiveness of Nutrient Reduction Scenarios Simulated by the Steady-State Model Using 1984 Circulation --- North-South Transect - Kilometers 148 to 187

Scenario	CHLOROPHYLL *a* Total Mass Bay and Tributaries (10^6 kg)	CHLOROPHYLL *a* Peak Summer Avg. Concentration in Bay Channel (ug/l)	DISSOLVED OXYGEN - DO 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	.806	18.3	.12	.226	.370	.77
b) Planned Upgrades**	.745	16.6	.22	.135	.311	.62
c) Planned Upgrades**, 2000X	.786	17.5	.17	.177	.332	.707
d) Planned Upgrades** + TP=1	.732	16.3	.24	.135	.295	.62
e) Planned Upgrades** + TP=2 TN=6 (BNR-Randall Est.)	.700	15.8	.31	.135	.259	.519
f) Planned Upgrades** + TP=2 TN=8 (BNR-EPA Est.)	.705	16.1	.29	.135	.275	.550
g) Limit of Technology**	.672	15.1	.39	.093	.206	.505
h) Planned Upgrades** + 2000 NPS	.716	15.6	.38	.093	.259	.536
i) TP=2, TN=8 + 2000 NPS	.676	15.1	.51	.093	.226	.475
j) Limit of Technology** + 2000 NPS	.647	14.3	.64	.063	.208	.432
k) Limit of Technology** + 40% Ag NPS	.627	13.7	.93	.016	.135	.412
l) 40% reduction of TP for all Point and Nonpoint Sources	.723	15.7	.42	.093	.240	.536
m) 40% Reduction of TP + TN for all Point and Nonpoint Sources	.661	14.8	.72	.047	.208	.432
n) Pristine Conditions	.560	12.6	2.00	0	.016	.259

* 3.3 mg/l summer average equates to an instantaneous minimum of 2.0 mg/l habitat requirement level in the reference 33.

** Municipal Sources

Note: Appendix B contains detailed scenario descriptions.

APPENDIX C

BELOW-THE-FALL-LINE MUNICIPAL NUTRIENT LOADS FOR YEAR 1985 WITH EXISTING TREATMENT AND FOR YEAR 2000 WITH HIGH LEVEL BNR TREATMENT

				1985			2000		
BASIN	FACILITY NAME	STATE	NPDES	FLOW	PHOSPHORUS	NITROGEN	FLOW	PHOSPHORUS	NITROGEN
E SHORE	CAMBRIDGE COMMISSIONERS-WWTR T	MD	21636	2.200	46907	120619	2.243	13664	54656
E SHORE	CHESTERTOWN UTILITIES COMMISSI	MD	20010	0.570	14758	44568	0.569	3466	13864
E SHORE	CRISFIELD SEWAGE TREATMENT PLA	MD	20001	0.700	14925	38379	0.777	4736	18942
E SHORE	EASTON WASTE STABILIZATION LAG	MD	20273	1.400	29850	76757	1.494	9099	36397
E SHORE	ELKTON SEWAGE TREATMENT PLANT	MD	22641	0.780	6415	42765	0.895	5451	21806
E SHORE	FEDERALSBURG SEWAGE TREATMENT	MD	20247	0.740	15778	33810	0.820	4996	19985
E SHORE	HURLOCK, TOWN OF	MD	22730	0.500	10661	27413	0.510	3105	12422
E SHORE	POCOMOKE CITY SEWAGE TREATMENT	MD	22551	0.900	19189	49344	1.069	6513	26051
E SHORE	QUEEN ANNE'S COUNTY SANITARY D	MD	23485	0.800	15839	50928	1.046	6372	25487
E SHORE	SALISBURY CITY WASTEWATER TRTM	MD	21571	4.600	98079	252203	5.177	31536	126142
E SHORE	FLOWS LESS THAN 0.5 MGD (34 PLANTS)			5.063	104953	285948	5.645	34326	137577
E SHORE	BASIN TOTAL			18.253	377354	1022734	20.245	123264	493329
W CHESAP	AA COUNTY BROADNECK	MD	21644	3.200	68229	235876	3.696	22514	90057
W CHESAP	ABERDEEN PROVING AREA-ABERDEEN	MD	21237	1.000	10661	54827	1.146	6980	27922
W CHESAP	ABERDEEN PROVING GROUND-EDGEWO	MD	21229	1.000	3046	50562	1.146	6980	27922
W CHESAP	ABERDEEN, TOWN OF STP	MD	21563	1.100	1340	60309	1.260	7679	30714
W CHESAP	ANNAPOLIS STP,CITY OF	MD	21814	6.300	134325	243704	7.276	44325	177299
W CHESAP	ANNE ARUNDEL CO DPW-COX CREEK	MD	21661	9.200	84068	560450	10.625	64728	258913
W CHESAP	BACKRIVER	MD	21555	63.000	312786	4029759	65.600**	399625*	1598501
W CHESAP	BETH STEEL (FROM BACK R STP)	MD	1201	100.500	355094	7316160	100.000**	609185*	2436740
W CHESAP	BROADWATER SEWAGE TREATMENT PL	MD	24350	0.500	10661	31525	0.577	3518	14071
W CHESAP	HAVRE DE GRACE WWTR TREAT PLT	MD	21750	1.500	31982	98688	1.719	10471	41883
W CHESAP	JOPPATOWNE STP.-MD.ENV.SERVICE	MD	22535	0.687	14659	25336	0.788	4799	19196
W CHESAP	MES-FREEDOM	MD	21512	1.300	27718	71275	1.611	9817	39267
W CHESAP	NORTH EAST WASTE WATER TREAT.	MD	22594	0.510	11651	27962	0.585	3564	14258
W CHESAP	PATAPSCO	MD	21601	43.000	458412	2619496	85.500**	520853	2083413
W CHESAP	SOD RUN	MD	21709	5.800	24733	473459	6.646	40487	161947
W CHESAP	TOWN COMMISSIONERS OF PERRYVIL	MD	20613	0.600	1279	32896	0.688	4193	16774
W CHESAP	FLOWS LESS THAN 0.5 MGD (16 PLANTS)			2.189	39241	116284	2.643	15584	64420
W CHESAP	BASIN TOTAL			241.386	1589885	16048568	291.506	1775302	7103297

Flow in millions of gallons per day (MGD)
Load in pounds per year
High level BNR technology treatment assumed to be achieved year round; total phosphorus=2.0 mg/l, total nitrogen=8.0 mg/l
Includes only Bay watershed municipal facilities in Maryland, Virginia, Pennsylvania and District of Columbia
* indicates facilities discharging below high level BRN effluent concentrations
** Year 2000 flow based on state projections, other year 2000 flows based on forecasted population growth

APPENDIX C (cont'd)

BELOW-THE-FALL-LINE MUNICIPAL NUTRIENT LOADS FOR YEAR 1985 WITH EXISTING TREATMENT AND FOR YEAR 2000 WITH HIGH LEVEL BNR TREATMENT

BASIN	FACILITY NAME	STATE	NPDES	1985 FLOW	1985 PHOSPHORUS	1985 NITROGEN	2000 FLOW	2000 PHOSPHORUS	2000 NITROGEN
PATUXENT	WESTERN BRANCH	MD	21741	10.800	108557	473702	23.600**	143768	575071
PATUXENT	BASIN TOTAL			10.800	108557	473702	23.600	143768	575071
POTOMAC	ALEXANDRIA CITY SANITARY AUTHO	VA	25160	35.600	16265	1995203	37.554	20589*	915088
POTOMAC	AQUIA SANITARY DISTRICT	VA	60968	1.140	2049	50314	1.662	911*	40489
POTOMAC	ARLINGTON	VA	25143	26.560	45304	1642265	26.998	14802*	657874
POTOMAC	BLUE PLAINS	DC	21199	300.700	109909	12273189	306.020	167780*	7456900
POTOMAC	CHARLES CNTY SAN DIST MATTAWOM	MD	21865	4.400	52268	170206	5.978	36419*	145674
POTOMAC	DALE SERVICE CORP. PLANT # 1	VA	24724	2.040	1118	93205	2.994	1641*	72946
POTOMAC	DALE SERVICE CORP. PLANT # 8	VA	24678	0.840	844	38379	1.233	676*	30037
POTOMAC	FAIRFAX CO-LITTLE HUNTING CR	VA	25372	3.820	2211	279250	4.499	2466*	109621
POTOMAC	LA PLATA, TOWN OF	MD	20524	0.610	13006	33444	0.829	5049*	20196
POTOMAC	LOWER POTOMAC, FAIRFAX CO	VA	25364	32.980	14064	1908638	38.839	21294*	946416
POTOMAC	MOONEY - PRINCE WM. CO.	VA	25101	7.580	3694	609526	11.123	6099*	271046
POTOMAC	PINE HILL RUN W.W.T.P.	MD	21679	1.900	34724	98383	2.408	14669*	58678
POTOMAC	PISCATAWAY	MD	21539	13.000	7127	570197	14.215	7793*	346374
POTOMAC	U.S. MARINE CORPS BASE-MAINSID	VA	28363	1.450	883	65675	2.128	1167*	51849
POTOMAC	UPPER OCCOQUAN SEWAGE AUTH-REG	VA	24988	9.400	716	598402	13.794	4202*	336125
POTOMAC	FLOWS LESS THAN 0.5 MGD (13 PLANTS)			1.309	24146	67291	1.631	9588	39764
POTOMAC	BASIN TOTAL			443.329	328328	20493567	471.905	315145	11499077
RAPP	CLAIBORNE RUN SEWAGE TREATMENT	VA	28096	0.880	17155	43074	1.283	7814	31255
RAPP	FREDERICKSBURG CITY STP	VA	25127	2.570	50099	165097	3.068	18689	74755
RAPP	SPOTSYLVANIA CO. - MASSAPONAX	VA	25658	1.550	29602	61579	1.850	11271	45086
RAPP	FLOWS LESS THAN 0.5 MGD (6 PLANTS)			0.610	11900	34567	0.696	4242	16968
RAPP	BASIN TOTAL			5.610	108756	304317	6.897	42016	168064
YORK	HRSD YORK STP	VA	64238	7.360	152442	481987	9.149	55736	222944
YORK	FLOWS LESS THAN 0.5 MGD (5 PLANTS)			0.634	11707	35728	0.778	4542	18969
YORK	BASIN TOTAL			7.994	164149	517715	9.927	60278	241913

Flow in millions of gallons per day (MGD)
Load in pounds per year
High level BNR technology treatment assumed to be achieved year round; total phosphorus=2.0 mg/l, total nitrogen=8.0 mg/l
Includes only Bay watershed municipal facilities in Maryland, Virginia, Pennsylvania and District of Columbia
* indicates facilities discharging below high level BRN effluent concentrations
** Year 2000 flow based on state projections, other year 2000 flows based on forecasted population growth

APPENDIX C (cont'd)

BELOW-THE-FALL-LINE MUNICIPAL NUTRIENT LOADS FOR YEAR 1985 WITH EXISTING TREATMENT AND FOR YEAR 2000 WITH HIGH LEVEL BNR TREATMENT

				1985			2000		
BASIN	FACILITY NAME	STATE	NPDES	FLOW	PHOSPHORUS	NITROGEN	FLOW	PHOSPHORUS	NITROGEN
JAMES	CHESTERFIELD CO./PROCTOR CREEK	VA	60194	3.760	62990	176371	5.777	35193	140773
JAMES	CHESTERFIELD-FALLING CREEK	VA	24996	10.110	209401	769858	15.534	94629	378515
JAMES	FT.EUSTIS-US ARMY TRANSPORTATI	VA	25216	1.650	32165	93982	1.855	11299	45197
JAMES	HOPEWELL STP CITY OF	VA	66630	30.820	178363	6101902	32.875	190254	801069
JAMES	HRSD - ARMY BASE	VA	25208	12.990	178050	775505	12.857	78322	313287
JAMES	HRSD - BOAT HARBOR	VA	25283	15.850	260701	1076597	15.688	95566	382263
JAMES	HRSD - CHESAPEAKE/ELIZ.***	VA	25275	14.360	284307	997260	14.213	86582	346328
JAMES	HRSD - JAMES RIVER	VA	25241	10.340	226763	633047	10.234	62344	249376
JAMES	HRSD - LAMBERTS POINT	VA	25259	19.970	200730	1338197	29.580	180239	720955
JAMES	HRSD - NANSEMOND	VA	64459	6.250	133259	510192	8.340	50805	203220
JAMES	HRSD - WILLIAMSBURG	VA	25267	9.720	112504	633577	9.620	58606	234423
JAMES	PETERSBURG WASTEWATER TREATMEN	VA	25437	8.480	144645	514006	8.288	50488	201951
JAMES	PORTSMOUTH CITY-PINNERS POINT	VA	25003	9.310	181488	530286	(FLOW DIVERTED TO LAMBERTS POINT)		
JAMES	RICHMOND CITY OF	VA	63177	66.100	845610	2456295	64.731	394328	1577312
JAMES	FLOWS LESS THAN 0.5 MGD (4 PLANTS)			0.850	16698	51418	1.012	6166	24665
JAMES	BASIN TOTAL			220.560	3067673	16658493	230.604	1394821	5619334
	BASIN TOTALS (MD VA PA AND DC)			947.932	5744703	55519096	1054.684	3854594	25700085
	BASIN TOTALS (DE WV AND NY)			2.190	40040	125052	2.406	13990	58639
	BASIN TOTAL (ALL STATES)			950.122	5784743	55644148	1057.090	3868584	25758724

Flow in millions of gallons per day (MGD)
Load in pounds per year
High level BNR technology treatment assumed to be achieved year round; total phosphorus=2.0 mg/l, total nitrogen=8.0 mg/l
Includes only Bay watershed municipal facilities in Maryland, Virginia, Pennsylvania and District of Columbia
* Indicates facilities discharging below high level BRN effluent concentrations
** Year 2000 flow based on state projections, other year 2000 flows based on forecasted population growth
*** Discharges to main bay

APPENDIX D

BELOW-THE-FALL-LINE MUNICIPAL NUTRIENT LOADS FOR YEAR 1985 WITH EXISTING TREATMENT AND FOR YEAR 2000 WITH LIMITS OF TECHNOLOGY TREATMENT

				1985			2000		
BASIN	FACILITY NAME	STATE	NPDES	FLOW	PHOSPHORUS	NITROGEN	FLOW	PHOSPHORUS	NITROGEN
E SHORE	CAMBRIDGE COMMISSIONERS-WWTR T	MD	21636	2.200	46907	120619	2.243	683	20496
E SHORE	CHESTERTOWN UTILITIES COMMISSI	MD	20010	0.570	14758	44568	0.569	173	5199
E SHORE	CRISFIELD SEWAGE TREATMENT PLA	MD	20001	0.700	14925	38379	0.777	237	7103
E SHORE	EASTON WASTE STABILIZATION LAG	MD	20273	1.400	29850	76757	1.494	455	13649
E SHORE	ELKTON SEWAGE TREATMENT PLANT	MD	22641	0.780	6415	42765	0.895	273	8177
E SHORE	FEDERALSBURG SEWAGE TREATMENT	MD	20247	0.740	15778	33810	0.820	250	7494
E SHORE	HURLOCK, TOWN OF	MD	22730	0.500	10661	27413	0.510	155	4658
E SHORE	POCOMOKE CITY SEWAGE TREATMENT	MD	22551	0.900	19189	49344	1.069	326	9769
E SHORE	QUEEN ANNE'S COUNTY SANITARY D	MD	23485	0.800	15839	50928	1.046	319	9558
E SHORE	SALISBURY CITY WASTEWATER TRTM	MD	21571	4.600	98079	252203	5.177	1577	47303
E SHORE	LESS THAN 0.5 MGD (34 PLANTS)			5.063	104953	285948	5.646	1720	51591
E SHORE	BASIN TOTAL			18.253	377354	1022734	20.246	6168	184997
W CHESAP	AA COUNTY BROADNECK	MD	21644	3.200	68229	235876	3.696	1126	33771
W CHESAP	ABERDEEN PROVING AREA-ABERDEEN	MD	21237	1.000	10661	54827	1.146	349	10471
W CHESAP	ABERDEEN PROVING GROUND-EDGEWO	MD	21229	1.000	3046	50562	1.146	349	10471
W CHESAP	ABERDEEN, TOWN OF STP	MD	21563	1.100	1340	60309	1.260	384	11518
W CHESAP	ANNAPOLIS STP,CITY OF	MD	21814	6.300	134325	243704	7.276	2216	66487
W CHESAP	ANNE ARUNDEL CO DPW-COX CREEK	MD	21661	9.200	84068	560450	10.625	3236	97092
W CHESAP	BACKRIVER	MD	21555	63.000	312786	4029759	65.600**	19981	599438
W CHESAP	BETH STEEL (FROM BACK R STP)	MD	1201	100.500	355094	7316160	100.000**	30459	913777
W CHESAP	BROADWATER SEWAGE TREATMENT PL	MD	24350	0.500	10661	31525	0.577	176	5277
W CHESAP	HAVRE DE GRACE WWTR TREAT PLT	MD	21750	1.500	31982	98688	1.719	524	15706
W CHESAP	JOPPATOWNE STP.-MD.ENV.SERVICE	MD	22535	0.687	14659	25336	0.788	240	7199
W CHESAP	MES-FREEDOM	MD	21512	1.300	27718	71275	1.611	491	14725
W CHESAP	NORTH EAST WASTE WATER TREAT.	MD	22594	0.510	11651	27962	0.585	178	5347
W CHESAP	PATAPSCO	MD	21601	43.000	458412	2619496	85.500**	26043	781280
W CHESAP	SOD RUN	MD	21709	5.800	24733	473459	6.646	2024	60730
W CHESAP	TOWN COMMISSIONERS OF PERRYVIL	MD	20613	0.600	1279	32896	0.688	210	6290
W CHESAP	LESS THAN 0.5 MGD (16 PLANTS)			2.190	39241	116284	2.644	805	24157
W CHESAP	BASIN TOTAL			241.387	1589885	16048568	291.507	88791	2663736

Flow in millions of gallons per day (MGD)
Load in pounds per year
Limits of technology treatment: total phosphorus=0.1 mg/l, total nitrogen=3.0 mg/l
Includes only Bay watershed municipal facilities in Maryland, Virginia, Pennsylvania and District of Columbia
** Year 2000 flow based on state projections, other year 2000 flows based on forecasted population growth

APPENDIX D

BELOW-THE-FALL-LINE MUNICIPAL NUTRIENT LOADS FOR YEAR 1985 WITH EXISTING TREATMENT AND FOR YEAR 2000 WITH LIMITS OF TECHNOLOGY TREATMENT

				1985			2000		
BASIN	FACILITY NAME	STATE	NPDES	FLOW	PHOSPHORUS	NITROGEN	FLOW	PHOSPHORUS	NITROGEN
PATUXENT	WESTERN BRANCH	MD	21741	10.800	108557	473702	23.600**	7188	215651
PATUXENT	BASIN TOTAL			10.800	108557	473702	23.600	7188	215651
POTOMAC	ALEXANDRIA CITY SANITARY AUTHO	VA	25160	35.600	16265	1995203	37.554	11439	343158
POTOMAC	AQUIA SANITARY DISTRICT	VA	60968	1.140	2049	50314	1.662	506	15183
POTOMAC	ARLINGTON	VA	25143	26.560	45304	1642265	26.998	8223	246703
POTOMAC	BLUE PLAINS	DC	21199	300.700	109909	12273189	306.020	93211	2796337
POTOMAC	CHARLES CNTY SAN DIST MATTAWOM	MD	21865	4.400	52268	170206	5.978	1821	54628
POTOMAC	DALE SERVICE CORP. PLANT # 1	VA	24724	2.040	1118	93205	2.994	912	27355
POTOMAC	DALE SERVICE CORP. PLANT # 8	VA	24678	0.840	844	38379	1.233	376	11264
POTOMAC	FAIRFAX CO-LITTLE HUNTING CR	VA	25372	3.820	2211	279250	4.499	1370	41108
POTOMAC	LA PLATA, TOWN OF	MD	20524	0.610	13006	33444	0.829	252	7573
POTOMAC	LOWER POTOMAC, FAIRFAX CO	VA	25364	32.980	14064	1908638	38.839	11830	354906
POTOMAC	MOONEY - PRINCE WM. CO.	VA	25101	7.580	3694	609526	11.123	3388	101642
POTOMAC	PINE HILL RUN W.W.T.P.	MD	21679	1.900	34724	98383	2.408	734	22004
POTOMAC	PISCATAWAY	MD	21539	13.000	7127	570197	14.215	4330	129890
POTOMAC	U.S. MARINE CORPS BASE-MAINSID	VA	28363	1.450	883	65675	2.128	648	19443
POTOMAC	UPPER OCCOQUAN SEWAGE AUTH-REG	VA	24988	9.400	716	598402	13.794	4202	126047
POTOMAC	FLOWS LESS THAN 0.5 MGD (13 PLANTS)			1.309	24146	67291	1.631	497	14904
POTOMAC	BASIN TOTAL			443.329	328328	20493567	471.905	143739	4312145
RAPP	CLAIBORNE RUN SEWAGE TREATMENT	VA	28096	0.880	17155	43074	1.283	391	11721
RAPP	FREDERICKSBURG CITY STP	VA	25127	2.570	50099	165097	3.068	934	28033
RAPP	SPOTSYLVANIA CO. - MASSAPONAX	VA	25658	1.550	29602	61579	1.850	564	16907
RAPP	LESS THAN 0.5 MGD (6 PLANTS)			0.610	11900	34567	0.696	212	6363
RAPP	BASIN TOTAL			5.610	108756	304317	6.897	2101	63024
YORK	HRSD YORK STP	VA	64238	7.360	152442	481987	9.149	2787	83604
YORK	LESS THAN 0.5 MGD (5 PLANTS)			0.634	11707	35728	0.778	227	7113
YORK	BASIN TOTAL			7.994	164149	517715	9.927	3014	90717

Flow in millions of gallons per day (MGD)
Load in pounds per year
Limits of technology treatment: total phosphorus=0.1 mg/l, total nitrogen=3.0 mg/l
Includes only Bay watershed municipal facilities in Maryland, Virginia, Pennsylvania and District of Columbia
** Year 2000 flow based on state projections, other year 2000 flows based on forecasted population growth

APPENDIX D (cont'd)

BELOW-THE-FALL-LINE MUNICIPAL NUTRIENT LOADS FOR YEAR 1985 WITH EXISTING TREATMENT AND FOR YEAR 2000 WITH LIMITS OF TECHNOLOGY TREATMENT

				1985			2000		
BASIN	FACILITY NAME	STATE	NPDES	FLOW	PHOSPHORUS	NITROGEN	FLOW	PHOSPHORUS	NITROGEN
JAMES	CHESTERFIELD CO./PROCTOR CREEK	VA	60194	3.760	62990	176371	5.777	1760	52790
JAMES	CHESTERFIELD-FALLING CREEK	VA	24996	10.110	209401	769858	15.534	4731	141943
JAMES	FT.EUSTIS-US ARMY TRANSPORTATI	VA	25216	1.650	32165	93982	1.855	565	16949
JAMES	HOPEWELL STP CITY OF	VA	66630	30.820	178363	6101902	32.875	10013	300401
JAMES	HRSD - ARMY BASE	VA	25208	12.990	178050	775505	12.857	3916	117483
JAMES	HRSD - BOAT HARBOR	VA	25283	15.850	260701	1076597	15.688	4778	143349
JAMES	HRSD - CHESAPEAKE/ELIZ.***	VA	25275	14.360	284307	997260	14.213	4329	129873
JAMES	HRSD - JAMES RIVER	VA	25241	10.340	226763	633047	10.234	3117	93516
JAMES	HRSD - LAMBERTS POINT	VA	25259	19.970	200730	1338197	29.580	9012	270358
JAMES	HRSD - NANSEMOND	VA	64459	6.250	133259	510192	8.340	2540	76208
JAMES	HRSD - WILLIAMSBURG	VA	25267	9.720	112504	633577	9.620	2930	87909
JAMES	PETERSBURG WASTEWATER TREATMEN	VA	25437	8.480	144645	514006	8.288	2524	75732
JAMES	PORTSMOUTH CITY-PINNERS POINT	VA	25003	9.310	181488	530286	(FLOW DIVERTED TO LAMBERT POINT)		
JAMES	RICHMOND CITY OF	VA	63177	66.100	845610	2456295	64.731	19716	591492
JAMES	FLOWS LESS THAN 0.5 MGD (4 PLANTS)			0.850	16698	51418	1.012	6166	24665
JAMES	BASIN TOTAL			220.560	3067674	16658493	230.604	76097	2122668
	BASIN TOTALS (MD VA PA AND DC)			947.933	5744703	55519096	1054.686	327098	9652938
	BASIN TOTALS (DE WV AND NY)			2.190	40040	125052	2.406	733	21990
	BASIN TOTAL (ALL STATES)			950.123	5784743	55644148	1057.092	327831	9674928

Flow in millions of gallons per day (MGD)
Load in pounds per year
Limits of technology treatment: total phosphorus=0.1 mg/l, total nitrogen=3.0 mg/l
Includes only Bay watershed municipal facilities in Maryland, Virginia, Pennsylvania and District of Columbia
** Year 2000 flow based on state projections, other year 2000 flows based on forecasted population growth
*** Discharges to main Bay

APPENDIX E

BELOW THE FALL LINE 1985 INDUSTRIAL NUTRIENT LOADS

BASIN	FACILITY NAME	STATE	NPDES	PHOSPHORUS	NITROGEN
E SHORE	CAMPBELL SOUP CO	MD	2232	1750.0	2000
E SHORE	DELMARVA P&L VIENNA	MD	94	.	8500
E SHORE	EASTERN SHORE RENDERING CO	MD	3247	4525.0	52500
E SHORE	HOLLY FARMS POULTRY IND-TEMPERANCEVILLE	VA	4049	.	24712
E SHORE	PERDUE FARMS INC	MD	51594	.	4825
E SHORE	PERDUE INC, ACCOMAC	VA	3808	.	216755
E SHORE	SHOWELL FARMS INC.	MD	965	4500.0	35750
	BASIN TOTAL			10775.0	345042
W CHESAP	ANCHOR HOCKING CORP.	MD	1414	.	178
W CHESAP	BALTI CITY DPW MONTEBELLO FILT	MD	3042	.	19275
W CHESAP	BETHLEHEM STEEL	MD	1201	.	166331
W CHESAP	CHEMETALS CORP	MD	1775	275.0	238500
W CHESAP	CHEVRON U.S.A.INC.	MD	1449	.	8700
W CHESAP	DUTTERERS OF MANCHESTER INC	MD	1040	2050.0	425
W CHESAP	EASTERN STAINLESS STEEL CO	MD	981	450.0	250300
W CHESAP	GENERAL ELECT INSULATOR DEPT	MD	2763	655.0	12935
W CHESAP	GRUMMAN AEROSPACE CORP.-PLANT	MD	2127	.	20000
W CHESAP	LEVER BROTHERS CO-BALT PLANT	MD	1627	675.0	50
W CHESAP	PROCTER & GAMBLE MFG CO-BALT	MD	1465	3500.0	10500
W CHESAP	SCM CORPORATION	MD	1279	2700.0	12025
W CHESAP	SPRINGFIELD HOSPITAL CENTER	MD	57398	1200.0	2200
W CHESAP	WR GRACE DAVISON CHEM DIV	MD	311	.	2825000
W CHESAP	OTHER INDUSTRIAL SOURCES			6000.0	20000
	BASIN TOTAL			17505.0	3586420
PATUXENT	PEPCO CHALK POINT	MD	2658	3982.5	28000
PATUXENT	OTHER INDUSTRIAL SOURCES			.	14116
	BASIN TOTAL			3982.5	42116
POTOMAC	MINERAL PIGMENTS CORP BLTVILLE	MD	3425	275.0	104250
POTOMAC	NAVAL ORDANCE STATION	MD	3158	2825.0	173250
POTOMAC	PEPCO MORGANTOWN	MD	2674	1500.0	21700
POTOMAC	OTHER INDUSTRIAL SOURCES			.	3000
	BASIN TOTAL			4600.0	302200
YORK	CHESAPEAKE CORP, WEST POINT	VA	3115	57507.5	79073
	BASIN TOTAL			57507.5	79073

Load in pounds per year based on 250 operating days per year
Includes only Bay watershed industrial facilities in Maryland, Virginia, Pennsylvania and District of Columbia discharging below the fall line

APPENDIX E (CONT.)

BELOW THE FALL LINE 1985 INDUSTRIAL NUTRIENT LOADS

BASIN	FACILITY NAME	STATE	NPDES	PHOSPHORUS	NITROGEN
JAMES	ALLIED CHEM CORP, HOPEWELL	VA	5291	.	1321029
JAMES	DUPONT SPRUANCE	VA	4669	.	88458
JAMES	HOLLY FARMS GLEN ALLEN	VA	4031	144.0	1024
JAMES	ITT GWALTNEY, SMITHFIELD	VA	2844	.	34722
JAMES	PHILIP MORRIS, BERMUDA HUNDRED	VA	26557	.	14609
JAMES	SMITHFIELD HAM PRDTS	VA	2852	.	118
JAMES	SMITHFIELD PACKING CO	VA	59005	.	38919
	BASIN TOTAL			144.0	1498880
	BASIN TOTALS (MD VA PA AND DC)			94514	5853734
	BASIN TOTALS (DE WV AND NY)			3599	1080
	BASIN TOTAL (ALL STATES)			98113	5854814

Load in pounds per year based on 250 operating days per year
Includes only Bay watershed industrial facilities in Maryland, Virginia, Pennsylvania and District of Columbia discharging below the fall line

Glossary

Alga: Any of a group of aquatic plants, including phytoplankton and seaweeds, ranging from microscopic to several meters in size.

Anadromous fish: Fish species (e.g. striped bass, shad, perch) that live in estuarine or marine waters but migrate to fresh water to spawn.

Anoxia: Total absence of dissolved oxygen in water.

Anthropogenic: Pertaining to or resulting from the impact of human activities.

Base flow: Subsurface flow of water to a stream or river from ground water. Stream flows during dry periods consist essentially of base flow.

Benthos: Marine plants and animals inhabiting stream, estuary or ocean bottoms, together with the sediment or rocks forming the bottom substrate.

Bioaccumulation: Uptake of contaminants into the tissue of organisms.

Bioassay: Measurement of an organism's response to controlled concentrations of a contaminant.

Bioavailability: Presence of a compound in a form biologically available for uptake by organisms.

Biological nutrient removal: Wastewater treatment processes that (1) create specific biological environments which enhance phosphorus removal, and (2) utilize chemical energy drawn from the wastewater itself to remove nitrogen.

Biochemical oxygen demand (BOD): A measure of the quantity of dissolved oxygen removed from water by the metabolism of microorganisms. Excessive BOD results in oxygen-poor water.

Biomonitoring: Any systematic collection of biological data such as benthic community sampling, toxicity testing, or finfish surveys.

Biota: Plant and animal life of an area.

Bioturbation: Disturbance or reworking of unconsolidated bottom sediments by organisms living or feeding in the sediments.

Blooms: Excessive growth of plankton in concentrations sufficiently dense to cause discoloration of water and reduced light penetration.

Chlorophyll: Green pigment in plants that is essential for photosynthesis. One type of the pigment (chlorophyll *a*) is commonly used as a measure of phytoplankton abundance.

Cladocerans: Minute freshwater and marine crustaceans.

Coliform: Bacteria from the feces of warm-blooded animals. The quantity of fecal coliform in water is a traditional measure of water pollution.

Conventional pollutants: Pollutants typically discharged by municipal sewage treatment plants and a number of industries. The category includes wastes with a high biochemical oxygen demand (BOD), total suspended solids, fecal coliform, pH, and grease and oil.

Copepods: Subclass of minute marine and freshwater crustaceans constituting an important food source for finfish.

Cultch: Old oyster shells, accumulating naturally or "planted" in Bay waters, which form a hard substrate on which oyster spat may set or attach.

Cyanobacteria: Extremely small blue-green algae, including many plants considered nuisances.

Denitrification: Conversion by bacteria of available forms of nitrogen (NO_3) into largely unavailable atmospheric nitrogen (N_2).

Dermo: Fungal disease that attacks and kills oysters. Most prevalent in the higher salinity waters of the lower Bay, it can move up the Bay in years of low freshwater flows.

Detention pond: Artificial pond, generally dry, but designed to detain stormwater runoff long enough for particulate pollutants to settle out.

Detritus: Organic or inorganic particulate matter in the water column or settled on the bottom.

Dissolved oxygen (DO): Concentration of oxygen in water, commonly employed as a measure of water quality. Low levels adversely affect aquatic life. Most finfish cannot survive when DO falls below 3 milligrams/liter for a sustained period of time.

Ecosystem: An ecological community including living organisms and their physical and chemical environment.

Effluent: Discharge or emission of a liquid or gas into the environment.

Epiphytes: Plants, usually microscopic or near-microscopic in size, that grow on leaves or stems of host plants but derive nutrients from the surrounding water.

Estuary: A semi-enclosed body of water, connected to the open sea, in which sea water is measurably diluted with fresh water from inland sources.

Eutrophication: Process of nutrient enrichment which increases primary productivity in a water body, resulting eventually in depletion of dissolved oxygen essential to aquatic life.

Fall line: Area in a tributary where tidal waters meet free-flowing fresh water; often called the "head of tide." In the Chesapeake Bay watershed, the fall line marks the boundary between older, resistant rocks of the Piedmont and younger sediments of the Coastal Plain.

Filter strip: A band of naturally occurring or planted vegetation maintained to capture nutrients and sediment in surface water runoff, reducing loads to nearby streams or rivers.

Fingerprinting: Matching characteristics of environmental samples to trace a particular compound to a specific point of origin.

Food web: The complex network of feeding interactions that links microbes, plants and animals in an ecosystem. In the process, energy produced by plants from sunlight is passed along to successively higher trophic levels.

Freshet: A rapid rise in the water level of a stream due to melting snow or heavy rain; commonly refers to the sizeable seasonal increase in river flows to the Bay each winter and spring.

Ground water: Subsurface water saturating soil or porous rock.

Groundtruth: Data gathered from observations on or near the surface of the earth which may be used to verify remotely sensed data such as aerial photographs or satellite imagery.

Hypoxia: Low levels of dissolved oxygen in water, defined as less than 2 mg/l.

Infiltration: The passage of water through the pores or cracks of soil or rock.

Inorganic compounds: Chemical substances without carbon.

Land treatment: Use of vegetated soils to treat wastewater. Water percolating through the soil is cleansed by filtration, precipitation, and the uptake of nutrients by plants.

Leaching: Process in which soluble compounds are selectively removed from rock or soil by percolating water.

Loading: Quantity of contaminants, nutrients, or other substances introduced to a water body.

Macrophage: Virus that affects bacterium by taking over the genetic code of the infested cell.

Mainstem: Primary channel of a stream or river. In the Chesapeake, the mainstem is the deep mid-channel forming the longitudinal axis of the Bay from the Susquehanna Flats to the Virginia Capes.

Marine: Pertaining to the ocean or sea.

Mesohaline: Water of medium salinity, 5 to 18 parts per thousand.

Model: A simplified mathematical representation of reality. Water quality modeling is used to study Chesapeake Bay processes and project effects of varying environmental conditions or management actions.

Monitoring: Observing, tracking, or measuring some aspect of the environment in order to establish base line conditions and short-term or long-term trend data.

MSX (Multinucleate sphere unknown): A parasitic, frequently fatal disease that infects oysters. MSX occurs primarily in the higher salinity reaches of the Bay.

Nitrogen: A nutrient essential for life. May be in organic form or inorganic (ammonia, nitrate, nitrite). Elemental nitrogen constitutes 78 percent of the atmosphere by volume.

Nonpoint source pollution: Toxicants, other contaminants, nutrients, or soil entering a water body from sources other than discrete discharges such as pipes. Includes pollution from the air as well as farm and urban runoff.

Nutrient flux: The rate of transfer of nutrients across a surface, usually the sediment/water column interface.

Nutrients: Chemicals required for growth and reproduction of plants. Excessive levels of the nutrients nitrogen and phosphorus can lead to excessive algae growth.

Oligohaline: Water of low salinity, 0.5 to 5.0 parts per thousand.

Organic compound: Combination of elements whose composition includes organic carbon. These compounds are the primary constituents of living matter.

pH: Value expressing the acidity (0 to 7) or alkalinity (7 to 14) of a solution. A value of 7 indicates neutrality.

Phosphorus: A nutrient essential for life found in both organic and inorganic forms.

Phytoplankton: Microscopic plants (algae) suspended in water.

Plankton: Microscopic plants and animals that live in water, drifting passively or swimming weakly.

Point source pollution: Contamination from waste effluent discharged into a water body through discrete pipes or conduits.

Polyhaline: Water with a salinity of 18 to 30 parts per thousand; generally the highest concentrations found in the Bay.

Pretreatment: Treatment of wastewater by industry prior to discharge to a municipal treatment plant to remove toxic materials and heavy metals likely to pass through or disrupt ordinary municipal treatment operations.

Primary productivity: Rate of production of living matter (through photosynthesis) by green plants and bacteria. The organic matter produced may be used as food by higher level organisms.

Priority pollutants: Substances EPA has identified as being of special environmental concern due to their toxicity and usage.

Riparian: Relating to the bank or shoreline area of a river, lake, pond, or other water body.

Runoff: Drainage of precipitation over the soil or a non-porous surface (e.g. asphalt) to a stream, river or other receiving body of water.

Salinity: Amount, by weight, of dissolved salts in 1,000 units of water (reported as parts per thousand).

Secondary treatment: Second stage of wastewater treatment in which organic matter is broken down by bacteria. The process reduces biochemical oxygen demand on the receiving stream and essentially speeds up the natural process by which water purifies itself.

Sediment oxygen demand: Rate at which biological and chemical reactions taking place in bottom sediments consume oxygen from the overlying water column.

Sorb: To take up and hold either by adsorption (adherence to the surface of a solid) or absorption (incorporation or assimilation, as liquids into solids or gases into liquids).

Spat: Juvenile oysters newly attached (set) to substrate.

Stock assessment: Determination and appraisal of changes in fish population numbers due to water quality conditions, fishing pressure, or natural environmental variability.

Stratification: In Chesapeake Bay, the layering of fresh water over salt water due to differences in relative density and temperature.

Shoreline stabilization: Securing stream banks or Bay shoreline with vegetation or engineering structures to prevent shoreline erosion.

Submerged aquatic vegetation (SAV): Vegetation that grows underwater along the fringes and in the shallows of the Bay.

Tidal-freshwater: Zone of stream or river affected by the tides but whose waters have little or no salinity.

Toxic substance: A compound that produces or has the potential to produce adverse effects on living organisms.

Tributary: A stream or river which joins and feeds into a larger stream, river or other body of water.

Tributyltin (TBT): A toxic chemical compound used as the active ingredient in some boat bottom antifouling paints.

Trophic level: Stratum of food web characterized by organisms the same number of steps removed from primary producers (phytoplankton).

Turbidity: Reduction of water clarity caused by suspended sediments and organics in the water.

Urban marshes: Artificial wetlands created to improve water quality and/or control flooding.

Wastewater treatment: Processes to remove pollutants, commonly categorized as primary, secondary, and advanced levels of treatment.

Water Column: A vertical extent of water reaching from the surface to the bottom substrate of a water body.

Water quality: Status or condition of a water body in terms of defined variables characterizing the "health" of the water.

Watershed: Area drained by a river system or other water body.

Wet pond: Artificial pond that captures stormwater runoff and removes particulate and soluble pollutants through settling and biological assimilation.

Wetlands: Semi-aquatic areas, periodically flooded or water-saturated close to the surface, including freshwater and saltwater marshes, swamps and bogs.

Zooplankton: Animal plankton of widely varying size that drift or swim weakly in the water. They consume the primary producers and are a second link in the food chain or food web.

Acronyms/Abbreviations:

ASCS:	Agricultural Stabilization and Conservation Service
BAT:	Best Available Technology
BMP:	Best Management Practice
BNR:	Biological Nutrient Removal
BOD:	Biological oxygen demand
CAC:	Citizens Advisory Committee
CBP:	Chesapeake Bay Program
CoE:	Corps of Engineers, U.S. Army
DO:	Dissolved oxygen
DoD:	Department of Defense
FWS:	Fish and Wildlife Service
IPM:	Integrated Pest Management
LOT:	Limits of Technology
LRTF:	Living Resources Task Force
mg/l:	milligrams per liter
MGD:	millions of gallons per day
ng/l:	nanograms per liter
NOAA:	National Oceanic and Atmospheric Administration
NPDES:	National Pollution Discharge Elimination System
RCRA:	Resource Conservation and Recovery Act
SCS:	Soil Conservation Service
STAC:	Scientific and Technical Advisory Committee
SAV:	Submerged aquatic vegetation
TBT:	Tributyltin
TRE:	Toxicity reduction evaluation
TSD:	Treatment, storage and disposal (hazardous waste facilities)
USGS:	U.S. Geological Survey

References

1. Chesapeake Bay Restoration and Protection Plan. Chesapeake Executive Council. Annapolis, Maryland. July 1985. 115 pages.

2. First Annual Report under the Chesapeake Bay Agreement. Chesapeake Executive Council. Annapolis, Maryland. December 1985. 24 pages.

3. Second Annual Progress Report Under the Chesapeake Bay Agreement. Chesapeake Executive Council. Annapolis, Maryland. February 1987. 36 pages.

4. 1983 Chesapeake Bay Agreement. Signatories to the Agreement. (Available in Reference 2.)

5. Draft 1987 Chesapeake Bay Agreement. Drafting Committee of the Executive Council. Available from Chesapeake Bay Program. Annapolis, Maryland. August 1987.

6. Chesapeake Bay Agreement. Signatories to the Agreement. December 15, 1987.

7. Chesapeake Bay Program: Findings and Recommendations. U.S. Environmental Protection Agency, Region III, Chesapeake Bay Program. Philadelphia, Pennsylvania. September 1983. 54 pages.

8. Chesapeake Bay: A Profile of Environmental Change. U.S. Environmental Protection Agency, Region III, Chesapeake Bay Program. Philadelphia, Pennsylvania. September 1983. 222 pages.

9. Blue Plains and Washington Area Wastewater Treatment Plants Take Leadership Role in Cleaning up the Potomac River and Chesapeake Bay. District of Columbia Department of Public Works. Washington, D.C. October 1987. 4 pages.

10. Personal communication. Telephone comments on the Interim Report draft from the District of Columbia Department of Public Works staff to Patricia Bonner, U. S. Environmental Protection Agency, Chesapeake Bay Liaison Office. September 1987.

11. Special Agreements between the U. S. Environmental Protection Agency and Six Federal Agencies. Memoranda of Understanding between USEPA and SCS, NOAA, CoE, USGS, FWS, November 1984, and Joint Resolution with DoD, September 1984. Available from Chesapeake Bay Program. Annapolis, Maryland. 20 pages.

12. Maryland's Chesapeake Bay Program Annual Report 1986. Office of the Governor. Annapolis, Maryland. 1987. 37 pages.

13. From the Waters of the District of Columbia to the Chesapeake Bay. Government of the District of Columbia. Washington, D. C. July 1986. 16 pages.

14. Progress Report of Virginia's Chesapeake Bay Program. Office of the Governor. February 1987. 70 pages.

15. Chesapeake Bay: You've Got a Friend in Pennsylvania, A Progress Report on Pennsylvania's Chesapeake Bay Program. Office of the Governor. Harrisburg, Pennsylvania. October 1986. 12 pages.

16. NOAA Involvement in the Chesapeake Bay. NOAA Estuarine Programs Office. Washington, D. C. November 1986. 23 pages.

17. Water Quality Assessment of DoD Installations/ Facilties in the Chesapeake Bay Region, Phase II Report, Development and Testing of Installation Assessment Methodolgy. TetraTech, Inc. for the Office of the Deputy Secretary of Defense for Environment. Contract DACA 31-85-C-0168. Arlington, Virginia. June 1987. 330 pages.

18. Chesapeake Bay: A Framework for Action. U.S. Environmental Protection Agency, Region III, Chesapeake Bay Program. Philadelphia, Pennsylvania. September 1983. 210 pages.

19. Final Report and Recomendations. Resource Users Management Team. U.S. Environmental Protection Agency, Chesapeake Bay Program. Philadelphia, Pennsylvania. Fall 1983. 13 pages.

20. Status and Recent Trends of Wetlands in Five Mid-Atlantic States: Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. Ralph W. Tiner and John T. Finn. U. S. Fish & Wildlife Service, Habitat Research, Region V. Newton Corner, Massachusetts. October 1987. 40 pages.

21. Chesapeake Bay Critical Area Law and Criteria. Maryland General Assembly. Natural Resource Article 8-1801-1816. Annapolis, Maryland. June 1986.

22. VR680-21-07.03 Special Standards and Designations, Nutrient Enriched Waters; and VR680-14-02 Policy for Nutrient Enriched Waters. Virginia Water Control Board. Richmond, Virginia. September 1987.

23. Chesapeake Bay - Nutrient Enrichment. House Joint Resolution No. 53; Senate Joint Resolution No 18. Maryland General Assembly. Annapolis, Maryland. May 13, 1986.

24. Federal Water Quality Act of 1987, Amendments to the Clean Water Act. Public Law 100-4. February 4, 1987. (Soon to be available from the Superintendent of Documents, Washington, D.C.)

25. Survey of Tributyltin and Dibutyltin Concentrations at Selected Harbors in Chesapeake Bay - Final Report. Richard Batiuk. U. S. Environmental Protection Agency, Chesapeake Bay Program Technical Report Series CBP/TRS14/87. Annapolis, Maryland. August 1987. 176 pages.

26. The State of the Chesapeake Bay, Second Annual Monitoring Report, 1984-85. Chesapeake Bay Program Monitoring Subcommittee. Annapolis, Maryland. March 1987. 26 pages.

27. The State of the Chesapeake Bay - Second Annual Monitoring Report, 1984-85, Compendium. Chesapeake Bay Program Monitoring Subcommittee. Annapolis, Maryland. April 1987. 196 pages.

28. Distribution and Abundance of Submerged Aquatic Vegetation in the Chesapeake Bay and Tributaries - 1985. R. Orth, J. Simons, J.Capelli, V. Carter, L. Hindman, S. Hodges, K. Moore and N. Rybicki. Funded through Maryland Department of Natural Resources, Virginia Institute of Marine Science, U.S. Fish & Wildlife Service, U.S. Army Corps of Engineers, and U. S. Environmental Protection Agency. 1985. 314 pages.

29. Distribution of Submerged Aquatic Vegetation in the Chesapeake Bay and Tributaries and Chincoteague Bay - 1986. Robert Orth, Jim Simons, Judith Capelli, Virginia Carter, Adam Frisch, Larry Hindman, Stephen Hodges, Kenneth Moore, and Nancy Rybicki. Funded through Maryland Department of Natural Resources, Virginia Institute of Marine Science, U.S. Fish & Wildlife Service, Corps of Engineers, U.S. Environmental Protection Agency, Committee to Preserve Assateague Island, Allied Chemical Corporation and National Oceanic and Atmospheric Administration. Annapolis, Maryland. October 1987. 191 pages.

30. Data Management Plan for Water Quality Data. U.S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. June 1987. 96 pages.

31. Description of the Chesapeake Bay Program's Phase II Implementation Program. Chesapeake Bay Liaison Office. Annapolis, Maryland. January 1987. 22 pages.

32. Chesapeake Bay: A Profile of Environmental Change. Appendices. U.S. Environmental Protection Agency, Region III, Chesapeake Bay Program. Philadelphia, Pennsylvania. September 1983. 338 pages.

33. Habitat Requirements for Chesapeake Bay Living Resources: A Report from the Chesapeake Bay Living Resources Task Force. Annapolis, Maryland. August 1987. 250 pages.

34. Report of the Workshop on Habitat Requirements for Chesapeake Bay Living Resources. U. S. Environmental Protection Agency, Chesapeake Bay Program Technical Report Series CBP/TRS 8/87. Annapolis, Maryland. July 1987. 106 pages.

35. Re-establishment of Submerged Aquatic Vegetation in Chesapeake Bay - Water Quality Requirements. J. Court Stevenson, Lorie W. Staver, and Jeffrey C. Cornwell. Horn Point Environmental Laboratories, Center for Environmental and Estuarine Studies. Cambridge, Maryland. 1986.

36. Chesapeake Bay: A Framework for Action. Appendices. U. S. Environmental Protection Agency, Region III, Chesapeake Bay Program. Philadelphia, Pennsylvania. September 1983. 554 pages.

37. Proceeding Number 2, Appendix D. Chesapeake Bay Stock Assessment Committee. NOAA Estuarine Programs Office. Washington, D.C. June 1987. 6 pages.

38. Chesapeake Bay Program Technical Studies: A Synthesis. U. S. Environmental Protection Agency, Region III, Chesapeake Bay Program. Philadelphia, Pennsylvania. September 1983. 275 pages. (page 231)

39. Ecology: The Experimental Analysis of Distribution and Abundance. Charles J. Krebs. Harper and Row. New York, New York. 1972. 694 pages. (pages 446-468)

40. Personal communication from John Friedman, Northern Virginia Planning District Commission, to Virginia Tippie, U. S. Environmental Protection Agency, Chesapeake Bay Program. July 12, 1982; and

Chesapeake Bay: A Framework for Action. Appendix B. (Reference 36)

41. Memorandum from Douglas M. Costle, U. S. Environmental Protection Agency Administrator, to Jack J. Schram, Regional Administrator, Region III. Review of the Upper Chesapeake Bay Phosphorus Limitation Policy. November 29, 1979.

42. 208 Water Quality Management Plan for the Patuxent River Basin. Maryland Office of Environmental Programs. June 1987. 750 pages.

43. Technical Support Document for Interim Control Decisions for the Potomac River. State/EPA Potomac Management Technical Subcommittee, December 1985. 61 pages.

44. Point Sources Atlas. U. S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. In preparation.

45. Chesapeake Bay Nonpoint Source Programs. Chesapeake Bay Implementation Committee. Annapolis, Maryland. In preparation.

46. Nutrients...the Missing Link. Paul O. Swartz. Presented at "Estuarine & Coastal Management Tools of the Trade", Tenth National Conference of The Coastal Society. New Orleans, Louisiana. October 1986.

47. Managing riparian ecosystems to control nonpoint pollution. Richard Lowrance, Ralph Leonard and Joseph Sheridan. Journal of Soil and Water Conservation. January-February 1985. Volume 40, Number 1, pages 87-91.

48. Chessee Data File DRD3:[CULTURE] LAND.SSD (prior to 1950) and U.S. Forest Service Resource Bulletins NE-69 (1982), NE-66 (1980), NE-78 (1983), NE-80 (1984), NE-38 (1975), NE 71 (1982), NE-32 (1874), NE-58 (1978) and NE-56 (1978).

49. A Steady-State Coupled Hydrodynamic/Water Quality Model of the Eutrophication and Anoxia Process in Chesapeake Bay. HydroQual, Incorporated, under contract to Battelle Ocean Sciences for U.S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. Contract Number 68-03-3319. August 1987. 410 pages.

50. A Steady-State Coupled Hydrodynamic/Water Quality Model of the Eutrophication and Anoxia Process in Chesapeake Bay. Appendix. HydroQual, Incorporated, under contract to Battelle Ocean Sciences for U. S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. Contract Number 68-03-3319. August 1987. 534 pages.

51. Estimates of Sediment Denitrification and its Influence on the Fate of nitrogen in Chesapeake Bay. R. R. Twilley and W. M. Kemp. Contract Number X-003310-01-0. U. S. Environmental protection Agency, Chesapeake Bay Program Technical Report Series CBP/TRS 1/87. Annapolis, Maryland. August 1987. 64 pages.

52. Chesapeake Bay Eutrophication Model: Results of Management Scenarios (draft). Charles App. U.S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. August 1987. 30 pages.

53. Assessment of Cost and Effectiveness of Biological Dual Nutrient Removal Technologies in the Chesapeake Bay Drainage Basin. Hazen & Sawyer, Inc. and J. M. Smith & Associates for U. S. Environmental Protection Agency, Performance Assurance Branch, Municipal Facilities Division. Washington, D. C. Contract Number 68-03-4049. September 1987. 231 pages.

54. Available Technologies for the Control of Nutrient Pollution in the Chesapeake Bay Watershed. Andrew A. Randall & Clifford W. Randall. Chesapeake Bay Scientific & Technical Advisory Committee. Annapolis, Maryland. October 1987. 118 pages.

55. Controlling Urban Runoff: A Practical Guide for Planning and Designing Urban BMPs. Thomas R. Schueler. Metropolitan Washington Council of Governments. July 1987. 276 pages.

56. The Cost Digest - Cost Summaries of Selected Environmental Control Technologies. Environmental Protection Agency, Office of Research and Development, EPA-60018-84-010, October, 1984.

57. Handbook - Retrofitting POTWs for Phosphorus Removal in the Chesapeake Bay Drainage Basin. Environmental Protection Agency, Office of Research and Development, EPA-625/6-87-017, September, 1987. 137 pages.

58. Personal communications from Dr. Joh Kang, Manager, Research and Development Division, McNamee, Porter and Seeley, Engineers/Architects, to Joe Macknis, U.S. Environmental Protection Agency, Chesapeake Bay Program. August and October 1987.

Chesapeake Bay: A Framework for Action. Appendix B. (Reference 36)

41. Memorandum from Douglas M. Costle, U. S. Environmental Protection Agency Administrator, to Jack J. Schram, Regional Administrator, Region III. Review of the Upper Chesapeake Bay Phosphorus Limitation Policy. November 29, 1979.

42. 208 Water Quality Management Plan for the Patuxent River Basin. Maryland Office of Environmental Programs. June 1987. 750 pages.

43. Technical Support Document for Interim Control Decisions for the Potomac River. State/EPA Potomac Management Technical Subcommittee, December 1985. 61 pages.

44. Point Sources Atlas. U. S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. In preparation.

45. Chesapeake Bay Nonpoint Source Programs. Chesapeake Bay Implementation Committee. Annapolis, Maryland. In preparation.

46. Nutrients...the Missing Link. Paul O. Swartz. Presented at "Estuarine & Coastal Management Tools of the Trade", Tenth National Conference of The Coastal Society. New Orleans, Louisiana. October 1986.

47. Managing riparian ecosystems to control nonpoint pollution. Richard Lowrance, Ralph Leonard and Joseph Sheridan. Journal of Soil and Water Conservation. January-February 1985. Volume 40, Number 1, pages 87-91.

48. Chessee Data File DRD3:[CULTURE] LAND.SSD (prior to 1950) and U.S. Forest Service Resource Bulletins NE-69 (1982), NE-66 (1980), NE-78 (1983), NE-80 (1984), NE-38 (1975), NE 71 (1982), NE-32 (1874), NE-58 (1978) and NE-56 (1978).

49. A Steady-State Coupled Hydrodynamic/Water Quality Model of the Eutrophication and Anoxia Process in Chesapeake Bay. HydroQual, Incorporated, under contract to Battelle Ocean Sciences for U.S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. Contract Number 68-03-3319. August 1987. 410 pages.

50. A Steady-State Coupled Hydrodynamic/Water Quality Model of the Eutrophication and Anoxia Process in Chesapeake Bay. Appendix. HydroQual, Incorporated, under contract to Battelle Ocean Sciences for U. S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. Contract Number 68-03-3319. August 1987. 534 pages.

51. Estimates of Sediment Denitrification and its Influence on the Fate of nitrogen in Chesapeake Bay. R. R. Twilley and W. M. Kemp. Contract Number X-003310-01-0. U. S. Environmental protection Agency, Chesapeake Bay Program Technical Report Series CBP/TRS 1/87. Annapolis, Maryland. August 1987. 64 pages.

52. Chesapeake Bay Eutrophication Model: Results of Management Scenarios (draft). Charles App. U.S. Environmental Protection Agency, Chesapeake Bay Program. Annapolis, Maryland. August 1987. 30 pages.

53. Assessment of Cost and Effectiveness of Biological Dual Nutrient Removal Technologies in the Chesapeake Bay Drainage Basin. Hazen & Sawyer, Inc. and J. M. Smith & Associates for U. S. Environmental Protection Agency, Performance Assurance Branch, Municipal Facilities Division. Washington, D. C. Contract Number 68-03-4049. September 1987. 231 pages.

54. Available Technologies for the Control of Nutrient Pollution in the Chesapeake Bay Watershed. Andrew A. Randall & Clifford W. Randall. Chesapeake Bay Scientific & Technical Advisory Committee. Annapolis, Maryland. October 1987. 118 pages.

55. Controlling Urban Runoff: A Practical Guide for Planning and Designing Urban BMPs. Thomas R. Schueler. Metropolitan Washington Council of Governments. July 1987. 276 pages.

56. The Cost Digest - Cost Summaries of Selected Environmental Control Technologies. Environmental Protection Agency, Office of Research and Development, EPA-60018-84-010, October, 1984.

57. Handbook - Retrofitting POTWs for Phosphorus Removal in the Chesapeake Bay Drainage Basin. Environmental Protection Agency, Office of Research and Development, EPA-625/6-87-017, September, 1987. 137 pages.

58. Personal communications from Dr. Joh Kang, Manager, Research and Development Division, McNamee, Porter and Seeley, Engineers/Architects, to Joe Macknis, U.S. Environmental Protection Agency, Chesapeake Bay Program. August and October 1987.

59. Personal communication from Tom Henry and John Minett, U.S. Environmental Protection Agency, Water Quality Control Section, Region 3, to Joe Macknis, EPA Chesapeake Bay Program. October 19.

60. Development of Water Quality-Based Permit Limitations for Toxic Pollutants. National Policy. Federal Register 49. Number 48. Friday, March 9, 1984, Pages 9016-9019.

61. Personal communication. Letter from Richard W. Ayers, Virginia State Water Control Board to Charles S. Spooner, U. S. Environmental Protection Agency, Chesapeake Bay Liaison Office. Annapolis, Maryland. April 7, 1987. 4 pages.

62. Personal communication. Letter from John Vail, Industrial Technology Division, Pennsylvania Department of Environmental Resources, to Joseph Macknis, U. S. Environmental Protection Agency, Chesapeake Bay Liaison Office, Annapolis, Maryland. August 31, 1987. 1 page.

63. Personal communication. Letter from Ronald Preston, U. S. Environmental Protection Agency, Wheeling West Virginia Laboratory to Joseph Macknis, U. S. Environmental Protection Agency, Chesapeake Bay Liaison Office. Annapolis, Maryland. August 3, 1987. 2 pages.

64. Personal communication. Telephone comments on the Interim Report draft, Chapter 4. District of Columbia, Consumer & Regulatory Affairs, Soil Resources Branch staff to Joseph Macknis. August 11, 1987.

65. The Chesapeake Bay - Report of a Research Planning Study: A Report to the National Science Foundation by the Johns Hopkins University, the University of Maryland and the Virginia Institute of Marine Science. R. F. Beers et al. 1971. 211 pages.

66. Background Papers on Chesapeake Bay Needs in Research and Related matters. Chesapeake Research Consortium. Gloucester Point, Virginia. Publication 111. 1983. 138 pages.

67. Ten Critical Questions for Chesapeake Bay in Research and Related Matters. L. E. Cronin. Chesapeake Research Consortium. Gloucester Point, Virginia. Publication 113. 1983. 161 pages.

68. Memorandum to Modeling and Research Subcommittee Members from C. App, Modeling Coordinator, Environmental Protection Agency, Region III, Chesapeake Bay Liaison Office re: Proposed Research Needs. 1986. Annapolis, Maryland. August 28, 1986. 3 pages.

69. Personal comunication. Letter to Charles S. Spooner, Director, Chesapeake Bay Liaison Office, from William M. Eichbaum, Director, Maryland Office of Environmental Programs, transmitting Research Needs for Chesapeake Bay. Maryland Department of Health & Mental Hygiene, Office of Environmental Programs. Baltimore, Maryland. February 2, 1987. 19 pages.

70. Technical Activities Matrix: A summary of Current Research Activities in the Chesapeake Bay Region Addressing Research and Management Questions Related to Nutrients, Toxicants, Land Use and Living Resources. (data file) Environmental Protection Agency, Region III, Chesapeake Bay Liaison Office. Annapolis, Maryland. 1985. 15 pages.

71. Technical Information and Research Needs to Support a National Estuarine Research Strategy. Final Report to EPA, Office of Marine and Estuarine Protection. V. Bierman. Prepared by Charles A. Menzie and Associates for Batelle, Washington Environmental Program Office. Washington, D.C. 1986. 76 pages.

72. National Research Priorities. National Oceanic & Atmospheric Administration, Marine and Estuarine Management Division, U. S. Department of Commerce. Washington, D.C. 1987. 5 pages.

73. Strategy for Marine Toxicological and Ecological Research Including Near Coastal Waters. Prepared by Environmental Research Laboratories (Narragansett, Rhode Island and Newport, Oregon), Office of Environmental Processes and Effects Research, Office of Research and Development, U.S. Environmental Protection Agency. 1987. 43 pages.