MANAGEMENT OF NUTRIENTS AND ORGANIC ENRICHMENT

PROBLEMS

Potential damage to living marine resources caused by low dissolved oxygen and other eutrophic effects

Noxious water quality conditions

Novel algal blooms

SOURCES

Nitrogen is the limiting nutrient in the Harbor/Bight system; significant sources of nitrogen include:

- Municipal discharges
- Tributary inputs
- Sediment flux
- Atmospheric deposition

Other Contributing Sources Include:

- Combined sewer overflows
- Storm water
- Other non-point sources

VISION *To establish and maintain a healthy and productive Harbor/Bight ecosystem with full beneficial uses.*

GOALS *To eliminate adverse impacts of eutrophication, including hypoxia, resulting from human activities.*

To better understand the causes of eutrophication and its symptoms including hypoxia, algal blooms, and changes in the abundance and diversity of marine organisms.

OBJECTIVES

N-1 Upgrade municipal sewage treatment plants to achieve full secondary treatment.

N-2 Establish environmental objectives for the Harbor/Bight.

N-3 Develop and implement, as appropriate, low-cost nitrogen reduction actions.

N-4 Develop and implement additional actions necessary to eliminate adverse effects of eutrophication, including hypoxia, on marine life in the Harbor, Bight, and Long Island Sound.

N-5 Conduct additional studies to understand the causes of hypoxia, algal blooms, and other eutrophication effects.

THE PROBLEMS

Overview

Eutrophication, or the excessive enrichment of a waterbody by nutrients and organic materials, is a problem in the Harbor/Bight and Long Island Sound. The most tangible symptoms of eutrophication in the Harbor/Bight and Sound are low dissolved oxygen (DO), noxious water quality conditions, and novel algal blooms. Eutrophication may occur naturally or as a result of human activity.

These symptoms often result directly in use impairments. However, eutrophication may have other adverse effects on marine ecosystems which, although closely related to the effects noted above, are more subtle or difficult to identify. For example, changes in the forms or concentrations of nutrients may result in changes in the species composition and diversity of phytoplankton. These changes may affect higher trophic levels, potentially leading to an altered ecosystem.

Identifying these changes and understanding their causes is difficult because of the confounding effects of natural variability in the abundance and composition of marine organisms, and other stressors, such as toxics.

To ensure we meet our goal to eliminate all adverse effects of eutrophication, the Plan includes development of several environmental objectives for eutrophication effects. These objectives will help us determine what actions are necessary and monitor the effectiveness of the actions taken to control nitrogen and organic loadings. The Plan also includes efforts to better understand the effects of eutrophication in the Harbor, Bight, and Sound.

Low Dissolved Oxygen

Low DO concentrations, called hypoxia, often occur in the bottom waters of portions of the New York-New Jersey Harbor, the Bight, and western Long Island Sound during the summer months.

The ecological effects of hypoxia are severe. DO concentrations of 5 mg/l and above are generally believed to be protective of marine life. As concentrations fall below that level, mobile organisms, such as fish, begin to leave the affected area; less mobile organisms can become stressed and may die. At DO concentrations of 3 mg/l and below, effects become progressively more severe. For example, at DO concentrations of 1.5 to 3 mg/l, many organisms leave or die within days to weeks; virtually all organisms die when concentrations below 1.5 mg/l persist for a few days or more.

New York and New Jersey water quality standards for DO range from not less than 3 mg/l, to support fish survival, to not less than 5 mg/l in waters with higher designated uses.

Over the last nine years, the Long Island Sound Study (LISS) has documented extensive areas of severely depressed DO concentrations. During the summer of 1987, 63 percent of the Sound's bottom waters experienced DO levels less than 5 mg/l, and 40 percent of these waters had DO levels less than 3 mg/l. Severe hypoxia also occurred during several subsequent summers, although conditions were not as bad as 1987 (see Figure 10).

Analyses of NYCDEP New York Harbor Water Quality Survey data from 1986-1992 indicate violations of the New York DO standards throughout the Harbor. During each summer from 1986-1991, bottom water DO concentrations lower than the standard were recorded at least once at roughly 80 percent of the 52 stations sampled. Compliance was significantly better in 1992, when violations were recorded at least once at only 50 percent of the sampled stations.

Chronic violations (i.e., mean summer bottom water DO concentration below the standard) were also common, except in 1992, when no chronic violations were found.

Long-term trend analyses reveal that water quality in some areas of the Harbor is improving, while other areas are experiencing a decline in DO concentrations. Over the last 15 years, there have been significant improvements in mean summer DO concentrations in bottom waters in portions of the Harlem River, Kill Van Kull, Arthur Kill, and Upper Bay. However, mean summer DO concentrations in bottom waters have significantly decreased in western Long Island Sound, parts of Jamaica Bay, the lower portion of the Arthur Kill, and the Lower Bay. The general trend over this period of time is improvement in the highly polluted waterways and inner Harbor areas and declines in the relatively cleaner bays and outer reaches of the Harbor. HEP efforts (e.g., see Actions N-4.1 and N-5.1 below) aim to help explain why this trend has occurred.

Figure 10. Areas of Long Island Sound with Minimum Bottom Water Dissolved Oxygen Levels below 5 mg/l in the Summers of 1987, 1989, and 1991

Dissolved oxygen levels in parts of Jamaica Bay are among the lowest in the Harbor (see Figure 11 below); for example, in summer 1993, several tributaries experienced minimum DO concentrations less than 1.5 mg/l. In addition, the Grassy Bay area experienced minimum DO concentrations less than 3.0 mg/l. The DO problem in Jamaica Bay has led NYSDEC and NYCDEP to implement low-cost nitrogen reductions for New York City's sewage treatment plants discharging to the Bay (see Action N-3.4 below). Raritan Bay has also experienced hypoxia, and other eutrophication-related effects, as shown in Figure 12 below.

Areas of the Bight routinely experience hypoxia during the summer, and the Bight has also experienced severe hypoxic conditions. Conditions are generally worse along the New Jersey coast and along the Long Island coast west of Fire Island Inlet. An analysis of data from 1977-1985 (see Figure 13 below) shows summer minimum DO concentrations less than 3 mg/l primarily inshore of the 20 meter depth contour in the Bight Apex. DO levels less than 1.5 mg/l regularly occur along the New Jersey coast inshore of the 20 meter depth contour.

A particularly severe and widespread anoxic (lack of DO) event occurred in the summer of 1976 in the Bight. The collapse of a massive bloom of the dinoflagellate C*eratium tripos* resulted in anoxia over an 8,600 km^2 area off New Jersey and mass mortalities of shellfish. This appears to have been an isolated occurrence which is attributed to a coincidence of meteorological and oceanographic conditions.

Recent reports of the USEPA Bight Monitoring Program have noted a general trend of improving water quality since 1985. Bottom DO levels in the Bight in recent summers (1992 and 1993) were generally good. Levels below 3 mg/l were recorded infrequently and persisted for only a short time. In contrast, water quality was particularly poor in the mid to late summer of 1985. During this period approximately 1,600 mi^2 of ocean bottom off the New Jersey coast experienced DO concentrations below 4 mg/l. The summer of 1990 was also a period of relatively poor water quality, although low DO was not as widespread or persistent as the summer of 1985.

It is important to note, however, that DO levels in the Bight, since 1985, may not reflect an actual trend of improving water quality, but may instead be due to interannual variability. This interannual variation is partially attributable to the prevalence of storm activity which mixes the water column, promoting aeration of bottom waters. Other investigators have seen no clear trend in DO levels in the Bight over the last 40 years or so.

Field studies have confirmed hypoxic impacts in Long Island Sound. Although effects are less well documented in the Harbor and Bight Apex, summer DO levels are low enough to harm sensitive organisms, as documented, for example, by NJDEP data from Raritan and Sandy Hook Bays.

Noxious Water Quality Conditions

Throughout the Harbor region, water quality has historically been poorest in the inner Harbor areas and tributaries, in particular those with restricted circulation. These areas commonly experience anoxia or severe hypoxia during the summer months. Noxious water quality conditions, such as odors and localized fish kills, are one result.

Novel Algal Blooms

Some algal blooms which have occurred in the New York-New Jersey Harbor region are unusual in terms of the type(s) of phytoplankton present, the persistence of the bloom over long periods of time, the vast area affected, and/or the high concentration of algal cells. These blooms are called novel algal blooms and they can have a variety of effects:

1) They can discolor the water and cause foaming, or release noxious odors.
2) They can release toxic substances which affect marine life.
3) They can block sunlight through the water. For example, the "brown tides" that occurred in Peconic Bay and bays on Long Island's south shore in the 1980s and 1990s, caused by a previously uncommon algal species, *Aureococcus anophagefferens,* blocked

Figure 11. Minimum Bottom Water Dissolved Oxygen Concentrations in Jamaica Bay, 1993

Figure 12. Eutrophication-related effects in Raritan Bay, 1988-1989
Contours showing distribution of surface chlorophyll *a* ($\mu g\ l^{-1}$) [a measure of algal bloom concentration] in the Raritan Bay on June 30, 1989, during the phytoflagellate red tide of June 26 - July 2. Black dots and shading indicate areas of bottom hypoxia (dot $\leq$2mg l^{-1}; shading $\leq$4mg l^{-1}) one to three weeks following the bloom. Black area delineates the portion of shoreline where dead fish were found in summer of 1988.

Figure 13. Minimum Bottom Water Dissolved Oxygen Concentrations (mg/l) in the Bight, July-September, 1977-1985

sunlight through the water, resulting in reduced eel grass beds.

4) These brown tides also decimated bay scallop populations, in part because the eel grass beds provide spawning habitat for the scallop, and also because *A. anophagefferens* is indigestible to the scallop.

5) The bloom that caused the Bight anoxia of 1976 had particularly widespread and severe impacts, as noted above.

Algal blooms, and in particular novel blooms where the composition of phytoplankton species deviates from "normal", may provide an indication of the adverse effects of pollution. As noted previously, subtle changes in phytoplankton may lead to or provide an indication of changes in ecosystem function. Such changes have not been documented in the Harbor/Bight, and are, in general, poorly documented in marine systems. HEP's Plan includes efforts to better document any changes in the Harbor/Bight.

Trends in the incidence of novel blooms in the New York-New Jersey Harbor region, since the 1950s, are not clear due to the lack of regular quantitative measurement of phytoplankton communities. However, anecdotal evidence indicates that blooms occur frequently. During the summer of 1992 and 1993, extensive phytoplankton blooms occurred in the intracoastal bays of New Jersey. Red algal blooms were predominant in Raritan and Sandy Hook Bays. In 1992, an isolated area in Stone Harbor, New Jersey, was affected by the same organism, the dinoflagellate *Gyrodinium aureolum,* that caused widespread green tides along the southern New Jersey coast in 1984 and 1985. The 1992 bloom only persisted for a short time.

SOURCES CONTRIBUTING TO THE PROBLEMS

Low Dissolved Oxygen

There is strong evidence that excessive discharges of nitrogen from both point and non-point sources are contributing to low DO in the Harbor, Bight, and Sound.

Excessive enrichment of waters by nutrients and organic materials can cause low DO concentrations. Waterbodies, and bottom waters in particular, are most prone to hypoxia during the summer because the vertical mixing of water, which replenishes oxygen in bottom waters, is restricted during that season. Nutrients, including nitrogen, fuel the growth of planktonic algae. As the algae die, they sink to the bottom and decompose, consuming additional oxygen.

The LISS has developed a mathematical model, called LIS 2.0, which establishes that 1) nitrogen is the nutrient that limits phytoplankton growth in the Sound, 2) hypoxia in the Sound is caused by excessive discharges of nitrogen directly to the Sound, and 3) the problem in the Sound is exacerbated by both point and non-point discharges of nitrogen in the Harbor. The LISS CCMP summarizes the current knowledge of the hypoxia problem in the Sound.

In most of the Harbor, the causes of low DO are not as clear. There is evidence, however, that both nitrogen and organic materials (i.e., carbon compounds) have a role. HEP studies show that temperature, organic carbon, and ammonia (a nitrogenous compound) are the dominant factors related to DO concentrations in the bottom waters of the Harbor. In virtually all of the data sets examined, inverse relationships were observed between temperature, nutrients, and carbon versus DO levels. In Jamaica Bay, studies show that nitrogen is the limiting nutrient.

A preliminary modeling analysis, conducted by HydroQual Inc. for the Bight Restoration Plan, indicates that nitrogen is the limiting nutrient in the Bight Apex off the New Jersey coast and that the nitrogen flux to the Bight from the Harbor (which includes the movement of water masses from the Harbor to the Bight, called the "Hudson River Plume") causes increased algal production and decreased bottom water DO concentrations in the Bight Apex. However, the analysis is not sufficient to quantify the relative significance of the nitrogen flux from the Harbor versus other sources of nitrogen in causing the hypoxia.

Figure 14. Distribution of the Nitrogen Load to Long Island Sound among Several Source Categories

The sources of nitrogen to Long Island Sound are well documented. Of the 93,600 tons per year, approximately 43 percent is from natural sources and not subject to reductions by management activity (see Figure 14). The remaining 57 percent is associated with human activities and has the potential to be reduced through management actions. Of this load, approximately 20 percent enters the Sound through its boundaries -- the East River in the west and The Race in the east; efforts to reduce the substantial western load are addressed in HEP's Plan. Most of the remaining human-caused load of nitrogen comes from coastal and tributary point (55%) and non-point source (16%) discharges in the Sound's drainage basin and are the subject of the LISS CCMP.

It is clear that municipal point sources are the dominant sources of nitrogen entering the Harbor. HEP studies estimate that municipal STPs contribute approximately 63 percent of the total nitrogen load to the Harbor. Tributary inputs are estimated to contribute approximately 29 percent of the total nitrogen load, while all other sources contribute the remaining 8 percent of the load.[1]

Estimates of total nitrogen loadings to the Bight Apex, prepared for the Bight Restoration Plan, indicate that coastal advective flux (i.e., transport of nitrogen from offshore waters by prevailing coastal currents), which is primarily not human-caused, is the dominant source of nitrogen to the Bight Apex, contributing an estimated 69 percent of the load. (Note: this is a rough estimate). Flux from the New York - New Jersey Harbor (22%) is the dominant source of nitrogen to the Bight Apex, which is primarily human-caused. Other sources of nitrogen estimated include sediment flux (5%); dredged material disposal (2%); atmospheric deposition (1%); and loads from the New Jersey and Long Island coastal zones, including municipal discharges and runoff (1%). It should be noted that some of these sources of loadings may be more significant when viewed on a localized scale.

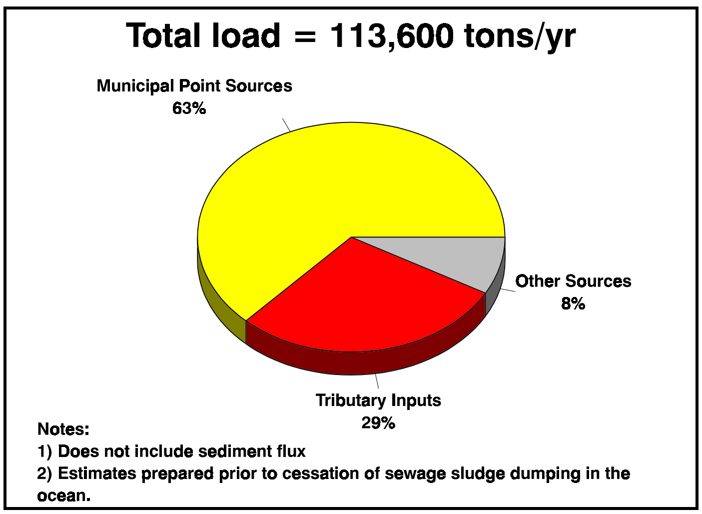

Figure 15. Nitrogen Loadings to New York- New Jersey Harbor

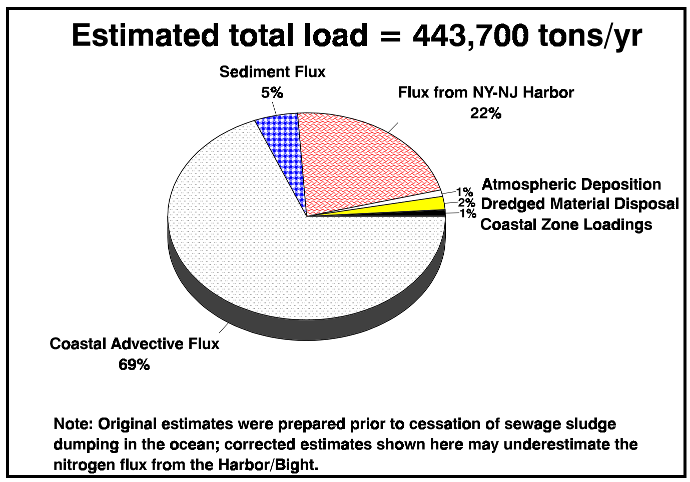

Figure 16. Nitrogen Loadings to Bight Apex

[1] The relative significance of direct groundwater flows in nitrogen contributions to the Harbor and Bight is estimated to be minor. Groundwater influences, to the extent they are significant, are inherently included in tributary flows and loadings developed for the Harbor and Bight. Direct groundwater flow to the Harbor and Bight, in addition to the groundwater flow in the tributaries, is estimated to comprise roughly 1% or less of the total flow to the Harbor and Bight.

These estimates of nitrogen loads were developed prior to implementation of the Ocean Dumping Ban Act (ODBA), which required STPs in the Harbor region to implement land-based disposal alternatives to the dumping of sewage sludge in the Atlantic Ocean. To comply with this requirement, STPs are first dewatering the sludge, which produces a nitrogen-rich centrate. This centrate is being returned to the STPs and discharged into the Harbor. USEPA estimates that such areas as Raritan Bay, Newark Bay, and the Hackensack River are experiencing increases in ambient total nitrogen levels as high as 6.7 percent due to ODBA dewatering operations.

Studies to date point to the need to develop a comprehensive system-wide eutrophication model (SWEM) for the Harbor/Bight/Sound system to predict load reductions necessary system-wide to alleviate hypoxia problems. The LISS has recommended that HEP develop such a model.

An interim step, currently proceeding under HEP, is New York City's development of a Harbor-wide Eutrophication Model (HEM), which will be used to establish the factors causing hypoxia in the Harbor and the relative significance of various sources of nitrogen in causing hypoxia in the Harbor/Bight.

Noxious Water Quality Conditions

Noxious water quality conditions in tributaries and inner Harbor areas may be caused by the decomposition of organic materials present in CSO discharges or may be associated with localized severe eutrophic conditions and poor flushing conditions. The latter is sometimes observed in tributaries without significant CSO discharges.

Novel Algal Blooms

The causes of algal blooms are only generally understood and often may not be related to macro-nutrients, such as nitrogen. Multiple environmental variables appear to contribute to any single bloom. These include winds, rainfall, nutrients, water stratification, and decreased zooplankton grazing. For example, a leading theory attributes the Peconic Bay brown tides to unusual hydrodynamic conditions combined with the presence of micro-nutrients, such as iron. With adequate environmental data, mathematical models can predict the effects of algal processes on hypoxia; however, understanding other adverse effects of algal blooms will require additional research. Investigators have observed that the increased incidence of novel blooms in the Bight Apex off the New Jersey coast is associated with the Hudson River plume.

THE PLAN TO SOLVE THE PROBLEMS

Overview of the Plan

To solve the problems related to nutrient and organic enrichment, HEP recommends the following actions:

- ♦ Complete upgrades of municipal discharges to secondary treatment.
- ♦ Develop a comprehensive program to control nitrogen loadings to the Harbor/Bight.
  - -- Establish environmental objectives including DO targets.
  - -- Develop and implement, as appropriate, low-cost actions to reduce nitrogen loads.
  - -- Develop and implement additional actions as necessary to eliminate the adverse effects of eutrophication, including hypoxia.
- ♦ Control rainfall-induced discharges of organic materials.
- ♦ Develop and conduct additional studies to better understand and manage the problems related to nutrient and organic enrichment.

COMMITMENTS AND RECOMMENDATIONS

Complete Upgrades of Municipal Discharges to Secondary Treatment

Ongoing STP upgrades are expected to continue improving water quality in the Harbor/Bight, by significantly reducing loads of nutrients and organic materials. There are 43 municipal STPs discharging to the Harbor core area and approximately 21 STPs discharging to the Bight, including the back bays.

The Clean Water Act requires all municipal STPs to achieve full secondary treatment. Most municipal

STPs discharging to the Harbor, and all those discharging to the Bight, already meet this requirement. The Owls Head Facility in New York has recently been upgraded, and a commitment is in place for the one remaining facility that does not meet full secondary treatment.

OBJECTIVE N-1 Upgrade municipal sewage treatment plants to achieve full secondary treatment

ACTION N-1.1
Newtown Creek Facility
NYCDEP will upgrade the Newtown Creek facility to full secondary treatment.

ACTION N-1.2
Owls Head Facility
NYCDEP upgraded the Owls Head facility to full secondary treatment in May 1995.

Control Nitrogen Loadings to the Harbor/Bight

The LISS is implementing a phased management approach for dealing with the hypoxia problem in the Sound. The first phase, currently being implemented in New York City, is to freeze nitrogen loadings to the East River from municipal point sources at levels prior to sludge dewatering (i.e., 1990 levels). This step, with similar point source freezes by New York State and Connecticut to waters contributing to Long Island Sound, is expected to prevent hypoxia problems in the Sound from becoming worse. The second phase, detailed in the LISS CCMP, includes significant, low-cost nitrogen reductions at sewage treatment plants, including biological nutrient removal (BNR) retrofits, that begin the process of reducing the severity and extent of hypoxia in the Sound. The third phase will establish nitrogen reduction targets to reduce known lethal and sublethal effects of hypoxia on the Sound's biota and will lay out the approach for meeting these nitrogen reduction targets. The details of the third phase are being developed using the results of a sophisticated water quality model, called LIS 3.0, recently completed.

OBJECTIVE N-2 Establish environmental objectives for the Harbor/Bight

HEP will use various environmental objectives to help determine the actions necessary, and measure the success of actions taken, to solve the eutrophication problems. In developing such objectives, we will gain a better understanding of the ecological significance of the various symptoms of eutrophication.

ACTION N-2.1
Dissolved Oxygen Targets
In parallel with the development of a program to reduce nitrogen loadings, as supported by the Harbor-wide Eutrophication Model (HEM), HEP will develop specific numeric DO targets for the Harbor/Bight, compatible with HEP's goal to eliminate the adverse effects of hypoxia resulting from human activities. HEP's effort will build upon LISS efforts to develop area specific DO targets and USEPA's efforts to develop DO criteria for marine waters.

ACTION N-2.2
Other Ecosystem Objectives for Eutrophication
In parallel with the development of a program to reduce nitrogen loadings, as supported by HEM, HEP will develop specific ecosystem objectives for eutrophication in the form of quantitative indicators and/or indices. These will provide managers with more refined tools by which to determine ecosystem change, providing feedback for adaptive management. In particular, HEP will consider objectives related to phytoplankton and algal community structure, biomass, and growth rates, as well as incidence of novel algal blooms. The objectives will be compatible with HEP's goal to eliminate the adverse effects of eutrophication resulting from human activities. The effort will build upon HEP's ongoing work to document novel algal blooms (see Objective N-5).

(Note: The efforts described in Actions N-2.1 and N-2.2 will proceed in parallel with development of SWEM (see Action N-4.1 below), if HEM results do not support the need for low-cost nitrogen reduction actions).

OBJECTIVE N-3 Develop and implement, as appropriate, low-cost nitrogen reduction actions

ACTION N-3.1
Harbor-wide Eutrophication Model (HEM)

-- NYCDEP is developing HEM as a preliminary tool to determine the feasibility and effectiveness of management alternatives for New York City point source discharges of nitrogen in the Harbor. If feasible options are found, New York City will use a System-wide Eutrophication Model to fully evaluate management alternatives (see Action N-4.1 below).

-- NYCDEP is committed to completing HEM under the auspices of HEP, with HEP support for data collection, to ensure that HEM meets HEP's needs for a tool to evaluate the necessity of preliminary nitrogen load reductions Harbor-wide.

ACTION N-3.2
Nitrogen Reduction Feasibility Studies and Data Collection
Municipal dischargers to the Harbor core area will conduct studies to identify options and costs for nitrogen reduction and collect data to quantify nitrogen loadings, as necessary, based on the results of HEM.

-- NYCDEP has evaluated low-cost process controls and has conducted additional feasibility studies for nitrogen control and pilot-scale implementation.

-- WCDEF and NJ dischargers should conduct feasibility studies for low-cost nitrogen reduction actions and collect loadings data if HEM supports the need to implement low-cost reduction actions.

(Note: Nitrogen reduction feasibility studies for additional nitrogen reductions may be necessary in parallel with SWEM).

ACTION N-3.3
LIS Nitrogen Load Reduction
New York City, under the LISS CCMP, is committed to implementing specific low-cost actions to reduce nitrogen loads from STPs in the Harbor which discharge in close proximity to the Sound. New York City will reduce its aggregate annual nitrogen load from six STPs by 25 percent (approximately 6,500 tons/year). The reductions are being accomplished by low-cost retrofits and/or operational changes at five STPs (completed); centrate treatment, or equivalent, at either the Hunts Point or Wards Island STP (by 2000); and installation of step denitrification at the Newtown Creek STP (by 2007), as part of the upgrade to full secondary treatment and expansion of the facility. Note that, under LISS interim actions, NYSDEC and New York City have reached full agreement on STP permit limits which freeze nitrogen loads (i.e., no net increase in load) from the four NYC STPs discharging to, or in close proximity to, the Sound at 1990 levels. Permits to implement the "no net increase" are final; the effective date is January 1, 1997.

ACTION N-3.4
Jamaica Bay Nitrogen Reduction
Consistent with the January 28, 1994, decision of the NYSDEC Commissioner, New York City will implement low-cost nitrogen reductions for STPs discharging to Jamaica Bay. New York City will reduce its aggregate annual nitrogen load from four STPs by approximately 500 tons/year. The actions will be achieved by the end of 1996.

ACTION N-3.5
Additional Low-cost Nitrogen Reduction
NYSDEC and NJDEP will seek commitments from STPs discharging to the Harbor/Bight to implement additional low-cost nitrogen reductions, such as process modifications and BNR retrofits, as supported by HEM.

Upon completion of HEM, nitrogen reduction feasibility studies, and associated monitoring and research, NYSDEC, NJDEP, and dischargers as appropriate, in consultation with HEP, will define the nitrogen reductions to be implemented and prepare a plan to implement them, as appropriate. The states and dischargers, in consultation with HEP, will also define any further research, monitoring, modeling, or studies needed to help attain HEP's goals related to nutrients and organic enrichment.

ACTION N-3.6
Pilot Projects for Nitrogen Reduction
In parallel with a program to reduce nitrogen loadings, as supported by HEM, HEP will develop and seek funding for a program of pilot studies to demonstrate innovative nitrogen reduction techniques in the Harbor, including wetlands restoration. (Note: This action will proceed in parallel with development of SWEM (see Action N-4.1 below) if HEM results do not support the need for low-cost nitrogen reduction actions).

-- The section of the CCMP on Habitat and Living Resources includes several actions for ongoing or planned habitat restoration efforts (e.g., see Actions H-12.3, H-12.4, and H-12.5). These may provide an opportunity to develop pilot projects for nitrogen reduction. HEP will work to ensure such opportunities are explored and implemented.

OBJECTIVE N-4 Develop and implement additional actions necessary to eliminate adverse effects of eutrophication, including hypoxia, on marine life in the Harbor, Bight, and Long Island Sound

ACTION N-4.1
System-wide Eutrophication Model
Develop a comprehensive system-wide eutrophication model to identify actions necessary to eliminate the adverse impacts of hypoxia and other eutrophic effects.

-- NYCDEP has initiated the development of SWEM in parallel with the Harbor-wide Eutrophication Model and with HEP oversight. New York City is developing SWEM to evaluate its options as part of facility planning for the Newtown Creek STP. However, New York City's effort will substantially, though not completely, meet HEP's need for a tool to identify the actions necessary to eliminate the adverse effects of hypoxia and other eutrophic effects, system-wide.

-- HEP is working to ensure that SWEM fully meets HEP's needs. An initial evaluation by HEP's Modeling Evaluation Group (MEG) indicates the need to address model kinetics (e.g., zooplankton), and to ensure adequate data collection to support model calibration (e.g., for tributary loads, atmospheric inputs, and algal species enumerations). In particular, MEG identified a shortfall in data on ambient levels and loadings of nitrogen, and related parameters, in the New Jersey areas of the Harbor/Bight.

- New York City is addressing these concerns with the exception of data collection for the New Jersey areas of the Harbor/Bight.
- The New Jersey Harbor Dischargers Group (NJHDG), composed of the 11 New Jersey municipal sewerage authorities in the Harbor core area, is collecting the data in the New Jersey areas of the Harbor/Bight.

-- If NYCDEP decides not to complete SWEM, HEP will evaluate options to achieve its goals, including completing SWEM. This will include identifying suitable sponsors, such as USACE, and/or funding.

--HEP recommends that USACE seek authorization and funding to conduct modeling and monitoring to address nutrients and organic enrichment in the Harbor/Bight, not tied to dredged material management.

--SWEM is HEP's primary vehicle to understand the relationships among nitrogen loadings, algal biomass, and dissolved oxygen in the Harbor, Bight, and Sound. However, HEP recognizes that SWEM will be insufficient to fully evaluate the steps necessary to meet HEP's goal to eliminate the adverse impacts of eutrophication resulting from human activities. For example, SWEM will not be suitable to predict the incidence and severity of novel algal blooms. HEP is therefore committed to developing and seeking funding for a program of research, in parallel with SWEM, to better understand and manage all the adverse impacts of eutrophication (see Objective N-5).

ACTION N-4.2
Further Nitrogen Reduction Actions
NYSDEC and NJDEP will require dischargers to implement nitrogen reductions to eliminate the adverse effects of hypoxia in the Harbor, Bight, and Sound, if there is adequate technical justification.

-- Upon completion of SWEM, and associated monitoring, research, and studies, NYSDEC and NJDEP, in consultation with HEP, NYCDEP, NJHDG, and other dischargers as appropriate, will define the additional nitrogen reductions to be required and prepare a plan to implement them, as appropriate. The states, in consultation with HEP and the dischargers, will also define any further research, monitoring, modeling, or studies needed to fully attain HEP's goal to eliminate the adverse impacts of eutrophication caused by human activities in the Harbor, Bight, and Sound.

Control Rainfall-Induced Discharges of Organic Material
The section on Rainfall-Induced Discharges below includes actions to control CSO and storm water discharges. This includes remediating noxious water quality conditions in inner Harbor areas and tributaries.

Develop and Conduct Additional Studies
HEP will work to understand and minimize the adverse effects of algal blooms and to better understand the causes and impacts of hypoxia. Actions to address nutrient-induced hypoxia are expected to reduce the adverse effects of algal blooms in general by reducing the nutrients limiting phytoplankton growth. The effect of these actions on the occurrence and severity of novel blooms is unknown. HEP is therefore conducting studies and will develop a research program to better understand the causes of algal blooms and their relationship to water quality factors, including hypoxia.

OBJECTIVE N-5 Conduct additional studies to understand the causes of hypoxia, algal blooms, and other eutrophic effects

ACTION N-5.1
Evaluation of Past Changes in Water Quality
HEP has computerized historical water quality data from NYCDEP's New York Harbor Water Quality Survey. NYCDEP will use these data to evaluate changes in water quality as a result of past management actions.

ACTION N-5.2
Historical Occurrences of Novel Algal Conditions
Using historical data, HEP is documenting the past occurrences of novel algal conditions and their relationship to water quality conditions.

ACTION N-5.3
"Normal" Phytoplankton Community Composition
HEP will, given sufficient funding, conduct a study to describe "normal" phytoplankton community composition for the Harbor/Bight area and document deviations from it.

ACTION N-5.4
Research on the Causes of Low Dissolved Oxygen
HEP will develop, and seek funding for, a program of basic research on the causes of low DO to complement SWEM. The program will build upon the ongoing HEP studies, described above.

ACTION N-5.5
Research on Causes and Dynamics of Algal Blooms
HEP will develop, and seek funding for, a program of basic research on the causes and dynamics of algal blooms. The program will build upon the ongoing HEP studies, described above.

COSTS OF IMPLEMENTING THIS PLAN

Many of the commitments and recommendations in the nutrients and organic enrichment component of the CCMP can be accomplished through the effective use of base program resources. In fact, full implementation of the CCMP relies, in large part, on continued operation, and funding at current levels, of existing programs to address nutrients and organic enrichment. The CCMP itemizes 10 new HEP-driven commitments to control nutrients and organic enrichment operating through base programs. These actions represent a major commitment to CCMP implementation.

The nutrients and organic enrichment component of the CCMP also includes 10 significant commitments and recommendations that entail enhanced program funding. As shown in Table 25(nc) below:

- ♦ The Plan includes 4 actions for which a total of $9.975 million has been committed by the responsible entities.
- ♦ The Plan includes 2 actions for which increased funding of $325,000 is recommended.
- ♦ The Plan includes 4 additional recommendations for action for which cost estimates will be developed during the continuing planning process.

This component of the CCMP also includes 7 actions that require or may require the expenditure of project implementation funds by responsible entities. As shown in Table 26(nc) below:

- ♦ The Plan includes 4 actions for which $132.5 million is being committed by New York City.
- ♦ The Plan includes 3 actions for which additional funds may be expended or be required to be expended by responsible entities, based on potential outcomes of several ongoing or planned HEP efforts. The costs of these actions to address nutrients and organic enrichment may be great. Cost estimates for these actions will be developed during the continuing planning process.

Table 25(nc). Enhanced Program Costs for Management of Nutrients and Organic Enrichment

ACTION	COMMITMENTS		RECOMMENDATIONS	
	Cost	Cost/Year	Cost	Cost/Year
ACTION N-3.1: Complete HEM.	$1.4 million			
ACTION N-3.2: Conduct nitrogen reduction feasibility studies.			$275,000+*	
ACTION N-4.1: Develop SWEM.	$8.44 million		*	
ACTION N-4.1: Conduct modeling (USACE) as necessary to supplement SWEM.			*	
ACTION N-5.1: Computerize NYC data; use to evaluate changes in water quality as a result of past management actions.	$88,000			
ACTION N-5.2: Document algal blooms.	$47,000			
ACTION N-5.3: Describe "normal" phytoplankton community.			$50,000	
ACTION N-5.4: Conduct research on low DO.			*	
ACTION N-5.5: Conduct research on phytoplankton blooms.			*	
TOTAL	$9,975,000		$325,000+*[1]	

* Enhanced program costs to be developed as part of the continuing planning process.
[1] Notation (+*) indicates cost plus additional costs to be determined.

Table 26(nc). Project Implementation Costs for Management of Nutrients and Organic Enrichment

ACTION	COMMITMENTS		RECOMMENDATIONS	
	Cost	Cost/Year	Cost	Cost/Year
ACTION N-3.2: Conduct NYC nitrogen reduction feasibility studies.	$5 million			
ACTION N-3.2: Conduct NYC nitrogen reduction pilots.	$10 million			
ACTION N-3.3: Implement NYC actions under LISS.	$102.5 million			
ACTION N-3.4: Implement NYC Jamaica Bay nitrogen reduction actions.	$15 million			
ACTION N-3.5: Implement additional low-cost nitrogen reduction actions, per HEM.			*	
ACTION N-3.6: Develop innovative nitrogen reduction pilot projects.			*	
ACTION N-4.2: Implement nitrogen reductions per SWEM.			*	
TOTAL	$132,500,000		*	

* Project implementation costs to be developed as part of the continuing planning process.

BENEFITS OF IMPLEMENTING THIS PLAN

♦ Completion of upgrades of municipal discharges to secondary treatment (Newtown Creek and Owls Head STPs) will result in improvements in DO in the areas near the affected discharges. (Note: Owls Head upgrade was recently completed).

♦ Implementation of low-cost actions to reduce nitrogen loads is expected to result in additional improvements in DO, thus reducing the adverse impacts of hypoxia. Under the LISS plan, New York City will achieve approximately 25 percent aggregate annual reductions in nitrogen loads from six STPs with implementation of low-cost controls. HEP hopes to achieve a similar percentage reduction with low-cost controls in the Harbor. However, these nitrogen reductions are not expected to be sufficient to achieve HEP's goal to eliminate the adverse impacts of eutrophication, including hypoxia, resulting from human activities. HEM will enable us to better predict the benefits of low-cost nitrogen reductions actions in reducing hypoxia.

♦ Additional nitrogen reduction actions based on SWEM would be intended to achieve HEP's goal for hypoxia throughout the Harbor, Bight, and Sound. These actions are also expected to reduce other adverse impacts of eutrophication.

♦ Actions to control rainfall-induced discharges of organic materials will eliminate violations of water quality standards due to these discharges.

♦ HEP's program of additional studies will help us to ensure that actions taken based on SWEM will have the benefits in reduced hypoxia predicted and will enable us to better address the other adverse impacts related to nutrient and organic enrichment.

Table 27(ns). Summary—Management of Nutrients and Organic Enrichment

ACTION	RESPONSIBLE ENTITY[1]	TARGET DATE	ESTIMATED COST	STATUS[2]
OBJECTIVE N-1: Upgrade municipal sewage treatment plants to achieve full secondary treatment.				
ACTION N-1.1 : Upgrade Newtown Creek facility to full secondary treatment.	NYCDEP	By Dec 31, 2007	Base program, core CWA requirement[3]	C/O
ACTION N-1.2: Upgrade Owls Head facility to full secondary treatment.	NYCDEP	Completed	Base program, core CWA requirement[3]	C/O
OBJECTIVE N-2: Establish environmental objectives for the Harbor/Bight.				
ACTION N-2.1: Develop specific numeric DO targets for the Harbor/Bight.	HEP	Dec 1996	Base program	C/N
ACTION N-2.2: Develop specific ecosystem objectives for eutrophication.	HEP	Dec 1996	Base program	C/N

Note: It is HEP's goal that all the recommendations in the CCMP become commitments.

-- In some cases CCMP actions are recommendations, not commitments, because responsible entities require resources to implement the action. HEP will advocate making these resources available.

-- In other cases, CCMP actions are recommendations because HEP has not obtained the commitment of regulated entities and other responsible entities to implement the action. By issuance of this final CCMP, HEP seeks the commitment of the responsible entities and requests that they step forward to voluntarily agree to implement the actions.

[1] Responsible entities may accomplish the actions directly or via contract or grant.

[2] C/O - An ongoing commitment, not driven by the HEP CCMP
C/N - A new commitment, driven by the HEP CCMP
R - Recommendation

[3] Table does not include costs of compliance with core elements of the Clean Water Act, specifically secondary treatment

(Continued)
Table 27(ns). Summary—Management of Nutrients and Organic Enrichment

ACTION	RESPONSIBLE ENTITY[1]	TARGET DATE	ESTIMATED COST	STATUS[2]
OBJECTIVE N-3: ***Develop and implement, as appropriate, low-cost nitrogen reduction actions.***				
ACTION N-3.1: Complete Harbor-wide Eutrophication Model.	NYCDEP with HEP & USEPA support for data collection	Completed	Enhanced program cost - NYC: $1 million; HEP/USEPA: $400,000	C/O
ACTION N-3.2: Conduct feasibility studies to identify options and costs for nitrogen reduction, and collect data to quantify nitrogen loadings for STPs discharging to the Harbor core area.				
-- Conduct feasibility studies for low-cost nitrogen reduction such as BNR retrofits and process modifications.	NYCDEP	Completed	Base program	C/O
-- Conduct additional feasibility studies for other nitrogen reduction options.	NYCDEP	Completed	Project implementation cost - $5 million	C/O
-- Conduct pilot-scale implementation of nitrogen reduction options.	NYCDEP	Completed	Project implementation cost - $10 million	C/O
-- Conduct feasibility studies as necessary based on the results of HEM.	WCDEF	Dec 1996	Enhanced program cost to be provided by WCDEF as necessary	R
-- Conduct feasibility studies as necessary based on the results of HEM.	New Jersey Harbor Dischargers Group (NJHDG)	Dec 1996	Enhanced program cost - $275,000	R

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R - Recommendation

(Continued)
Table 27(ns). Summary—Management of Nutrients and Organic Enrichment

ACTION	RESPONSIBLE ENTITY[1]	TARGET DATE	ESTIMATED COST	STATUS[2]
ACTION N-3.3: Under LISS CCMP, reduce aggregate annual nitrogen load from 6 STPs in NYC by 6,500 tons/year (Note: permit limits freezing the nitrogen loads from four of these STPs at levels prior to the de-watering of sludge are currently in force).	NYCDEP	5 actions completed; 1 action by Dec 31, 2000; Newtown Creek by Dec 31, 2007.	Project implementation cost - $102.5 million	C/O
ACTION N-3.4: Per recent NYSDEC decision, reduce aggregate annual nitrogen load from 4 STPs discharging to Jamaica Bay by 500 tons/year (Note: permit limits freezing the nitrogen loads from these STPs at levels prior to the de-watering of sludge are currently in force).	NYCDEP	Dec 1996	Project implementation cost - $15 million	C/O
ACTION N-3.5: Develop and implement additional low-cost nitrogen reductions such as process modifications and biological nutrient removal (BNR) retrofits, as supported by HEM.				
-- Upon completion of HEM, feasibility studies, and associated monitoring and research, define and develop an implementation plan for low-cost nitrogen reductions, as appropriate. This will include defining any additional research, monitoring, modeling, and studies necessary to help attain HEP's goals related to nutrients and organic enrichment.	NYSDEC, NJDEP, NYCDEP, NJHDG, WCDEF as appropriate, in consultation with HEP	Mar 1997	Base program	C/N
-- Seek commitments to implement reductions.	NYSDEC & NJDEP	Jun 1997	Base program	C/N

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C/N - A new commitment, driven by the HEP CCMP
R - Recommendation

(Continued)
Table 27(ns). Summary—Management of Nutrients and Organic Enrichment

ACTION	RESPONSIBLE ENTITY[1]	TARGET DATE	ESTIMATED COST	STATUS[2]
-- Implement.	NYCDEP, WCDEF, NJHDG as appropriate	Beginning Jun 1997	Project implementation cost to be provided by dischargers based on results of HEM and feasibility studies	R
ACTION N-3.6: Develop and seek funding for a program of pilot studies to demonstrate innovative nitrogen reduction techniques in the Harbor, including wetlands restoration.	HEP	Dec 1996	Base program	C/N
-- Implement program.	HEP, in concert with responsible agencies	Begin by Dec 1996	Project implementation cost to be developed based on above work program	R

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C/N - A new commitment, driven by the HEP CCMP
R - Recommendation

(Continued)

Table 27(ns). Summary—Management of Nutrients and Organic Enrichment

ACTION	RESPONSIBLE ENTITY[1]	TARGET DATE	ESTIMATED COST	STATUS[2]
OBJECTIVE N-4: Develop and implement additional actions necessary to eliminate adverse effects of eutrophication, including hypoxia, on marine life in the Harbor, Bight, and Sound.				
ACTION N-4.1: Develop a comprehensive system-wide eutrophication model (SWEM) to identify actions necessary to eliminate adverse effects of hypoxia and other eutrophic effects on marine life in the Harbor, Bight, and Sound.				
-- Develop SWEM to meet NYC facility planning needs, and also substantially, though not completely, meet HEP's needs.	NYCDEP*	Dec 1997	Enhanced program cost - $8 million	C/O*
-- Collect data necessary for model calibration for NJ areas of the Harbor/Bight, to ensure NYC's effort to develop SWEM fully meets HEP's needs.	NJHDG	Ongoing	$442,000	C/N
-- Seek authorization and funding to conduct modeling and monitoring to address nutrients and organic enrichment in the Harbor/Bight, not tied to dredged material management.	USACE	Ongoing	Base program	C/N
-- Supplement NYC modeling effort as necessary.	USACE under the auspices of HEP	Target date to be developed as necessary	Enhanced program cost estimate to be determined based on need to supplement NYC modeling effort	R

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[2] C/O - An ongoing commitment, not driven by the HEP CCMP
C/N - A new commitment, driven by the HEP CCMP
R - Recommendation

* NOTE: NYCDEP has initiated development of SWEM in parallel with HEM, under the auspices of HEP. If NYCDEP chooses not to complete SWEM, HEP will evaluate options to meet its goals including completion of SWEM.

(Continued)

Table 27(ns). Summary—Management of Nutrients and Organic Enrichment

ACTION	RESPONSIBLE ENTITY[1]	TARGET DATE	ESTIMATED COST	STATUS[2]
ACTION N-4.2: Require dischargers to implement additional nitrogen reductions to eliminate the adverse effects of hypoxia in the Harbor, Bight, and Sound if there is adequate technical justification.				
-- Upon completion of SWEM and associated monitoring, research, and studies, define and develop an implementation plan for additional nitrogen reductions to be required, as appropriate. This will include defining any additional research, monitoring, modeling, or studies necessary to fully attain HEP's goal to eliminate the adverse impacts of eutrophication caused by human activities in the Harbor, Bight, and Sound.*	NYSDEC & NJDEP, in consultation with HEP and dischargers as appropriate	By Dec 31, 1998	Base program	C/N
-- Modify permits as necessary.	NYSDEC & NJDEP	By Dec 31, 2000	Base program	C/N
-- Comply.	NYCDEP, WCDEF, NJHDG and other dischargers, as appropriate	Begin by Dec 31, 2000	Project implementation cost to be developed by dischargers based on SWEM results and feasibility studies	R

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[2] C/O - An ongoing commitment, not driven by the HEP CCMP
C/N - A new commitment, driven by the HEP CCMP
R - Recommendation

* NOTE: NYCDEP has initiated development of SWEM in parallel with HEM, under the auspices of HEP. If NYCDEP chooses not to complete SWEM, HEP will evaluate options to meet its goals including completion of SWEM.

(Continued)

Table 27(ns). Summary—Management of Nutrients and Organic Enrichment

ACTION	RESPONSIBLE ENTITY[1]	TARGET DATE	ESTIMATED COST	STATUS[2]
OBJECTIVE N-5: Conduct additional studies to understand the causes of hypoxia, algal blooms, and other eutrophication effects.				
ACTION N-5.1: Computerize historical data from NY Harbor Water Quality survey.	HEP	Completed	Enhanced program cost - $28,000	C/N
-- Use the data to evaluate changes in water quality as a result of past management activities.	NYCDEP	May 1996	Enhanced program cost - $60,000	C/N
ACTION N-5.2: Document past occurrences of novel algal conditions.	HEP	Feb 1996	Enhanced program cost - $47,000	C/N
ACTION N-5.3: Describe "normal" phytoplankton community composition and document deviations from it.	HEP	Begin by Dec 31, 1996	$50,000	R
ACTION N-5.4: Conduct a program of basic research on the causes of low DO to complement SWEM.	HEP	Dec 1996	Enhanced program cost to be developed by HEP through work program (below)	R
-- Develop program and seek funding.	HEP	Jul 1996	Base program	C/N
ACTION N-5.5: Conduct program of basic research to better understand causes and dynamics of phytoplankton blooms.	HEP	Dec 1996	Enhanced program cost to be developed by HEP through work program (below)	R
-- Develop program and seek funding.	HEP	Jul 1996	Base program	C/N

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C/N - A new commitment, driven by the HEP CCMP
R - Recommendation