A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound

Prepared in Conformance
with Section 303(d) of the
Clean Water Act and the
Long Island Sound Study

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December 2000

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I. Introduction

## A.	Long Island Sound Study

The Long Island Sound Study (LISS) began in 1985 when Congress appropriated funds for the U.S. Environmental Protection Agency (EPA) to carry out a program to research, monitor, and assess the water quality of Long Island Sound in concert with the states of Connecticut and New York through the Connecticut Department of Environmental Protection (CTDEP) and the New York State Department of Environmental Conservation (NYSDEC), respectively. Pursuant to the Clean Water Act (CWA) Amendments in 1987, Section 320 of the Act established the National Estuary Program. At the request of the states of Connecticut and New York, Long Island Sound was officially designated an “Estuary of National Significance” under this program[1]. A Management Conference, consisting of federal, state, interstate and local agencies, universities, environmental groups, industry, and the public, was convened in March 1988 and charged with developing a Comprehensive Conservation and Management Plan (CCMP) to protect and improve the environmental quality of Long Island Sound while ensuring compatible human uses.

The CCMP[2], approved in 1994, focused on seven topics: (1) low dissolved oxygen (hypoxia), (2) toxic contamination, (3) pathogen contamination, (4) floatable debris, (5) the impact of these water quality problems, and habitat degradation and loss, on the health of living resources, (6) land use and development resulting in habitat loss and degradation of water quality, and (7) public involvement and education. The Management Conference has focused its efforts and resources on the most pressing problem among these, hypoxia (generally defined as levels of dissolved oxygen (DO) of 3 mg/l or less), which affects a substantial portion of Long Island Sound in late summer.

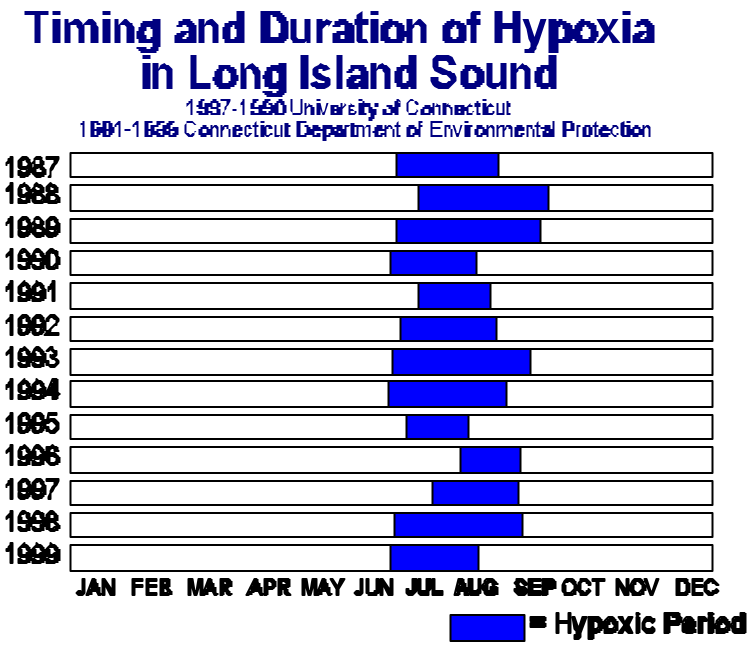

Figure 1.	**Timing and duration of hypoxia in Long Island Sound, 1987-1999.**

## B.	Hypoxia

Hypoxia is a common occurrence in Long Island Sound bottom waters during the late summer-usually from July through September[3] (**Figure 1**). It’s linked to an overabundance of nitrogen combined with the naturally occurring density stratification of the water column. While nitrogen is essential to a productive ecosystem, too much nitrogen fuels the excessive growth of algae. When the algae die, they sink to the bottom, where they are consumed by bacteria. The microbial decay of algae and the respiration of oxygen-breathing organisms use up the available oxygen in the lower water column and in the bottom sediments, gradually reducing the dissolved oxygen concentration to unhealthy levels. If the water column remains stratified for an extended period, and the amount of organic carbon (primarily from decaying algae) is high enough, oxygen may fall to hypoxic or even anoxic levels. Under these conditions, some organisms may suffocate and die, while others flee the hypoxic area. Dense algal blooms also can inhibit light penetration, preventing sufficient light from reaching the bottom in shallow areas to support the growth of submerged aquatic vegetation, an important habitat for shellfish and juvenile fish. Consequently, excessive nitrogen impairs the function and health of Long Island Sound. The LISS has estimated that the load of nitrogen delivered to Long Island Sound has more than doubled since pre-colonial times. Discharges from sewage treatment plants, atmospheric deposition, and runoff are the primary sources of nitrogen enrichment to Long Island Sound.

C. Requirements of Section 303(d)

Section 303(d)(1)(C) of the CWA and EPA's implementing regulations (40CFR Part 130) require states to identify those waterbodies that do not meet water quality standards after application of the technology-based effluent limitations required by the Act. New York and Connecticut have identified Long Island Sound as "water quality limited" due to hypoxia and a priority for developing a TMDL.

By definition, a TMDL specifies the allowable pollutant loading from all contributing sources (e.g., point sources, nonpoint sources, and natural background) that will attain the applicable water quality standards with seasonal variations and a margin of safety. The margin of safety takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. In essence, a TMDL defines the assimilative capacity of the waterbody to absorb a pollutant and still meet water quality standards.

D. Fulfillment of Section 303(d)

To address the hypoxia problem, the LISS has been proceeding with a phased approach to nitrogen reduction, allowing the program to move forward in stages as more information is obtained to support more aggressive steps.

The first formal action to address hypoxia took place in 1990 with the release of the *Status Report and Interim Actions for Hypoxia Management*[4]. The report announced a freeze on point and nonpoint nitrogen loadings to the Sound in key geographic areas at 1990 levels. This constitutes what is know as Phase I of the hypoxia management program.

Phase II, which was adopted in 1994 upon release of the CCMP, initiated actions to begin to reduce the load of nitrogen to the Sound through low-cost actions. This phase is being actively implemented in Connecticut and New York. These actions, while significant, will not restore the health of Long Island Sound. Therefore, the LISS made a commitment to identify a third phase of nitrogen controls to guide long-term management.

On February 5, 1998, the states of Connecticut and New York and the Environmental Protection Agency adopted a plan for *Phase III Actions for Hypoxia Management*[5], including nitrogen reduction targets of 58.5 percent for 11 "management zones" that comprise the Connecticut and New York portion of the Long Island Sound watershed. Action 3.A. under the plan is a commitment to administer and enforce the nitrogen targets through development of a Total Maximum Daily Load (TMDL) analysis consistent with requirements under section 303(d) of the Clean Water Act.

> *CTDEP and NYSDEC will work with EPA to develop, by July 1998, a TMDL necessary to meet the dissolved oxygen standards. NYSDEC and CTDEP will propose the TMDL in August 1998 and submit the TMDL, as appropriate, to EPA by December 1998 for approval. EPA will develop the TMDL if it is disapproved, as required by the CWA.*
>
> > *The TMDL will include point and nonpoint source controls in the New York and Connecticut portion of the watershed to meet the 58.5 percent reduction target.*
> >
> > *The TMDL will also include future actions and schedules beyond the 15-year Phase III plan for achieving water quality standards, such as the control of carbon and nitrogen from outside of the LISS management area, including point and nonpoint sources north of Connecticut in New England, atmospheric deposition, point and nonpoint sources affecting import from New York Harbor and The Race, and other alternatives, such as aeration and load relocation.*
> >
> > *The TMDL will include a provision for periodic review every five years and revision as appropriate.*

Action 3.B. scheduled completion of the Wasteload Allocation (WLA) and Load Allocation (LA) for one year after the release of the TMDL.

A preliminary draft of the TMDL was completed by July 1998, as scheduled. However, based on evolving national policy on TMDLs, EPA required the TMDL to identify how the total load allocation will be distributed between point and nonpoint sources (the WLA/LA). Compliance with this requirement delayed the release of the draft TMDL by the states of Connecticut and New York until November 1999. Many comments were received by the two states and compiled into responsiveness reports. Among the changes that have been incorporated into the TMDL is a listing of individual point source contributions of nitrogen and the final management goal for each source (the WLA). Because of the large number of point sources, the complexities of nitrogen delivery through the watershed, and the potential for nitrogen trading, a public WLA process was needed in Connecticut. That requirement was met in the fall of 2000, putting all the necessary components in place to finalize the TMDL.

While completion of the TMDL has been delayed from its original target date, the time frames for implementation remain the same.

II. Waterbody Location and Description

Long Island Sound lies in the midst of the highly urbanized and suburbanized northeast seaboard, one of the most densely populated regions in the nation. It is characterized by a chain of urban centers surrounding it. Included in that chain is New York City, the country's largest city.

The watershed of the Sound drains an area of more than 16,000 square miles (**Figure 2**). It encompasses virtually the entire state of Connecticut, portions of Massachusetts, New Hampshire, and Vermont, with a small area at the source of the Connecticut River in Canada. It also includes portions of New York City, and Westchester, Nassau, and Suffolk Counties in New York state. The study area for the LISS was defined as the Battery on Manhattan Island to the west and The Race to the east. Long Island Sound covers about 1,300 square miles, measuring more than 100 miles from east to west and about 21 miles wide at its widest point between New Haven, CT and Port Jefferson, NY. Mid-Sound depths range from 60 to 120 feet.

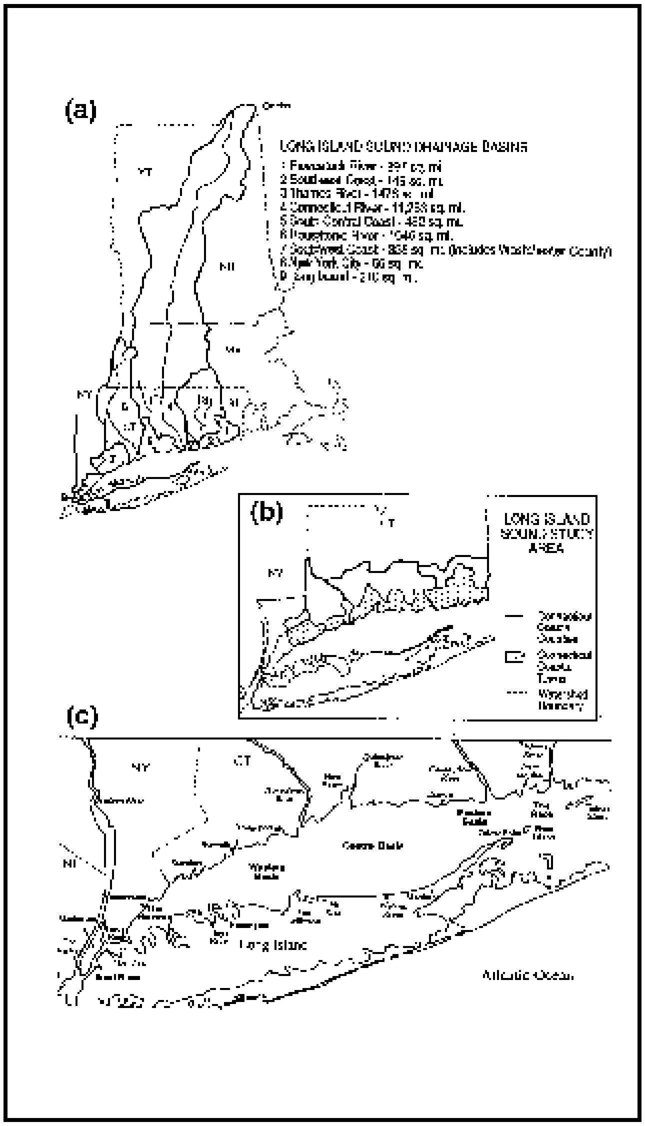

Figure 2. **Maps of (a) major drainage basins and tributaries of Long Island Sound; (b) the Long Island Sound Study area; (c) basins within Long Island Sound.**

Unlike a typical estuary, the Sound has no major direct source of fresh water at its head. Instead, the Sound has two marine inlets. Lower salinity waters enter the western Sound from the Upper Bay of New York Harbor through two tidal straits, the East River and the Harlem River. Higher salinity waters of the Atlantic Ocean enter at its eastern end, through Block Island Sound and The Race. The largest source of fresh water is the Connecticut River, discharging into the eastern Sound, which contributes about 70 percent of the more than six trillion gallons of fresh water discharged to the Sound by major tributaries each year. These unusual characteristics contribute to the Sound's complex circulation and mixing patterns. Furthermore, waters from outside the Sound's drainage basin that enter through its boundaries are significant sources of pollutants, underscoring the need for comprehensive regional management of those sources.

III. Applicable Water Quality Standards

A. Nutrient Enrichment

In Long Island Sound, nitrogen is the primary limiting nutrient for algal growth that leads to low DO levels and the subsequent loss of designated uses. Nitrogen's relationship to impaired designated uses is indirect and complex, with intermediate steps of algal blooms and decomposition, low DO, poor water clarity, inhibited plant growth, and ultimately marine organism stress. The relationship between nitrogen loading and ambient nitrogen concentration and DO conditions is highly complex, nonlinear, and typically requires calibrated and verified mathematical models to account for the controlling hydrologic, physical, chemical, and biological interactions.

EPA is developing guidance on deriving numeric nutrient water quality criteria for four basic types of waterbodies: lakes and reservoirs, rivers and streams, estuaries and coastal waters, and wetlands. EPA is also compiling an extensive national database of nutrient concentrations and associated response variables needed to derive criteria. EPA will use the national database to derive national recommended numeric nutrient water quality criteria for specific ecological regions, in accordance with the Agency's waterbody guidance, for total nitrogen concentration, total phosphorus concentration, and associated response variables (e.g., chlorophyll *a* concentrations and turbidity). EPA has not yet published recommended criteria for nitrogen in estuarine environments, nor have states established criteria for nitrogen in estuarine environments. Ongoing workgroup activities related to EPA's regional nutrient criteria development indicate that such criteria may need to be estuary-specific or at least estuary type-specific and may not be in the form of nutrient concentrations in the water column. Long Island Sound has long been recognized as a unique estuary. Potential candidates for criteria must be qualified by attention to tide cycles, density and salinity gradients, and currents.[6] (EPA Strategy for Nutrient Criteria 1998, p. 19).

Based on monitoring and modeling, the LISS has been determined that reducing nitrogen loads necessary to achieve the water quality standards for DO will protect and maintain designated uses in the Sound. While the TMDL for nitrogen is translated from DO standards, other eutrophication-related impairments resulting from the intermediate steps of algal blooms and decomposition, poor water clarity, inhibited submerged aquatic plant growth, and stress to marine organisms have been considered and would benefit from the proposed nitrogen reduction program.

B. New York

New York state's marine water classifications, designated best uses, and dissolved oxygen standards are contained in NYSCRR, Title 6, Chapter X, Parts 701 and 703.

<u>Saline Surface Waters - New York</u>

CLASS SA	The best uses of Class SA waters are shellfishing for market purposes, primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival. Dissolved oxygen shall not be less than 5.0 mg/l at any time.

CLASS SB The best uses of Class SB waters are primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival. Dissolved oxygen shall not be less than 5.0 mg/l at any time.

CLASS SC The best use of Class SC waters is fishing. These waters shall be suitable for fish propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes. Dissolved oxygen shall not be less than 5.0 mg/l at any time.

CLASS I The best uses of Class I waters are secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival. Dissolved oxygen shall not be less than 4.0 mg/l at any time.

CLASS SD The best use of class SD water is fishing. These waters shall be suitable for fish survival. Dissolved oxygen shall not be less than 3.0 mg/l at any time.

The spatial extent of the applicable water quality standards for the open waters of the East River and Long Island Sounds are as follows:

Water Class	Mile Point		Description
	From	To	
I	0.0	14.5	From Battery to Throgs Neck Bridge
SB	14.5	23.17	From Throgs Neck Bridge to Execution Rock
SA	23.17	144	From Execution Rock to Race

All the embayments in Nassau and Suffolk counties are classified as SA, whereas all the embayments in Westchester County are classified as SB. However, waters of Hempstead Harbor and Manhasset Bay are further classified into SB and SC, as applicable.

C. Connecticut

Connecticut's water quality standards set an overall policy for management of water quality in accordance with the directive of Section 22a-426 of the Connecticut General Statutes. Standards are published in CTDEP's *Water Quality Standards*[7] document and are updated periodically as required.

Coastal and Marine Surface Waters - Connecticut

CLASS SA Designated uses are for marine fish, shellfish and wildlife habitat, shellfish harvesting for direct human consumption, recreation, and all other legitimate uses including navigation. Dissolved oxygen not less than 6.0 mg/l at any time.

CLASS SB Designated uses are for marine fish, shellfish and wildlife habitat, shellfish harvesting for transfer to a depuration plant or relay (transplant) to approved areas for purification

	prior to human consumption, recreation, industrial and other legitimate uses including navigation. Dissolved oxygen not less than 5.0 mg/l at any time.
CLASS SC	May be suitable for fish, shellfish, and wildlife habitat, certain aquaculture operations, recreational uses, industrial and other legitimate uses including navigation. Present water quality conditions preclude full attainment of one or more designated uses some or all of the time. One or more water quality criteria are not being consistently achieved. Dissolved oxygen standard in accordance with SA or SB goal except where a Use Attainability Analysis demonstrates that the water resource has been irreparably altered to the extent that certain designated uses have been permanently lost.
CLASS SD	Present water quality conditions persistently preclude the attainment of one or more designated uses for Class SB waters. One or more water quality criteria for Class SB waters are not being achieved most or all of the time. Class SD waters may be suitable for bathing or other recreational purposes, certain fish and wildlife habitat, industrial or other legitimate uses, including navigation, may have good aesthetic value. Class SD water quality results from sources of pollution which are not readily correctable through implementation of established state water quality management programs to control point and nonpoint sources of pollution. Dissolved oxygen standard in accordance with SA or SB goal except where a Use Attainability Analysis demonstrates that the water resource has been irreparably altered to the extent that certain designated uses have been permanently lost.

Connecticut's portion of Long Island Sound is about 613 square miles. Nearly 480 square miles, including most of the offshore areas relevant to LISS hypoxia management efforts, are classified SA. Another 44 square miles have a SA goal, but do not presently meet criteria for that classification. About 85 square miles either are SB or have a goal of SB. Just over 62 square miles of those waters are SC waters with a goal of SB and five square miles are presently classified SD with a goal of SB. SC waters are scattered within the embayments and harbors along the coast, but parallel urban areas such as New Haven, Bridgeport, Norwalk, Stamford and Greenwich. Waters presently classified SD/SB are located in inner portions of New Haven Harbor and a small area at the mouth of the Byram River in Greenwich. While many offshore areas are classified SA, areas impacted by hypoxia do not presently meet class SA oxygen standards.

D. EPA Marine Dissolved Oxygen Criteria

Before this year, EPA had not issued saltwater criteria for dissolved oxygen because of insufficient information. As a result, the states of New York and Connecticut adopted the saltwater protection limits for dissolved oxygen described in the previous section primarily based on criteria developed from research done on freshwater organisms. In Connecticut, the Class SA waters in Long Island Sound have a protection limit for DO of not less than 6.0 mg/l at any time. In New York, Class SA, SB, and SC waters of Long Island Sound have a DO protection limit of not less than 5.0 mg/l at any time.

However, in January 2000, EPA released a draft document entitled *Draft Ambient Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*[8]. This document was the result of efforts by the EPA's Office of Research and Development Laboratory in Narragansett, RI to develop saltwater criteria to provide a better basis for assessing oxygen conditions sufficient to protect aquatic life in marine environments. For more than ten years, with partial support from the LISS, scientists have researched the effects of low oxygen levels on aquatic life along the Atlantic coast from Cape Cod, MA to Cape Hatteras, NC. Field studies conducted by the CTDEP were reviewed along with other laboratory studies. The information from these studies was used by the LISS to characterize the impacts from low DO in the Sound[9].

The draft DO criteria document approach to protect saltwater animals from Cape Cod to Cape Hatteras took into account both continuous (i.e., persistent) and cyclic (diel, tidal, or episodic) exposures to low DO. The continuous situation considers exposure durations of 24 hours or greater. Criteria for cyclic situations would cover hypoxia exposures of less than 24 hours, but which may be repeated over a series of days. Both scenarios cover three areas of protection: 1) juvenile and adult survival; 2) chronic growth effects; 3) larval recruitment effects. The draft juvenile/adult survival and growth criteria provide useful screening boundaries within which to judge the DO status of a given site. If the DO conditions are above the chronic growth criterion (4.8 mg/l), then this site would meet objectives for protection. If the DO conditions are below the juvenile/adult survival criterion (2.3 mg/l), then this site would not meet objectives for protection. When the DO conditions are between these two values, then the site would require evaluation of the duration and intensity of hypoxia to determine the suitability of habitat for the larval recruitment objective.

The criteria, finalized by EPA in December 2000, now provide a firmer scientific basis for planners, regulators, and the public to address the question, "What oxygen conditions are sufficient to protect aquatic life in Long Island Sound and provide for a healthy, diverse aquatic community?" The criteria will also provide guidance for the states of Connecticut and New York to evaluate their existing DO standards. In April 2000, CTDEP proposed revisions to its DO standard based on the EPA draft criteria document. After considering public input and the final EPA guidance, CTDEP expects to adopt a revised standard in late 2000 or early 2001.

The LISS is committed to reevaluating management goals and actions every five years to incorporate new information. The saltwater oxygen criteria and any revisions to state water quality standards will be assessed as part of the evaluation. Revisions in state DO standards will modify the degree to which nitrogen reduction or other management controls would be needed to attain water quality standards. Any changes in state DO standards will be will be considered during the planned five-year review periods and in future revision to the TMDL.

IV. CWA Section 303(d) Listing

A. Use Impairment

Monitoring of the Sound during the summers of 1986-2000 has demonstrated that significant areas of the Sound's bottom waters are subject to DO levels below 5 mg/l. In 1989, a particularly severe summer for hypoxia, more than 500 square miles (40 percent) of the Sound's bottom waters had DO levels less than 3 mg/l. During many of these years, DO in a portion of the Sound (up to 50 square miles) fell below 1 mg/l and in 1987 anoxia, the absence of free oxygen, was recorded in a portion of the Western Narrows. As recently as 1994, 25 percent of the Sound was affected. Generally, hypoxia occurrences have spanned a period of 40 to 80 days from July through September (**Figure 1**).

Use impairments related to hypoxia and to eutrophication of the Sound are many, including a decrease in bathing area quality, an increase in unhealthy areas for aquatic marine life, an increase in mortality of sensitive organisms, poor water clarity for scuba divers, a reduction in commercial and sport fisheries values, a reduction in wildlife habitat value, degradation of seagrass beds, impacts on tourism and real estate, and poorer aesthetics. All these key uses would realize benefits from improved water quality resulting from nitrogen reduction in the Sound.

Based upon the water quality impairment due to low oxygen conditions, NYSDEC and CTDEP have included Long Island Sound on their Section 303(d) lists since 1992. It has been listed as an impaired waterbody due to low DO and a priority for TMDL development.

B. Pollutants of Concern

The primary pollutant contributing to hypoxia in Long Island Sound is nitrogen, which is the limiting nutrient for algal production and leads to the generation of organic carbon. This process is the dominant mechanism for causing low DO and the violation of water quality standards in Connecticut and New York. The principal pollutant for this TMDL analysis, therefore, is nitrogen. Organic carbon is also a key ingredient in the process leading to hypoxia and, while not a pollutant targeted for reduction in this analysis, will be described and quantified in this report because it is expected to undergo load changes as nitrogen reduction technologies are implemented. For example, technologies used to control point and nonpoint sources of nitrogen will also reduce organic carbon loading. Based on monitoring and modeling, phosphorus does not appear to be limiting in Long Island Sound and is not targeted for management measures to benefit the Sound at this time.

C. Pollutant Sources

There are a number of significant sources of nitrogen that contribute to low DO in Long Island Sound:

C Municipal and industrial wastewater treatment facilities. More than 1 billion gallons of treated effluent are discharged into Long Island Sound each day. There are more than 100 municipal treatment facilities in the New York and Connecticut portions of the watershed alone.

- Combined sewer overflows (CSOs).

- Nonpoint sources, or runoff from land use activities, which includes stormwater from urban areas, and runoff and groundwater transport from all land covers.

- Atmospheric deposition directly to water surfaces and to the land, a portion of which eventually washes into Long Island Sound.

These sources of nitrogen originate within the New York and Connecticut portions of the watershed, from sources within the watershed north of Connecticut, and from oceanic delivery through the eastern and western connections of the Sound with the Atlantic Ocean.

V. TMDL Development

A. Available Ambient Data

The LISS has sponsored water quality sampling programs continuously since 1986 to develop a coupled set of circulation and water quality models, called LIS 3.0, and to understand trends in the temporal and spatial extent of hypoxia (See Section V.C. for details on the models). Intensive water quality monitoring of the Sound was conducted from April 1988 to September 1989 between Governor's Island in New York Harbor and Block Island Sound in the Atlantic Ocean to collect necessary data for developing the hydrodynamic and water quality models. More than 25 water quality constituents were monitored - water quality transparency, salinity, temperature, various nutrients (nitrogen, phosphorus, and silica) and their forms, chlorophyll *a*, DO, BOD_5, total organic carbon, and suspended solids among others.

CTDEP continued the monitoring of water quality in Long Island Sound in 1991 and expanded its network to 48 axial and lateral monitoring stations in 1994[10]. Monthly samples for nutrient and other chemical analyses are taken throughout the year at 18 stations, along with water column profiles of temperature, salinity, and DO. During the summer months (June - September), CTDEP monitors the additional 30 stations for DO during the regular monthly surveys, and all 48 stations are monitored for DO an additional time each month to better characterize hypoxic conditions. Additional data from 16 New York City Department of Environmental Protection (NYCDEP) Harbor Survey stations in the East River and western Narrows of the Sound complement the regular monitoring program in the Sound[11]. NYCDEP's 52-station Harbor Survey, in its 85th year, includes five stations in the East River and 11 in the western Narrows section of the Sound. The Survey was expanded in 1988 to year-round DO, CTD (conductivity, temperature, and depth profiles), nutrient, and chlorophyll monitoring conducted approximately twice per month. NYCDEP also splits samples monthly from three stations to send to the CTDEP for expanded nutrient analyses. Since 1991, the Interstate Sanitation Commission (ISC) has also conducted weekly surveys[12] in the Narrows and western basin during the critical summer season to supplement the studies conducted by CTDEP and NYCDEP. ISC currently has 21 stations to sample temperature, salinity, and DO at multiple depths by probe. A number of citizen volunteer monitoring programs also exist and can provide valuable information on water quality in local harbors and bays[13].

B. Nutrient Loading Data

The LISS has classified nitrogen loads into several categories, depending on geographic origin, source type, and whether it is of natural or human origin. Major divisions are between: 1) nutrients originating from within the Connecticut and New York portions of the Long Island Sound drainage basin, including those deposited directly on the Sound's surface, referred to as *in-basin* contributions, and 2) nutrients from all other sources beyond the in-basin boundaries, including tributary transport from north of Connecticut and oceanic transport through The Race and the East River, referred to as the *imported* load or *out-of-basin* load. Each source is further subdivided into a pre-colonial load and a human-caused, or *enriched*, load. The pre-colonial load is an estimate of the amount of nitrogen that was delivered to Long Island Sound before the basin was colonized by European settlers. The pre-colonial condition estimates what a *natural* load might have been. Wastewater treatment facilities, nonpoint source runoff from terrestrial sources, CSOs, and atmospheric deposition all contribute to in-basin and imported sources of enrichment. Although the origin of atmospheric nitrogen deposition may be many hundreds of miles away, it is presently included in the geographic category where it is deposited.

For purposes of this report, nonpoint sources include diffuse sources (e.g., runoff from farms and to groundwater) *and* runoff that is conveyed through stormwater outfalls. Since stormwater outfalls discharge to receiving waters via discreet conveyances (i.e., pipe outlets), they are by definition point sources for regulatory purposes under the Clean Water Act. However, for the purposes of this TMDL, stormwater loads are included in the nonpoint category. Justification for this categorization is provided in Section V.B.4.

Nitrogen loads are presented as annual loads estimated for an *average* flow year. These loads, therefore, differ somewhat from the time variable nitrogen loads specific to 1988-1989 used to calibrate the LIS 3.0 model. The in-basin area contributes an estimated 53.3 thousand tons of nitrogen per year including both the pre-colonial and enrichment loads. Another 13.6 thousand tons per year comes from drainage (tributary) areas north of Connecticut. The marine boundaries contribute about 33.6 thousand tons of nitrogen each year. These loads provide the baseline load for the TMDL analysis.

The in-basin loads were further partitioned by location into twelve *management zones*, eleven of which surround the Sound in Connecticut and New York. The twelfth zone is the surface of Long Island Sound. The terrestrial management zones (zones 1-11) generally follow natural river basin boundaries in Connecticut and political boundaries in New York (**Figure 3**). Due to its shape and size management zone 11 was also divided into an eastern and western segment. Tributary areas north of Connecticut are referred to by the major river name, e.g., the “Connecticut River” tributary import. The larger management zones in Connecticut are further divided into *tiers*. The tiers were needed to account for attenuation during transport from one tier to the next. These *attenuation factors* are important for quantifying relationships between discharge points and actual delivery of nitrogen to Long Island Sound.

Oxidizable carbon loads were also estimated for Long Island Sound using the same categories and approach that was used for nitrogen. Carbon is of interest because of its contribution to low dissolved oxygen levels in the Sound. While nitrogen plays the dominant role in causing hypoxia, the Long Island Sound water quality model estimates that oxidation of carbon loads is responsible for as much as 25 percent of the oxygen consumption. Because source management to remove nitrogen will also remove some of the total organic carbon (TOC) load, both nitrogen and carbon reductions are considered in quantifying the dissolved oxygen improvements. Since the carbon reductions are incidental to the management of nitrogen, no targets for TOC reduction have been established.

The following annual load summaries are presented as tons of nitrogen and TOC *delivered* to Long Island Sound. The statistics for nitrogen and TOC *generated* in the basin are also available[14]. However, the generated loads have been attenuated to represent the actual loads delivered to the Sound. For nitrogen, no attenuation was applied to the loads generated in proximity to Long Island Sound. The entire drainage area in New York and the coastal tiers in Connecticut were considered to be in proximity to Long Island Sound. For TOC, which is readily oxidized during transport, attenuation was applied in most of the coastal tiers in order to best characterize and balance the TOC loading budget delivered to Long Island Sound.

1. In-Basin Point Sources

As a part of the LISS, CTDEP and NYSDEC collected flow and effluent quality data from the major municipal and industrial wastewater dischargers throughout the portions of the states that drain to Long Island Sound. In general, point source monitoring data from 1988 through 1990 were used to calculate nutrient loads for both model development and to serve as the baseline from which reductions would be measured. For many point sources, particularly in the upper tiers of Connecticut, nutrient monitoring was not established until 1993 or later. For those facilities, estimated nitrogen and TOC concentrations (usually 15 mg/l for nitrogen and 20 mg/l for TOC) were applied to 1990 measured flow to develop each zone's aggregate baseline load estimates. When the Ocean Dumping Ban Act requirement to cease the ocean disposal of sludge by 1992 created the need for the de-watering of sludge, the Long Island Sound Management Conference recognized New York City's need to de-water its sludge at the East River facilities by increasing the nitrogen baseline in zone 8 to include the centrate of the de-watered sludge.

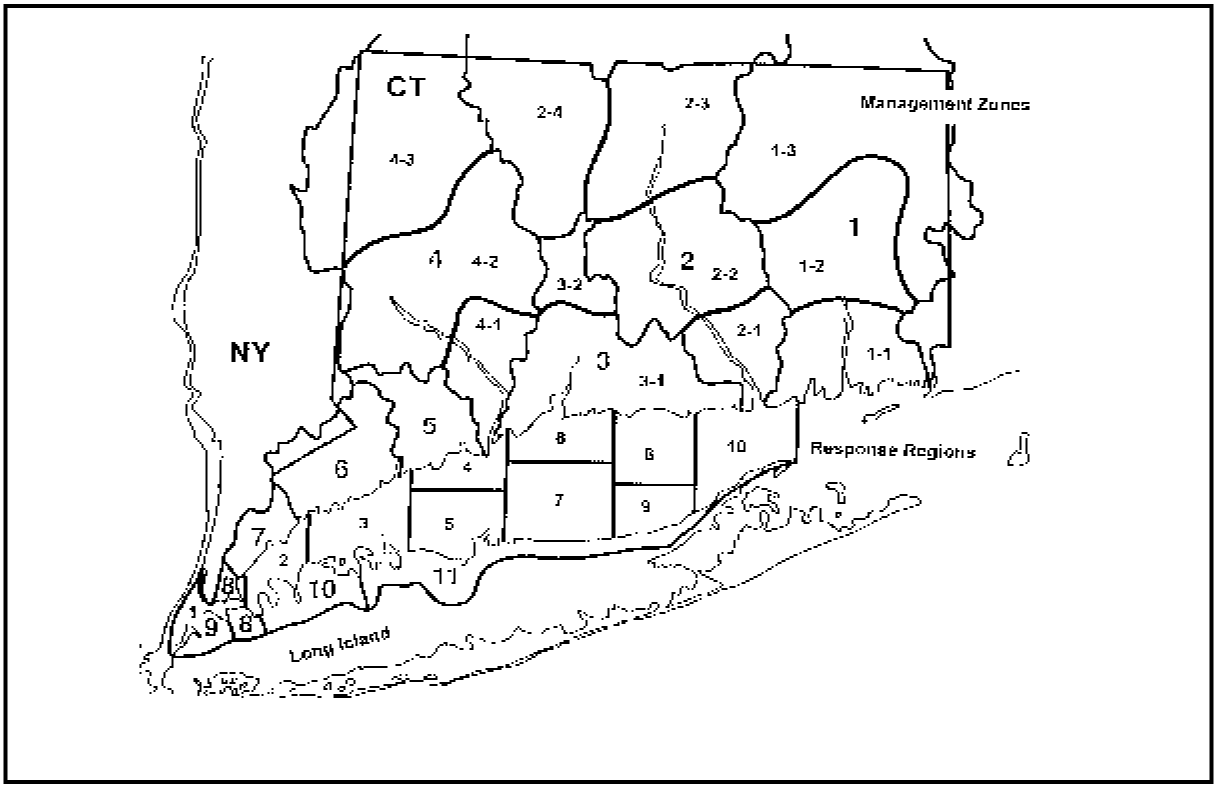

Figure 3. Geographic segments (zones and tiers) and response regions for Long Island Sound.

Loading estimates for combined sewer overflows (CSOs) from New York City are available and are included in the point source category. Additional information on the categorization of CSOs and stormwater between point and nonpoint sources is provided in section V.B.4.

Table 1. Summary of in-basin total nitrogen loading (tons/yr), as delivered to Long Island Sound (attenuation considered) from all source types.

Zone	Nonpoint Sources				Point Sources			
	Pre-Colonial	Terrestrial	Atmospheric	Total[a]	WWTP	CSO	Total[b]	Total Load[c]
1	991.3	256.1	604.7	1852.1	1242.6	0.0	1242.6	3094.7
2	1158.6	479.5	835.1	2473.2	2805.0	0.0	2805.0	5278.2
3	408.0	235.5	355.7	999.2	2103.3	0.0	2103.3	3102.5
4	808.2	305.7	538.0	1651.9	1668.6	0.0	1668.6	3320.5
5	179.1	121.2	174.3	474.6	947.9	0.0	947.9	1422.5
6	195.9	146.8	202.2	544.9	1108.0	0.0	1108.0	1652.9
7	43.5	68.7	77.3	189.5	837.0	0.0	837.0	1026.5
8	N/A	N/A	N/A	N/A	17502.0	578.5	18080.5	18080.5
9	N/A	N/A	N/A	N/A	9103.0	314.1	9417.1	9417.1
10	81.9	84.2	108.6	274.7	484.0	0.0	484.0	758.7
11-west	104.0	133.5	155.2	392.7	191.0	0.0	191.0	583.7
11-east	9.1	11.6	13.5	34.2	13.9	0.0	13.9	48.1
12	1785.8	0.0	3699.2	5485.0	0.0	0.0	0.0	5485.0
Total	5765.4	1842.8	6763.8	14372.0	38006.3	892.6	38898.9	53270.9

[a] The sum of Pre-Colonial, Terrestrial, and Atmospheric nitrogen delivered from the watershed.
[b] The sum of Wastewater Treatment Plants (WWTP) and Combined Sewer Overflows (CSO).
[c] The sum of Nonpoint Sources and Point Sources of total nitrogen.

Point sources contribute the bulk of the nitrogen that reaches Long Island Sound, providing about 73 percent of the total, in-basin load, or 38.9 thousand tons of nitrogen per year (**Table 1**). Point sources contribute about 61 percent of the combined point and nonpoint, in-basin TOC load, or about 83.6 thousand tons of TOC per year (**Table 2**). Excluding the pre-colonial loads, point sources comprise about 82 percent and 79 percent of the nitrogen and TOC loads, respectively.

2. In-Basin Nonpoint Sources

Nitrogen and carbon inputs from rainfall runoff, groundwater transport, and atmospheric deposition were estimated for the Long Island Sound drainage areas within Connecticut and New York. Including the pre-colonial, terrestrial, and atmospheric contributions, in-basin wet weather runoff delivers about 14.4 thousand tons of nitrogen and 53.6 thousand tons of TOC to Long Island Sound each year (**Tables 1 and 2**). Of these loads, about one-third of the nitrogen (5,765 tons/yr) and almost 60 percent of the carbon (31,624 tons/yr) are estimated to represent pre-colonial loading conditions. The remainder is believed to be of human origin, or enrichment.

Terrestrial load estimates were calculated using land export coefficients for three broad land cover categories (urban/suburban, agriculture, and forest) and estimates of attenuation related to distance from the Sound. Atmospheric and pre-colonial contributions aside, terrestrial sources, excluding New York City CSO loads, are estimated to contribute 1,843 tons of in-basin nitrogen per year. This represents about 3.5 percent of the total, in-basin nitrogen load to Long Island Sound. Terrestrial TOC loading is about 11 percent of the total in-basin load delivered to Long Island Sound or about 15.5 thousand tons of TOC per year.

Estimates of atmospheric inputs, exclusive of the pre-colonial and terrestrial sources described above, were made subsequent to most of the modeling and initial loading analysis efforts. Early estimates used for modeling were based on measurements of wet deposition of nitrogen from precipitation directly on the surface waters of Long Island Sound at four sites in the LISS area in 1988 and 1989. Recently, more intensive monitoring of both wet and dry nitrogen deposition was conducted at two coastal sites and one inland site in Connecticut to develop better estimates of the role of atmospheric nitrogen loading. Those data were used to develop estimates of direct and indirect (inland) total nitrogen loads to Long Island Sound.

Table 2. Summary of in-basin total organic carbon loading (tons/yr), as delivered to Long Island Sound (attenuation considered) from all source types.

Zone	Nonpoint Sources				Point Sources			Total Load[c]
	Pre-Colonial	Terrestrial	Atmospheric	Total[a]	WWTP	CSO	Total[b]	
1	6001.8	2079.2	519.2	8600.2	3995.7	0.0	3995.7	12595.9
2	7966.8	4550.2	929.2	13446.2	4670.8	0.0	4670.8	18117.0
3	2036.0	1707.3	322.5	4065.8	2282.8	0.0	2282.8	6348.6
4	5688.2	2710.4	552.7	8951.3	2149.9	0.0	2149.9	11101.2
5	999.1	1026.1	188.7	2213.9	1656.0	0.0	1656.0	3869.9
6	1019.9	1164.4	209.5	2393.8	1009.2	0.0	1009.2	3403.0
7	240.6	605.7	100.1	946.4	1203.0	0.0	1203.0	2149.4
8	N/A	N/A	N/A	N/A	24135.4	8350.7	32486.1	32486.1
9	N/A	N/A	N/A	N/A	29441.4	4070.7	33512.1	33512.1
10	408.8	670.7	118.0	1197.5	528.4	0.0	528.4	1725.9
11-west	434.0	872.8	145.6	1452.4	125.7	0.0	125.7	1578.1
11-east	37.8	76.0	12.7	126.5	8.2	0.0	8.2	134.7
12	6790.8	0.0	3395.4	10186.2	0.0	0.0	0.0	10186.2
Total	31623.8	15462.8	6493.6	53580.2	71206.5	12421.4	83627.9	137208.1

[a] The sum of Pre-Colonial, Terrestrial, and Atmospheric carbon delivered from the watershed.

[b] The sum of Wastewater Treatment Plants (WWTP) and Combined Sewer Overflows (CSO).

[c] The sum of Nonpoint Sources and Point Sources of total organic carbon.

Annually, about 3,065 tons of nitrogen enrichment wash into the Sound from in-basin atmospheric deposition and another 3,700 tons are deposited directly on the Sound's surface waters. Combined, this represents about 13 percent of the in-basin nitrogen delivered to Long Island Sound. Loading of atmospheric TOC is not well documented as it was not part of the atmospheric depositional monitoring conducted on behalf of the LISS. Estimates developed for the Long Island Sound water quality model were used to estimate TOC deposition on the watershed. Delivery to Long Island Sound was estimated using the same general methodologies and calibrations that were used for nitrogen delivery rates. Accordingly, less than 6,500 tons of TOC enrichment delivered to Long Island Sound each year are attributable to atmospheric sources, a little less than 5 percent of the total in-basin load.

3. Tributary Import

Tributary inputs represent loadings of water quality constituents that are delivered from upland watersheds, north of Connecticut, to Long Island Sound. These contributions result from groundwater inflows, surface land runoff, direct and indirect atmospheric deposition, CSOs, and wastewater treatment plant discharges to the waterbodies throughout the basins in Massachusetts, New Hampshire, and Vermont. The loads are delivered to Long Island Sound via the Housatonic, Connecticut, and Thames River systems. Estimates of nitrogen and TOC enrichment delivered from these northern basins have been made, applying the same methodologies used to estimate in-basin loads, and include estimates of attenuation during transport through the state of Connecticut (**Tables 3 and 4**). The three major tributaries annually deliver about 13.6 thousand tons of nitrogen and 56.9 thousand tons of TOC to Long Island Sound. Although the database for the imported load (i.e., land cover and point source estimates) is relatively weak, it is estimated that as much as 60 percent of the tributary nitrogen load (8,091 tons/yr) and 37 percent of the tributary TOC load (21,217 tons/yr) may be of human origin.

Table 3. Summary of total nitrogen loading (tons/yr), as delivered to Long Island Sound (attenuation considered) from tributary sources.

Tributary	Nonpoint Sources				Point Sources	Total Load[b]
	Pre-Colonial	Terrestrial	Atmospheric	Total[a]		
Thames	91.9	30.5	57.3	179.7	155.9	335.6
Farmington	46.7	11.5	28.9	87.1	0.0	87.1
Connecticut	5157.6	1593.5	3219.1	9970.2	2572.7	12542.9
Housatonic	177.4	58.7	100.7	336.8	262.6	599.4
Total	5473.6	1694.2	3406.0	10573.8	2991.2	13565.0

[a] The sum of Pre-Colonial, Terrestrial, and Atmospheric nitrogen delivered from tributaries to LIS.
[b] The sum of Total Nonpoint Sources and Point Sources of total nitrogen.

Table 4. Summary of total organic carbon loading (tons/yr), as delivered to Long Island Sound (attenuation considered) from tributary sources.

Tributary	Nonpoint Sources				Point Sources	Total Load[b]
	Pre-Colonial	Terrestrial	Atmospheric	Total[a]		
Thames	536.0	226.2	48.2	810.4	116.6	927.0
Farmington	330.6	112.1	29.2	471.9	0.0	471.9
Connecticut	33322.7	13362.4	2999.0	49684.1	3213.5	52897.6
Housatonic	1508.8	565.8	111.7	2186.3	431.9	2618.2
Total	35698.1	14266.5	3188.1	53152.7	3762.0	56914.7

[a] The sum of Pre-Colonial, Terrestrial, and Atmospheric carbon delivered from tributary areas to LIS.
[b] The sum of Total Nonpoint Sources and Point Sources of total organic carbon.

4. CSO and Stormwater Loads

A portion of the nonpoint source load categorized as terrestrial and atmospheric is actually conveyed through stormwater outfalls and combined sewer overflows (CSOs) to Long Island Sound. Since CSO and stormwater outfalls discharge to receiving waters via discreet conveyances (i.e., pipe outlets), they are by definition point sources for regulatory purposes under the Clean Water Act. However, given the geographic scale of the LIS TMDL and the land use-based approach used to estimate loadings, it was not feasible to meaningfully separate loadings from point source stormwater runoff and CSOs from the general nonpoint source categories, with the exception of the New York City CSO loads (zones 8 and 9).

For example, in Connecticut, pollutant loading estimates for CSOs were not available due to a scarcity of monitoring data for both pollutant concentrations and discharge volumes. Instead, the sewage treatment plant loads, based on discharge monitoring, include the nitrogen that would overflow during wet weather conditions. Similarly, the export coefficients used to estimate land runoff of nitrogen account for stormwater contributions on CSO areas. In this approach, Connecticut CSO loads were effectively distributed between the point source and nonpoint source categories. None of the CSO nitrogen load was missed; it was just assigned to the point and nonpoint source categories relevant to each CSO drainage area. In the future, as New Haven, Hartford, Norwalk, Bridgeport, and Norwich develop long-term control plans for their CSO systems, monitoring data will be collected to more clearly document discharge volumes and pollutant concentrations.

With EPA’s recent (December 8, 1999) promulgation of phase II stormwater regulations, many previously unregulated stormwater discharges will require NPDES permit coverage and will require the application of best management practices and other measures. Since, at present, there is insufficient information to determine the universe of point source vs. nonpoint source stormwater discharges anywhere in the basin, it is reasonable for now to collectively characterize these sources. Development of the phase II stormwater permitting program over the next few years will provide opportunities for the states to elucidate the load from stormwater sources and, building on the phase II regulations, identify appropriate wasteload allocations.

5. Boundary Loads

Nitrogen is also transported into Long Island Sound from the Atlantic Ocean at The Race and from New York Harbor through the East River. The total amount of nitrogen transported is dependent on the net flow of water through these boundaries, and the concentration of nitrogen in the water. Both variables are sensitive to hydrographic conditions will vary over time. Through the water quality modeling described in Section V.C., the LISS estimated the boundary loads for the 1988-89 period under which the model was calibrated. During this period the boundaries provided 33,600 tons of nitrogen per year to the Sound. Of that total annual load, it was estimated that pre-colonial levels contribute 22,900 tons of nitrogen while human activities contribute 10,700 tons. Pre-colonial and enriched TOC was estimated at 224,068 tons per year through the boundaries. About 51,000 tons of the annual TOC boundary load was attributed to human enrichment.

6. Summary of Nutrient Loads and Uncertainties

An estimated 100,436 tons of nitrogen enters Long Island Sound each year. Of that total, about a third enters the Sound through its water boundary at The Race to the east and from New York Harbor through the East River to the west. About 42 percent of the load is from point sources (both in-basin and out-of-basin), 13 percent from nonpoint source runoff (both in-basin and out-of-basin), and 12 percent from atmospheric deposition. The atmospheric deposition category includes both direct and indirect deposition–nitrogen deposited directly on the Sound and nitrogen delivered to the Sound from deposition on its drainage basin.

Figures 4 and 5 summarize the first order estimates of nitrogen and carbon loadings to the Sound during mean rainfall conditions. Actual loadings will vary from year to year depending on the amount and intensity of rainfall and on meteorological conditions that affect water circulation and boundary fluxes.

The atmospheric deposition figure is considered preliminary and a conservative estimate of its relative importance. Ongoing work is expected to result in a revision of those estimates upward, highlighting the importance of geographically distant sources on nitrogen emissions to the atmosphere. Additional improvements in the estimates of land-based contributions are expected from development of a watershed model that will aide the assessment of how nitrogen is attenuated within the watershed.

C. Water Quality Model

The LISS sponsored the development of a coupled three-dimensional, time variable hydrodynamic/water quality model, called LIS 3.0[15,16], to help understand oxygen dynamics in Long Island Sound and to evaluate the range of options for improving conditions[17]. The basis for the water quality components of the model is an extension of a time-variable coupled eutrophication/sediment flux model of Chesapeake Bay that was developed by the U.S. Army Corps of Engineers[18] and HydroQual, Inc.[19] The model incorporates advanced physical, biological and chemical kinetics (processes) that relate nutrients and carbon-based pollutants to phytoplankton (primary productivity) dynamics and DO. The model has been calibrated using ambient monitoring data collected over the eighteen-month period from April 1988 through September 1989 described earlier. The eighteen-month calibration period covers all seasons of the year; actual hydrological and meteorological conditions for that time period were input into the model. Tributary loadings and combined sewer overflows were also determined using time-variable rainfall and river flow data. Other factors that influence external boundary conditions and internal circulation within the Sound, such as hydrological and meteorological conditions (seasonal variations, such as wet and dry weather conditions) have been considered and are included in the model.

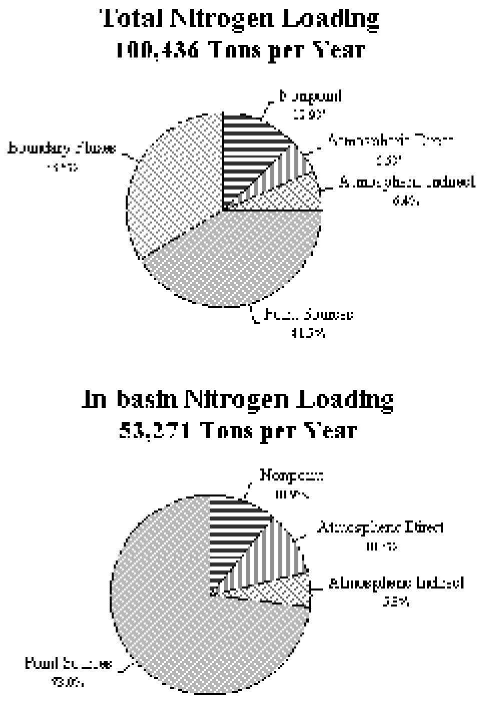

Figure 4. Sources of nitrogen to Long Island Sound.

The LIS 3.0 model reproduced temporal and spatial trends in observed data (in terms of pollutant transport and transformation) and successfully simulated 1988-1989 conditions, gaining approval of the LISS Modeling Evaluation Group[20] for use as a predictive tool.

While hypoxia generally occurs from June through September, nitrogen loadings throughout the year contribute to the pool of nitrogen available for uptake by phytoplankton. The model did not show a strong relationship between hypoxia and the seasonality of nitrogen loads to Long Island Sound that would warrant special attention to seasonal management of nitrogen. This is because algal growth occurs over seasonal and annual cycles where the total pool of nitrogen available is the critical factor. This supports the use of a maximum annual load used in this TMDL, rather than seasonal or daily load limits.

Based upon the annual surveys from 1986-1998 and a review of the historical data[21,22], the 1988-1989 modeling time frame was the most severe period of hypoxia on record. While nitrogen loads are related to the amount of phytoplankton growth, physical factors, such as the strength of stratification in the water column, affect the degree to which the decay of that phytoplankton results in hypoxic conditions in Long Island Sound[17]. As a result, model simulations of reduced nitrogen inputs will predict water quality conditions that would result during the same physical conditions that existing during the 1988-89 period. Because 1988-89 was a severe period, average year conditions would predict better water quality conditions. By calibrating the model to the severe conditions that existed in 1988-89, a conservative level of nitrogen reduction is identified, providing a margin of safety (MOS) for average years.

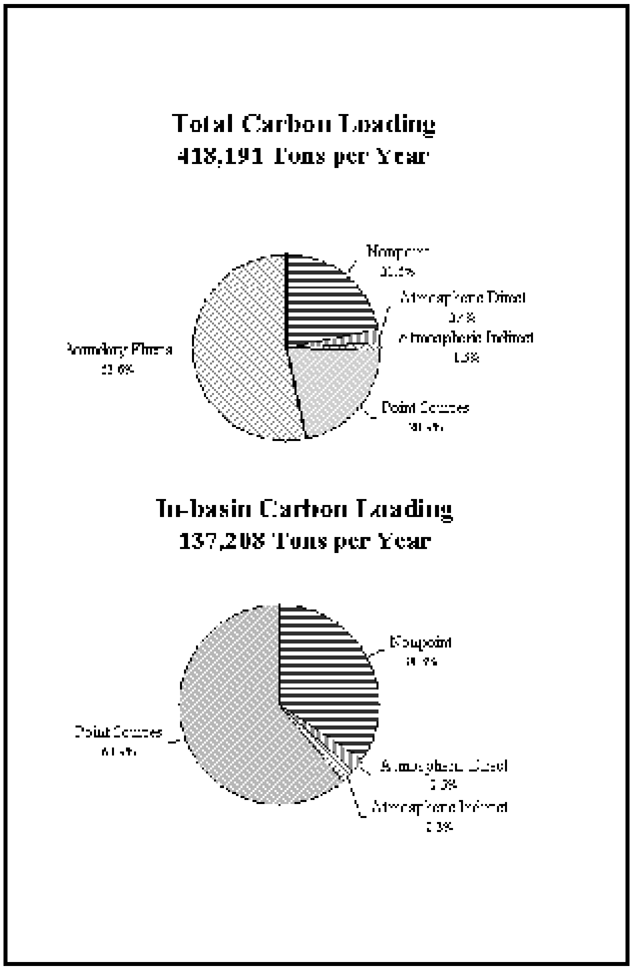

Figure 5. **Sources of carbon to Long Island Sound.**

1. Water Quality Model Projections

The LIS 3.0 model was run under a range of nutrient loadings to simulate their effect on DO levels in Long Island Sound. Of particular importance were simulations of "base" and "pre-colonial" conditions. The base condition consisted of pre-management loadings of nutrients and carbon (corresponding to the 1988-89 modeling period) and provided important information on the dynamics of oxygen in Long Island Sound and the causes for its depression. The pre-colonial condition included loadings of nutrients and carbon estimated to run off of a pristine, forested watershed that presumably existed before colonial settlement of the watershed. This condition provided insight into what oxygen concentrations might have been in the Sound before intensive colonization of the Long Island Sound area.

Based on the data analysis and model results, the following conclusions were drawn:

- The model approximately reproduced the principal interactions among density-induced circulation, nutrient inputs, and phytoplankton on an annual cycle. In addition, the principal components of the DO budget were incorporated in the model and, in general, it reproduced the observed temporal distributions of DO in the critical region of the western Sound.

- Based on model computations, it was calculated that almost 75 percent of the DO depression at the critical location in Long Island Sound results from nutrients, with the remainder due to oxidizable carbon.

- Both data and modeling results indicate that nitrogen, not phosphorus, is the limiting nutrient, although the data and modeling also suggest there are short periods of time when silica limits algal growth.

- Under the base line loading scenario, the 1988 conditions for minimum DO levels, the hypoxic area affected, and the duration of hypoxia were more severe than the 1989 conditions. The 1988 model year therefore represents the more critical condition. (The base case loading scenario assumed all treatment plants were discharging effluent at the secondary treatment level. The loading scenario also included the increased nitrogen loads from the sludge de-watering at the New York City plants[1].)

  - The hourly minimum DO level for 1988 conditions was 1.1 mg/l, occurring in the western Narrows. Conditions below 3.5 mg/l lasted for 52 days. The maximum area below 3.5 mg/l was 200 square miles[2] (**Table 5**).

- Under the pre-colonial scenario (which excludes anthropogenic nitrogen sources), nutrient loadings were high enough to cause a reduction of DO levels in the water column from saturation levels. The pre-colonial simulation estimates the DO levels that would occur if all human sources of nutrients were eliminated (**Table 5**).

  - Pre-colonial scenario spatial profiles of hourly minimum DO levels, using 1988 meteorological conditions, were above the applicable New York standards of 4.0 and 5.0 mg/l for the East River and the Sound, respectively.

  - Pre-colonial scenario spatial profiles of hourly minimum DO levels, using 1989 meteorological conditions, were higher than under 1988 conditions, generally above 5.5 mg/l in the Sound and above 4.5 mg/l in the East River.

It is important to note that the pre-colonial scenario is sensitive to the methods used to estimate natural loadings to Long Island Sound. The elimination of all point source discharges and their associated pollutant loads is straightforward. However, estimating the amount of nitrogen runoff from natural, forested areas is not. Nutrient runoff coefficients for existing forested areas in Connecticut have been estimated[23] but include the impact of current atmospheric deposition

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[1] Beginning in 1992, New York City ceased disposal of sewage sludge into the ocean. De-watering the sludge for land disposal added approximately 25,000 lbs/day of nitrogen to the New York City load.

Table 5. Comparison of model scenarios for minimum hourly DO concentrations in Connecticut and New York, relative improvement in DO, and maximum area (mi^2) with DO below 3.5 mg/l.

Scenario	Hourly Minimum DO (mg/l) in NY Waters*	DO (mg/l) improvement over Baseline in NY Waters	Hourly Minimum DO (mg/l) in CT Waters*	DO (mg/l) improvement over Baseline in CT Waters	Maximum Area (mi^2) with DO less than 3.5 mg/l
Baseline	1.1	0.0	3.4	0.0	200
Phase III	3.0	1.9	4.1	0.7	60
Limit of Technology	3.1	2.0	4.1	0.7	55
Pre-Colonial	5.3	4.2	5.6	2.2	0

* Hourly minima were taken for the critical cell (lowest DO concentration) within response region 2 for NY and response region 6 for CT (refer to **Figure 3** for response region locations).

rates, which are enriched compared to pre-colonial rates. Attenuation of nutrient loads during tributary transport add another variable in estimating natural runoff loads. The more recent estimates of the pre-colonial load of nitrogen presented in Table 1 are lower than the estimates used in the pre-colonial model run. Therefore, the oxygen levels predicted by LIS 3.0 for pre-colonial conditions are lower than would have been predicted with revised loading estimates.

2. Development of Nitrogen Reduction Plans

The LIS 3.0 model was also used to simulate the effect of reducing nitrogen on DO levels in Long Island Sound[24]. Of particular interest were the "limit of technology" (LOT) and "cost-sensitive" scenarios. The LOT scenario reflected loading of nitrogen at the current limits of control technology for point and nonpoint sources within the New York and Connecticut portions of the watershed. The cost of implementing this level of treatment was estimated to be $2.5 billion for upgrading the point sources alone. Under the LOT scenario, the hourly minimum DO level for 1988 conditions was around 3.1 mg/l (**Table 5**). The maximum area below 3.5 mg/l was reduced to 55 square miles and these conditions lasted for only four days. The LOT analysis showed that despite significant improvements in conditions, neither the Connecticut DO standard of 6 mg/l nor the New York DO standard of 5 mg/l were met in the entire Sound at all times.

The "cost-sensitive" scenario identified a level of nitrogen reduction estimated to maximize increases in DO levels relative to the implementation cost[25]. The reason for developing this scenario was that nitrogen reductions at the current limit of technology on sources within the New York and Connecticut portions of the watershed would not fully achieve water quality standards. Therefore, out-of-basin source reductions and/or alternatives to nitrogen removal are necessary to achieve water quality standards. Since additional measures will be needed, a cost-effective approach to in-basin source reductions is justified.

To identify cost-effective actions, an additional management tool, called the unit response matrix, was developed using the LIS 3.0 model. The unit response matrix identified the relationship between the location of a nitrogen discharge and the response in DO in the Sound. To simplify the analysis, the Sound was divided into ten response regions and the watershed into 11 management zones (**Figure 3**). Within each region, one model grid cell was selected as representative of the worst case condition in that response region. That grid cell is referred to as the "critical cell." LIS 3.0 model runs were then performed, 22 in all, in which all of the nitrogen and carbon delivered from each watershed management zone was removed and the effect on DO in each response region calculated. A spreadsheet was developed that summarized the relative response of DO in each response region from nitrogen and carbon control in each watershed management zone.

The spreadsheet provided a convenient means to assess a wide range of control options and was used to develop plots of cost versus DO improvement for response regions two, five, and six. The plots provided a means to assess the point at which additional nitrogen reductions resulted in diminished DO improvements relative to increase cost. Using this approach, a 58.5 percent reduction in nitrogen from point and enriched nonpoint in-basin sources was identified and was tested as a scenario (Phase III) using the LIS 3.0 model.

Under this scenario, the hourly minimum DO level for 1988 conditions was around 3.0 mg/l. The maximum area below 3.5 mg/l was reduced to 60 square miles (**Table 5**); the duration of these conditions was only 6.5 days. Although the water quality improvements were nearly the same as the LOT scenario, the estimated cost of implementing the point source actions was $650 million, down from the $2.5 billion of the LOT scenario.

Using the LIS 3.0 model output along with research data on the ecological impact from low DO levels, the LISS estimated some of the ecological and environmental benefits resulting from implementation of Phase III actions.

- The maximum area of the Sound that is unhealthy for aquatic life will be reduced by 75 percent. The period during which unhealthy conditions exist in the Sound will be reduced by 85 percent, from more than 50 days to 6.5 days.

- By limiting the area and duration of unhealthy conditions, overall adverse biological effects caused by hypoxia will be greatly reduced Soundwide.

    - In the western Narrows, death rates of larvae of marine life sensitive to hypoxia will be reduced by 67 percent; adverse impacts to fish abundance will be reduced by 97 percent; adverse impacts on scup (porgy) abundance will be reduced by 61 percent, on winter flounder abundance by 99 percent, and effects on lobster abundance will be eliminated.

    - In the waters off of New Haven, CT, mortality of sensitive larvae will be reduced by 65 percent and adverse impacts on fish abundance will be eliminated.

    - In the waters off of Stony Brook, NY, larval mortality will be reduced by an estimated 84 percent and adverse impacts on fish abundance will be eliminated.

- While the LISS analysis focused on the open waters of the Sound, improvements are expected in harbors, embayments, and nearshore waters as well. These waterways are flushed with water from the Sound as a result of tidal action. As the quality of water from the Sound improves, we can expect improvement in the harbors, embayments, and nearshore waters. Improved water clarity (or light penetration) will also expand the amount of shallow water area conducive to the growth of submerged aquatic vegetation, an important habitat that has diminished in range from historical levels.

As a result of these analyses, the LISS released a proposal for *Phase III Actions for Hypoxia Management*, including a nitrogen reduction target of 58.5 percent to be achieved in 15 years, for public comment in February 1997[26]. Twelve public meetings to present the proposed plan and receive comments from attendees were scheduled and held in New York and Connecticut[27,28]. On February 5, 1998, after a year of public review, comment and revision, the Policy Committee for the LISS adopted the final plan for *Phase III Actions for Hypoxia Management*[29].

VI. TMDL/WLA/LA for Nitrogen

CWA Section 303(d) requires the establishment of TMDLs that will result in the attainment of water quality standards. As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measures. As presented in Section V.C., nitrogen loadings throughout the year contribute to the pool of nitrogen available for uptake by phytoplankton. Hypoxia resulting from the ultimate decay of that phytoplankton is not sensitive to daily or short term nitrogen loadings. Instead, DO levels are a function of annual loading rates. As a result, the LIS TMDL is expressed as an allowable annual load of nitrogen.

While achieving the Phase III nitrogen reduction target of 58.5 percent for in-basin sources is predicted to greatly reduce hypoxia and minimize adverse impacts on aquatic life, there will be some areas of the Sound that will continue to experience DO concentrations below water quality standards for a shorter period of time. Therefore, this TMDL identifies the additional actions and schedules beyond the 15-year Phase III plan for achieving water quality standards. These actions include the control of carbon and nitrogen from outside the basin (including point and nonpoint sources north of Connecticut in New England, atmospheric deposition, and point and nonpoint sources affecting import from New York Harbor and The Race) and the application of non-treatment alternatives. More stringent reductions from in-basin sources of nitrogen, such as requiring implementation of the current limit of treatment technology, were not recommended in developing Phase III because it has been documented that they would result in only minor water quality improvements for large increases in cost. The TMDL is the sum of the Phase III nitrogen reduction targets, nitrogen and carbon reductions from outside the basin, and the application of non-treatment alternatives necessary to attain water quality standards for DO with an implicit margin of safety.

TMDL = 58.5 percent nitrogen reduction from in-basin sources + reductions in nitrogen and carbon from out-basin sources + non-treatment alternatives + margin of safety

Sections A through C that follow identify the pollutant reductions and resultant DO improvements from each of these components. In sum, these management actions are predicted to result in the attainment of the water quality standards for Long Island Sound. The unit response matrix that was developed using the LIS 3.0 model has been used to identify the DO improvements resulting from nitrogen and carbon controls beyond Phase III. Modeling and other analyses have been used to assess the degree to which mixing/aeration and other alternative technologies can provide the remaining improvements in DO necessary to attain the water quality standards. The margin of safety provided in the analysis is discussed in Section VI. D.

It must be noted that there is some uncertainty as to whether it is technologically feasible, or ecologically beneficial, to achieve the DO water quality standard in all areas of the Sound. The reason for this uncertainty is that the LIS 3.0 model scenario for pre-colonial conditions in the Sound projects DO levels that are at, or just below, the applicable DO criteria in the states' water quality standards. This is particularly true for Class SA waters in Connecticut where a DO standard of 6.0 mg/l applies. This suggests that the natural condition of Long Island Sound, the condition existing prior to any enrichment of nitrogen from human activities, may not be supportive of current state DO standards everywhere and at all times. However, it is also important to stress that the LIS 3.0 model simulation of pre-colonial conditions is at best an approximation because:

- The pre-colonial nitrogen loadings used in the simulation may be too high, resulting in predictions of DO conditions that are too low.
- The role of wetland loss and habitat alteration is not accounted for.
- Modeling refinements may change the predicted DO conditions for all scenarios.

Given the scope and magnitude of this effort, the TMDL stresses implementation of the Phase III nitrogen reduction target and establishes preliminary targets and recommended actions for out-of-basin nitrogen source reductions and alternatives to nutrient control for improving water quality. The TMDL also establishes a process and schedule for better defining, evaluating, and ultimately implementing additional controls and actions beyond Phase III. This approach is consistent with EPA's *Guidance for Water Quality-based Decisions: The TMDL Process*[30] , which states that "For certain non-traditional problems, if there are not adequate data and predictive tools to characterize and analyze the pollution problem, a phased approach may be necessary." A phased approach " . . . requires additional data to be collected to determine if the load reductions required by the TMDL lead to attainment of water quality standards. Data collection may also be required to more accurately determine assimilative capabilities and pollution allocations." The details to this approach are described in Section VII.

A. In-Basin Sources

1. Allocation of the In-Basin TMDL

As detailed in the *Phase III Actions for Hypoxia Management*, a 58.5 percent reduction target has been established for enriched nitrogen from in-basin sources. This reduction target has been applied to the cumulative point and terrestrial runoff nitrogen load from urban and agricultural land covers (Appendix A) within each of the 11 management zones set up around the Sound (**Table 1**). Reductions allocated to point sources (the wasteload allocation, or WLA) and nonpoint sources (the load allocation, or LA) within each management zone are identified in **Table 6**.The load allocations are based upon achieving a 10 percent reduction in the total nonpoint source load of nitrogen from urban and agricultural land covers within a management zone. The methodology for estimating the in-basin nonpoint source runoff load and load allocation is detailed in Appendix A. A 10 percent reduction in the total nonpoint source load of nitrogen from urban and agricultural land covers is considered to be achievable through an aggressive nonpoint source runoff control program.

The wasteload allocations are based upon the additional reductions to point sources within a zone that are necessary to achieve the overall 58.5 percent zone reduction target. In response to comments presented on the draft TMDL, CTDEP public noticed a revised WLA that reallocated the entire state's WLA equally among all 85 affected point sources. However, any reallocation among management zones affects the "edge of Sound" TMDL as described in Appendix B. However, the "effective" nitrogen as measured in terms of DO impact in Long Island Sound is not changed when the appropriate factors are applied (**Table 7**). The WLAs for each facility in both Connecticut and New York are identified in Appendix C.

Table 6. In-basin Phase III nitrogen TMDL/WLA/LA by management zone.

Manage-ment Zone	Point Source Load (tons/yr)[a]	Nonpoint Source Load (tons/yr)[b]	Total Nitrogen Load (tons/yr)	WLA Target Load (tons/yr)	LA Target Load (tons/yr)	Load Reduction from Baseline (tons/yr)
1	1243	1852	3095	454	1787	854
2	2805	2473	5278	1024	2350	1904
3	2103	999	3102	768	937	1397
4	1669	1652	3321	609	1575	1137
5	948	475	1423	346	443	634
6	1108	545	1653	404	506	743
7	837	190	1027	325	172	530
8	18081	0	18081	7504	0	10577
9	9417	0	9417	3908	0	5509
10	484	275	759	175	252	332
11-west	191	393	584	37	357	190
11-east	14	34	48	2	31	15
Total	38900	8888	47788	15556	8410	23822

[a] Total Point Source nitrogen (WWTP and CSO) from Table 1.

[b] Total Nonpoint Source nitrogen (Pre-Colonial, terrestrial and atmospheric) from Table 1.

[c] Management Zone 11 has been split into two sub-zones.

Table 7. River delivery factors, Long Island Sound transport factors, and calculated equivalency factors that combine river and Long Island Sound effects for in-basin management zones and tiers.

Zone-Tier1	River Delivery Factor	LIS Transport Efficiency	Combined Equivalency Factor
1-1	1.00	0.17	0.17
1-2	0.91	0.17	0.15
1-3 Quinebaug	0.75	0.17	0.13
1-3 Shetucket	0.83	0.17	0.14
2-1	1.00	0.20	0.20
2-2	0.93	0.20	0.19
2-3	0.87	0.20	0.17
2-4	0.81	0.20	0.16
3-1	1.00	0.55	0.55
3-2	0.83	0.55	0.46
4-1	1.00	0.62	0.62
4-2 Housatonic	0.69	0.62	0.43
4-2 Naugatuck	0.90	0.62	0.56
4-3 Housatonic	0.52	0.62	0.32
4-3 Naugatuck	0.90	0.62	0.56
5-1	1.00	0.79	0.79
6-1	1.00	0.93	0.93
7-1	1.00	0.83	0.83
8-1	1.00	0.21	0.21
9-1	1.00	0.11	0.11
10-1	1.00	1.00	1.00
11-1 West	1.00	0.94	0.94
11-1 East	1.00	0.55	0.55

See Figure 3 for location of zones and tiers. Factors are expressed as the decimal fraction of the nitrogen load delivered

Opportunities and priorities for source reductions will vary among and within management zones. For example, the states, working with affected municipalities, may reallocate the

WLA between two facilities within a management zone to take advantage of greater reduction opportunities at one facility versus another. Likewise, the states, working with affected municipalities, may reallocate the WLA between two facilities in different management zones as long as the new allocations result in equal or greater water quality improvements, as defined by the use of equivalency factors (**Table 7**). These adjustments and trades will affect the "edge of Sound" loading expressed as the TMDL/WLA/LA. For this reason, the TMDL "edge of Sound" loading may be adjusted on an ongoing basis, but will maintainan equal or greater DO improvement. These equivalency factors account for two nitrogen loss effects from discharge point to oxygen impact in Long Island Sound: 1) attenuation during river transport and 2) transfer efficiency from the "edge-of-Sound" to areas of hypoxia. Losses during river transport are generally modest except for the highly impounded Housatonic River where long travel times allow for almost a 50 percent loss from the upper reaches to Long Island Sound. In-Sound losses are high from the eastern half of Connecticut and the lower East River in New York City, mostly because of hydrodynamics that force much of the nitrogen from those areas out of the Sound through The Race and New York Harbor, respectively. Exchange ratios are a combination of the two effects and are presented as an equivalency factor that describes the portion of the nitrogen from a geographic area that has an effect on DO in the Sound.

Exchange ratios are a critical component of any reallocation or "trading" of nitrogen among the zones because they account for the relative impact of each zone's nitrogen load. Application of these ratios among sources preclude any compromise of the anticipated oxygen benefit for Long Island Sound when trades are made between management tiers or zones. In no case will a WLA be revised upward if it would cause localized adverse water quality impacts.

This flexibility to reallocate nitrogen source reductions among all sources as plans are formalized for each management zone or trading programs are implemented, is expected to result in significant cost savings and increase nitrogen control program efficiency. Revisions in the nitrogen loading numbers may include reallocations in the WLAs within a management zone and reallocations of WLAs among management zones using the equivalency factors, but, again, the total oxygen improvement expected in Long Island Sound will not be altered by any of those actions.

Any reallocations of LAs among management zones, or reallocations between WLA and LAs within and among management zones, will be reflected in a revised TMDL to ensure that there is a reasonable assurance that the modified LAs could be achieved. This approach could be modified pending development of a trading program that lays out the framework and requirements necessary to provide reasonable assurance on achievement of LAs.

The planned Phase III reduction target of 58.5 percent was applied to in-basin point and nonpoint sources using the LIS 3.0 unit response matrix described above. Phase III actions would also yield reductions in TOC, roughly 10 percent from both point and nonpoint sources. The DO improvement from the TOC reductions were also estimated using the LIS 3.0 unit response matrix. Compared with the base condition, the hourly minimum dissolved oxygen improvement would be about 1.9 mg/l in the critical cell of response region 2 (**Figure 3**) in New York waters and about 0.7 mg/l in the critical cell of response region 6 in Connecticut waters (**Table 8**). As discussed in section V.C.2., the LIS 3.0 model predicts that these reductions will improve oxygen levels in Long Island Sound considerably, raising the hourly minimum DO level to around 3.0 mg/l in the New York critical cell and to 4.1 mg/l in the Connecticut critical cell (**Table 8**).

The WLA/LA is a cap on nitrogen discharges. Once the WLA/LA is achieved, any population growth and development would need to be offset by additional treatment to stay within the WLA/LA cap. For example, a growing community might need to further upgrade wastewater treatment capabilities to achieve additional nitrogen removal.

Table 8. Comparison minimum hourly DO concentrations (in mg/l) in Connecticut and New York, relative improvement in DO, and maximum area (mi^2)with DO below 3.5 mg/l for baseline, Phase III, Phase IV, and Phase V.

Scenario[1]	Hourly Minimum DO in NY Waters[2]	DO improvement over Baseline in NY Waters	Hourly Minimum DO in CT Waters[2]	DO improvement over Baseline in CT Waters	Maximum Area (mi^2) with DO less than 3.5 mg/l
Baseline	1.1	0.0	3.4	0.0	200
Phase III	3.0	1.9	4.1	0.7	60
Phase IV load reductions	3.5	2.4	4.3	0.9	0
Phase V	5.0	3.9	6.0	2.6	0

[1] Oxygen responses are cumulative for each scenario, i.e., Phase V = Phase III actions + Phase IV load reductions + Phase V non-treatment alternatives.

[2] Hourly minima were taken for the critical cell (lowest DO concentration) within response region 2 for NY and response region 6 for CT (refer to **Figure 3** for response region locations).

It should be noted, however, that the watershed is generally well developed already and population growth is forecasted to be relatively modest. For example, population growth in Connecticut is predicted to be slow over the next ten years, picking up somewhat in the 2010 to 2020 period, according to Connecticut's Office of Policy and Management[31]. Population is expected to remain static through the year 2000 and grow only 1.5 percent between 2000 and 2010. Estimated growth between 2010 and 2020 is 6.4 percent. Between 2000 and 2015, projected population will grow from 3,316,120 people to 3,512,240 people, nearly a six percent increase during the Phase III nitrogen implementation period.

2. Reasonable Assurance for Load Allocation

EPA guidance requires that the TMDL/WLA/LA provide reasonable assurance that wet weather runoff controls will be implemented and maintained and are sufficient to achieve the LA. Establishing reasonable assurance that the load allocation can be achieved requires that 1) the load allocation be technically achievable and 2) the programs and controls to be implemented that are sufficient to meet the load allocation are identified.

As described in Appendix B, the LA was calculated based upon achieving a 10 percent reduction in the total nonpoint source load of nitrogen from urban and agricultural land covers. Forested land was not included because opportunities for applying structural and nonstructural best management practices within this land cover are considered to be limited. The 10 percent reduction level reflects both the effectiveness of urban and agricultural controls in controlling nitrogen[32,33] and the rate at which such controls can be applied in the region.[34] It represents an aggressive and costly, but technically feasible, reduction target. However, it is difficult to ensure, *a priori*, that implementing nonpoint source controls will achieve the projected nitrogen load reductions because of the nature of nonpoint source pollution. Nonpoint sources are difficult and costly to quantify, monitor, and manage and are subject to wide variations in loading forced by weather conditions. To meet the load allocation requirements of the TMDL, both Connecticut and New York plan to use existing pollution control programs and closely coordinate the efforts and authorities of state water quality and coastal zone management programs. The approach will be to implement specific, required management measures, where not already in effect, to reduce nitrogen loads to Long Island Sound at federal, state, and municipal levels, as appropriate.

Both states' control activities will draw heavily from the recent Coastal Zone Management Act Reauthorization Amendments (CZARA) nonpoint source plans developed as required by Section 6217. The Coastal Nonpoint Pollution Control Programs provide for the implementation and enforcement of management measures, either through existing or new authorities, many of which will effectively reduce nitrogen loads. Additional activities that will benefit nonpoint nitrogen control efforts include the states' Nonpoint Source Management Plans and Programs, rivers restoration and watershed group activities, stormwater permitting, and implementation of TMDLs for other impaired waterbodies. In some cases, the States will augment programs relevant to nonpoint source pollution control to meet the nitrogen load allocation. However, in most cases, the only need that exists is to further strengthen the relationship between the various programs and agencies, and not create new authorities.

Connecticut plans to track nonpoint source implementation activities in two ways: 1) use of ambient monitoring network data in Connecticut that will give general trend indication in watershed areas and 2) use of a statewide watershed model under development that will estimate gross benefits of applied best management practices. These two mechanisms will help ensure nonpoint source management progress is meeting TMDL requirements. New York will monitor application of BMPs and use existing embayment monitoring networks to ensure that the TMDL nonpoint source nitrogen reductions are being met. Continued monitoring of Long Island Sound waters will further document the benefits of nitrogen control activities over the next 15 years.

Urban land uses located closest to the Sound and its major tributaries are estimated to contribute the most nonpoint source pollution to coastal waters. Thus, both States' nonpoint nitrogen control efforts will focus on urban sources that are proximate to Long Island Sound and its major tributaries. This nonpoint management effort will be implemented over a 15-year time span, which will allow the States to adjust and augment existing programs to address the most pressing nonpoint sources first, directing and redirecting limited resources as available and as necessary. Nonpoint source efforts will undoubtedly become more important in later years within the 15-year time frame as less costly, point source management actions are first implemented. Opportunities for trading nitrogen load reductions, even between point and nonpoint sources, is an option that will be further investigated. Implementation of the Clean Air Act will augment Phase III, on-the-ground nonpoint source nitrogen reductions substantially as nitrogen deposition levels decrease in coming years.

The following is a list of new or enhanced efforts that the states will ultimately undertake to control coastal nonpoint source pollution as part of the 6217 plans. These efforts will also control nonpoint nitrogen and provide a foundation for the efforts to meet the TMDL load allocation.

- Expand the Stormwater General Permit program, including enhanced monitoring, to address stormwater runoff from urban areas not currently covered.
- Seek further nitrogen reductions through the implementation of the Phase II Stormwater Program.
- Establish a program to improve urban stormwater collection systems to treat runoff and trap sediments.
- Continue ongoing opportunities to provide technical assistance to municipal land use officials and their staff to address nonpoint source impacts from new and existing development.
- Improve the monitoring and tracking of septic system performance in areas close to coastal waters;
- Expand upon the Connecticut priority areas identified in the Long Island Sound Study for nonpoint source pollution control on a watershed-by-watershed basis, addressing impacts through various methods including coastal site plan review, Section 319 demonstration projects, river restoration projects, and tidal wetlands/riparian wetlands restoration projects.
- Make priority use of Connecticut's Clean Water Fund to finance ongoing CSO abatement programs in Bridgeport, New Haven, Norwich, Norwalk, Middletown and Hartford and expand the Clean Water Fund to address nonpoint sources, particularly in coastal areas.
- New York, through the Clean Air/ Water Bond Act, will provide funds for projects that reduce nitrogen from point and nonpoint sources.
- New York will coordinate takeoffs between sewered and unsewered areas for cost sharing of point and nonpoint controls.

Both states are embarking on watershed management approaches that will enhance nonpoint source control activities. As part of these programs, watershed management processes are being developed that include the eleven management zones. While watershed management activities are broadly-based to include all water quality and quantity issues, they will consider the 15-year nitrogen reduction plan, the role of trading, and how control activities will be monitored and tracked. Enforceable mechanisms are already in place, as elaborated in the states' Coastal Nonpoint Pollution Control Program and

Nonpoint Source Management Plans. The States have already taken major steps to include nitrogen control needs in the plans and in Clean Water Act Section 319 and Bond Act projects that have been funded.

B. Out-of-basin Sources

1. Allocation of the Out-of-Basin TMDL

Tributary nitrogen enrichment can be reduced by about 1,173 tons per year (delivered to Long Island Sound) through the application of through low-cost BNR retrofits of existing sewage treatment plants (resulting in a 25 percent reduction in point sources) and urban and agricultural nonpoint source controls (resulting in a 10 percent reduction) throughout the Long Island Sound basin north of Connecticut. Additional benefits from implementation of the CAA will reduce basinwide nitrogen loads by another 1,524 tons per year, an 18 percent reduction in the atmospheric nitrogen enrichment.

The reduction to atmospheric deposition is consistent with Regional Acid Deposition Model (RADM) estimates associated with the regional NOx SIP (state implementation plan) call.[35, 36] Not quantified, but possibly very important, are atmospheric nitrogen loads deposited on the Atlantic Ocean that are transported into the Sound. A rough estimate of reductions would suggest that the CAA would reduce enriched nitrogen transport through the boundaries by 5 percent.

Based on the unit response matrix analysis, these additional “Phase IV” basinwide nitrogen and carbon reductions, in combination with the Phase III reductions, would result in a dissolved oxygen improvement of 2.4 mg/l over the baseline condition in the critical cell of response region 2 in New York and 0.9 mg/l in the critical cell of response region 6 in Connecticut (**Table 8**). No area of Long Island Sound would be left with DO concentrations less than 3.5 mg/l.

In addition to scheduled CAA activities, the EPA must work with states contributing atmospheric deposition to the Long Island Sound watershed to develop an approach and schedule to achieve a further reduction (e.g., perhaps 50 percent or more in keeping with aggressive reductions required for point and nonpoint sources in CT and NY) in atmospheric sources to the Sound. A more aggressive approach to atmospheric nitrogen management, such as a 50 percent reduction, could reduce nitrogen loads to Long Island Sound by another 2700 tons/year beyond CAA requirements. This would not only increase the margin of safety, but would help address other oxides of nitrogen emission problems including acid effects on lakes, and forests and ozone noncompliance in northeastern states. It is also likely that more aggressive emissions controls through federal EPA coordination and enforcement will be a key component of future TMDLS required when nutrient criteria are developed and state standards are adopted. Because New York and Connecticut cannot enforce nitrogen reductions from point and atmospheric sources in other states in the Long Island Sound TMDL process, EPA will need to take the lead on future interstate WLA/LA needs.

2. Reasonable Assurance for Load Allocation

The 10 percent nitrogen reduction target for terrestrial nonpoint sources located out-of-basin is the same as the target for in-basin sources. As a result, the technical achievability of the load allocation for in-basin loads discussed in Section VI.A.2. applies to the out-of-basin load allocation as well and is not repeated here. To achieve the out-of-basin load allocation, EPA and the states of New York and Connecticut will coordinate with the out-of-basin sources and states to establish targets and schedules. This is discussed in more detail in Section VII. D. (implementation of Phase IV).

The atmospheric nonpoint source reduction is derived from the RADM estimates and will be partially implemented and enforced through the NOx SIP call. Additional atmospheric nitrogen controls, to achieve reductions in the range of 50 percent, should be evaluated, planned, and implemented, as appropriate, by EPA. These controls should precede any use of the alternative technologies that are discussed below. The point source load reduction of 25 percent is achievable through low-cost retrofits of existing facilities and will also be pursued by EPA and the states of New York and Connecticut with the out-of-basin sources and states to establish targets and schedules.

C. Non-treatment Alternatives

1. Background

As outlined in 40 CFR 125.3(f), the use of non-treatment alternatives may be considered as a method of achieving water quality standards on a case-by-case basis when technology-based treatment requirements applicable to the discharge are not sufficient to achieve the standards. Such techniques must be the preferred environmental and economic method to achieve standards after consideration of alternatives, such as advanced waste treatment and other available methods.

As demonstrated in this TMDL, the technology-based treatment requirements are not sufficient to achieve the DO standards in Long Island Sound. WLAs requiring advanced waste treatment are identified. However, as discussed in Section V.C.2, based on analyses that have been performed to date, nitrogen reductions at the current limit of technology to sources within the New York and Connecticut portions of the watershed will not *fully* achieve water quality standards during the summer in the bottom waters of the Sound. Therefore, this TMDL additionally identifies nitrogen reductions to out-of-basin sources *and* the use of non-treatment alternatives to achieve water quality standards.

The LISS has assessed different non-treatment alternatives for improving DO levels[37,38,39]. Among those considered were mixing/aeration of the western Long Island Sound, installation of tide gates at Throgs Neck[40], creation of artificial wetlands to treat stormwater runoff, and alternative discharge locations for New York City sewage treatment plants[41], such as New York Harbor or the Bight. These preliminary assessments conclude that non-treatment alternatives can practicably be implemented from a technical standpoint. However, at this point in time there is still an inadequate basis for determining which one(s) would be the preferred environmental and economic alternative(s) to employ as part of the overall hypoxia management effort. Additional study is needed to assess the utility, feasibility, consequences, and economics of the different alternatives.

As a result, this TMDL identifies the different alternatives, provides perspective on the potential of each to contribute to standards attainment, and identify the process and schedule for evaluating and demonstrating the preferred environmental and economic alternative(s) necessary to satisfy 40 CFR 125.3(f). The TMDL also highlights the schedule to employ the non-treatment alternatives (in the event they are still necessary after earlier phases are implemented) as Phase V actions.

2. Preliminary Assessment of Alternatives

Non-treatment alternatives range from those that could be employed on a small, local scale to large, engineered alternatives that would have far-ranging, even Soundwide effect. None of these alternatives have been fully assessed for environmental benefit or impact. The complexity of evaluation increases with the scale and potential consequences of the project. This section will highlight, in alphabetical order, some of the alternatives that have been reviewed and identify some of the issues that would require further assessment (**Table 9**).

Altering the Basin Morphology of The Sound: Dredging the Mattituck Sill, East River, and Hempstead Sill may increase water circulation in the Sound. Like tide gates, this option has the potential to alter the ecosystem of the Sound, resulting in consequences that are difficult to predict.

Artificial Wetlands: Creating artificial wetlands can provide treatment for stormwater runoff entering Long Island Sound. Artificial wetlands, if well designed and managed properly, may be able to remove nitrogen from runoff. However, it is, at best, a partial solution that can be incorporated into the overall nitrogen control strategy, complementing natural wetland protection and restoration efforts.

Mixing/Aeration of Bottom Waters: Mixing/aeration is a common technique in lake and reservoir management and has been applied on a smaller scale to marine harbors[42]. Locating mechanical aerators in hypoxia "hot spots" would introduce oxygen to oxygen-depleted waters. Aerators could also help break up vertical density stratification in the water column, allowing mixing of oxygen-rich surface waters with oxygen-depleted bottom waters. Although impractical for large areas, this alternative may have application after planned nitrogen reductions have reduced the areal extent of hot spots. The LIS 3.0 model predicted that approximately 125 model segments would not meet the Long Island Sound DO standards after the Phase III and Phase IV reductions. The New York City Department of Environmental Protection performed a planning level analysis of mixing/aeration alternatives for the East River and western Long Island Sound[43]. The analysis concluded that a number of boat-based aeration alternatives were feasible, with capital costs ranging from $200-250 million, but that pilot testing would be required before proceeding with design. Based on information from that analysis, it has been estimated that at least 10,000 lbs./day of oxygen per segment is needed to attain applicable water quality standards[44]. While mixing/aeration has been successfully applied elsewhere on a smaller scale and could theoretically attain water quality standards, the practicality of applying it on the scale discussed here will require additional evaluation.

Relocation of Sewage Treatment Plant Outfalls: This alternative involves redirecting New York City sewage treatment plant outfalls from the East River to New York Harbor or the Atlantic Ocean. The New York City Department of Environmental Protection has studied relocation of outfalls from the East

River toward the Atlantic Ocean via a tunneled outfall[41]. The use of deep tunnels for sewage effluent disposal has been employed in a number of locations, notably Florida and, more recently, Boston Harbor. Outfall relocation would reduce nitrogen levels in the East River and alleviate hypoxia in Long Island Sound. The costs of outfall relocation would depend on the discharge point and associated conditions for tunneling but would range in the hundreds of millions of dollars. While a demonstrated alternative in practice elsewhere, relocation of the East River outfalls still needs further evaluation. Of particular concern would be changes in salinity in the western Sound that might affect the health of oyster beds, creating more favorable conditions for parasites or disease.

Seaweed Farms: Raising benthic macro algae (seaweeds) may help alleviate the hypoxia problem by removing nitrogen from the water column through biological uptake. As with creation of artificial wetlands, seaweed farms are at best a partial solution that can be incorporated into an overall nitrogen management plan.

Tide Gates: Tide gates have been proposed to prevent the tidal inflow of water through the East River into Long Island Sound. Preliminary estimates by two engineering firms placed construction costs at $500 million to $1 billion. Some of the cost could be defrayed if the tide gate served a dual purpose, such as providing a structure for a railroad crossing. Operational costs are anticipated to be relatively low. While this option would flush Long Island Sound with cleaner Atlantic Ocean water, it has the potential to change the ecosystem in the western Sound. Salinity changes and the effect on oysters along with migratory fish disruptions are among the key concerns.

3. Evaluation Steps and Schedule

This TMDL analysis must, by law, describe the process for achieving water quality standards. The TMDL goes beyond Phase III (58.5 percent nitrogen reduction) implementation by describing additional nitrogen reduction actions from sources outside of the Connecticut and New York portions of the watershed, reductions in atmospheric deposition through CAA emission controls, more aggressive actions that could be taken by EPA to control both water and atmospheric out-of-state sources, and non-treatment alternatives to further reduce nitrogen levels or to directly increase DO.

Each of the suggested non-treatment alternatives requires additional engineering and scientific analysis and negotiation among federal and state regulatory agencies. Some of the alternatives could function on a small scale, providing some incremental improvement in DO levels. Others, such as mixing/aeration and outfall relocation, would require large capital outlays and, based on existing analyses, could result in full attainment of water quality standards.

The non-treatment alternatives will be further analyzed according to the steps and schedule presented in Section VII. E. The non-treatment alternatives to control low DO will be assessed, with a focus on model analysis and pilot testing, as appropriate. Conclusions on the necessity of the non-treatment options, the preferred environmental alternative(s), and an implementation schedule will be presented in the next phase TMDL. The next phase of the TMDL is planned after promulgation/adoption of the revised marine water dissolved oxygen criteria and assessment of progress in achieving the first 5 year nitrogen reduction targets. The Systemwide Eutrophication Model (SWEM), which encompasses the

New York/New Jersey Harbor, the Bight, and Long Island Sound provides a tool to assess regional impacts from these alternatives.

Table 9. Alternative strategies for hypoxia management.

Alternative	Advantages	Disadvantages
Altering Basin Morphology	-Increases bottom water renewal from the Atlantic Ocean -Can be implemented in phases -Potential source of sand for beach nourishment -Technologically simple	-Disposal of any contaminated dredged material -Salinity alterations -Expense -Adverse effects on coastal erosion -Changes in characteristics of surface sediments and benthic communities in dredged areas
Artificial Wetlands	-Removes nitrogen -Filters out contaminants -Provides valuable shoreline habitat	-Limits public access to the shoreline -Presents potential land use conflicts -Requires large area to have a measurable benefit
Mixing and Aeration of Bottom Waters	-Direct solution to hypoxia -Easy to operate -Flexible deployment -Relatively low capital costs -Proven successful in small scale operations -Can be switched on and off	-Resuspension of sediments and associated chemical contaminants -Disruption of marine organism movement and migration -May eject bacteria and viruses into the atmosphere -Bubbles create froth on the water's surface -Long-term maintenance of mechanical equipment -Cost of intense energy requirements
Relocation of Sewage Treatment Plant Outfalls	-Improves dissolved oxygen in western LIS and the East River -Reduces toxic contaminant loading in the East River -Cost-effective -May reduce CSO impacts	-Adverse water quality impacts at new discharge locations -Increases nutrients to the New York Bight and Raritan Bay; -Changes in flora, fauna and fish migration patterns -Salinity and temperature alterations -Adverse effects at Atlantic Ocean beaches -Habitat disturbance near discharge diffuser field
Seaweed Farms	-Removes nutrients from the water column -Photosynthesis may increase DO -Proven success of seaweed farms -Market exists for seaweed products	-Limited effect on the hypoxia problem -Not demonstrated to be feasible for Long Island Sound -Floating structures may interfere with navigation.
Tide Gates	-Flushes Long Island Sound and New York Harbor with cleaner Atlantic Ocean water - Increases water circulation in the Sound and adjacent water bodies -Reduces pollutants entering the Sound from NY Harbor	-Affects tidal heights and currents -Potential impact on flora, fauna and fish migration -Salinity and temperature alterations -Increases pollutant transport to the New York Bight -Impedes vessel navigation in the western Sound.

D. Margin of Safety

TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between pollutant loads and water quality. EPA guidance explains that the MOS may be implicit, i.e., incorporated into the conservative assumptions used in the analysis, or explicit, i.e., expressed in loading set aside as a separate component of the TMDL (TMDL = WLA + LA + MOS). This TMDL uses an implicit MOS through the use of conservative assumptions in the analysis such as the use of the 1988-89 worst case scenario as the base condition and safety factors in the calculation of aeration levels.

The most important implicit assumption is the use of 1988-89 as the base condition. As discussed in Section V.C., based upon the annual surveys from 1986-1998 and a review of the historical data[17, 18], the 1988-1989 modeling time frame was the most severe period of hypoxia on record. While nitrogen loads are related to the amount of phytoplankton growth, physical factors, such as the degree of stratification in the water column, affect the degree to which the decay of that phytoplankton results in hypoxic conditions in Long Island Sound[17]. As a result, model simulations of reduced nitrogen inputs will predict water quality conditions that would result during the same physical conditions that existed during the 1988-89 period. Average year conditions would predict better water quality conditions. Since the water quality model is calibrated to the severe conditions that existed in 1988-89, the level of nitrogen reduction identified in conjunction with non-treatment alternatives is conservative, providing a margin of safety (MOS) for average years.

Another implicit assumption in this TMDL is the use of safety factors in the calculation of aeration levels necessary to disrupt stratification[45] or for other non-treatment alternatives. This provides a margin of safety in achieving water quality standards for DO.

E. Seasonal Variations

An important factor in the TMDL analysis is to adequately account for seasonal variations in pollutant loading and water quality. This requires accounting for seasonal variations in any modeling analyses, identifying whether a critical period for attainment of water quality standards exists, and, if so, basing the TMDL on that critical condition.

As identified in Section V.C., the LIS 3.0 water quality model was calibrated using ambient monitoring data collected over the eighteen-month period from April 1988 through September 1989. The eighteen-month calibration period covers all seasons of the year; actual hydrological and meteorological conditions for that time period were input into the model. Tributary loadings and combined sewer overflows were also determined using time-variable rainfall and river flow data. Other factors that influence external boundary conditions and internal circulation within the Sound, such as hydrological and meteorological conditions (seasonal variations, such as wet and dry weather conditions) have been considered and are included in the model.

As previously discussed, hypoxia in Long Island Sound typically occurs from June through September in below pcynocline waters. This TMDL uses the minimum hourly DO concentrations simulated by the LIS 3.0 model during the summer hypoxic period as a baseline to assess actions necessary to attain water quality standards. Furthermore, the 1988-1989 modeling time frame was the most severe period of hypoxia on record. Model simulations of reduced nitrogen inputs will predict water quality conditions that would result during the same physical conditions that existing during the 1988-89 period. Average year conditions would predict better water quality conditions. As a result, this TMDL is based on the critical condition in Long Island Sound on both seasonal and inter annual scales.

F. Total Maximum Annual versus Daily Loads

CWA Section 303(d) requires the establishment of TMDLs for pollutants that will result in the attainment of water quality standards. As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measures. As presented in Section V.C., nitrogen loadings throughout the year contribute to the pool of nitrogen available for uptake by phytoplankton. Hypoxia resulting from the ultimate decay of that phytoplankton is not sensitive to daily or short term nitrogen loadings. Daily load allocations are not necessary to ensure that standards are met. Instead, DO levels are a function of annual loading rates. While hypoxia generally occurs from June through September, nitrogen loadings throughout the year contribute to the pool of nitrogen available for uptake for phytoplankton. The LIS 3.0 model did not show a strong relationship between hypoxia and the seasonality of nitrogen loads to Long Island Sound that would warrant special attention to seasonal management of nitrogen. This is because algal growth occurs over seasonal and annual cycles where the total pool of nitrogen available is the critical factor. This supports the use of a maximum annual load used in this TMDL, rather than seasonal or daily load limits. Therefore, the TMDL/WLA/LA is presented as an annual load in tons per year.

G. Summary

Based on this analysis, DO standards in both New York and Connecticut waters of Long Island Sound would be attained through the implementation of the phased TMDL that would include reductions in nitrogen and TOC loading from in-basin and out-of-basin sources and supplementary non-treatment alternatives (**Table 8**). Improvements in DO from nutrient management would yield 2.4 mg/l in the critical cell in New York waters, most of it (1.9 mg/l) gained from Phase III implementation. Similarly, the critical cell in Connecticut waters would improve by 0.7 mg/l from Phase III implementation plus another 0.2 mg/l from Phase IV nutrient control. Despite these significant gains in nutrient control that approach limit of technology applications and the use of supplementary actions for out-of-basin sources, non-treatment alternatives that were discussed in Section VI C. would be required to attain existing state DO standards for Long Island Sound.

To summarize: TMDL = Phase III in-basin nitrogen WLA/LA + Phase IV out-of-basin nitrogen WLA/LA and in-basin and out-of-basin atmospheric loads + Phase V non-treatment alternatives + Implicit Margin of Safety

Where:

Phase III in-basin nitrogen WLA = 15,556 tons/yr

(Point sources from CT and NY reduced from 38,900 tons/yr by 23,344 tons/yr to a WLA of 15,556 tons/yr)

Phase III in-basin nitrogen LA = 8,410 tons/yr

(Total nonpoint sources from CT and NY reduced from 8,888 tons/yr by 478 tons/yr to a LA of 8,410 tons/yr)

Phase IV in-basin and out-of-basin WLA = 17,799 tons/yr

(Phase III in-basin load of 15,556 tons/yr WLA plus an out-of-basin WLA of 2,243 tons/yr. The out-of-basin reduction is 25 percent or 748 tons/yr from the 2,991 ton/yr baseline)

Phase IV in-basin and out-of-basin LA = 54,440 tons/yr

(Phase III in-basin LA of 8,410 tons/yr, plus out-of-basin load of 10,574 tons/yr, plus deposition directly on Long Island Sound of 5,485 tons/yr, plus boundary load of 33,600 tons/yr for a total of 58,069 tons/yr reduced by out-of-basin nonpoint sources and atmospheric sources basinwide, including boundary load reductions, of 3,629 tons/yr) (More aggressive atmospheric reductions coordinated by EPA could reduce the Phase IV LA by another 2,700 tons/year)

Phase V non-treatment alternatives (e.g., mixing/aeration = 10,000 lbs./day/segment not meeting standards; relocation of East River STP discharges to the Atlantic Ocean)

Implicit Margin of Safety =Nitrogen reductions were calculated based on worst hypoxia years on record to provide a MOS for average year conditions and safety factors were used in the estimation of non-treatment alternatives to obtain water quality standards.

VII. Implementation

This section presents a schedule for commitments to 1) achieve the Phase III nitrogen reduction target for in-basin sources; 2) establish and begin to implement Phase IV hypoxia management efforts for out-of-basin sources 3) evaluate and implement Phase V non-treatment alternatives, as necessary, to attain water quality standards; and 4) refine management actions, as appropriate, considering new information. It's envisioned that any changes to commitments 1 and 2 will be made only upon completion of the first five-year evaluation in February 2003. Any changes will be incorporated, as appropriate, in a revised TMDL by August 2003.

The phased implementation of this TMDL continues the principle of *adaptive management* adopted by LISS. Considerable progress in understanding causes and consequences of hypoxia has been made over the last decade; similarly, much more is known about nitrogen removal technologies at sewage treatment plants and BMPs for the control of a wide range of nonpoint source and stormwater pollutants, including nitrogen. Management efforts in Connecticut and New York have benefitted from adaptive management techniques. As they have become more progressive, the implementation phases have built upon the higher level of scientific certainty that the research and pilot studies have provided.

Adaptive management is especially critical to the success of achieving this TMDL because attaining water quality standards would require nitrogen reduction beyond the limits of current technology. It is expected that, over time, treatment technology will continue to improve, amendments to national and state air and water legislation will be enacted, and new and innovative funding sources will become available. The states of New York and Connecticut are prepared to respond to these changes. Similarly, EPA should begin to take more aggressive steps to control out-of-state air and water sources of nitrogen, in keeping with the level of understanding of their relationship to hypoxia in Long Island Sound.

Hypoxia management Phases I, II, and III were outlined in the introduction to this document. Each are briefly reviewed here along with the additional phases necessary to attain water quality standards.

A. Phase I

In 1990, under the LISS Phase I Program, nitrogen loads in key contribution areas were retained at 1990 levels to prevent the hypoxia problem from getting worse in the Sound. With the inclusion of an increase in nitrogen loads from New York City caused by the offshore ban on sewage sludge dumping, in-basin nitrogen enrichment stabilized at about 48,000 tons/year (**Table 10**), the baseline from which this TMDL is built.

Table 10. Changes in in-basin nitrogen loads to Long Island Sound with Phases of implementation.

Condition	Load (tons/yr)	Percent Change
Base [a]	47,788	0
Ph. II [b]	43,888	-8.2
Ph. III (1998)[c]	23,966	-50

a 1990 load plus increase in NYC from the offshore disposal ban.
b Reductions achieved by 1997 from Phase II retrofits.
c The 58.5% reduction is calculated against the in-basin point and terrestrial nonpoint source load of 40,741.7 tons/yr, which excludes atmospheric, tributary, and boundary sources of nitrogen enrichment.

B. Phase II

The Phase II action plan was developed and immediately went into effect in 1994 to improve DO levels in the Sound. The Phase II plan consisted of a series of low cost sewage treatment plant retrofits using a variety of biological nitrogen removal technologies at selected facilities. By 1997, these actions had reduced the annual load from peak levels by an estimated 3,900 tons (**Table 10**).

C. Phase III

In February 1998, the LISS Management Conference adopted *Phase III Actions for Hypoxia Management*. Phase III sets a 58.5 percent reduction target from in-basin, point and terrestrial nonpoint source nitrogen loads (40,742 tons/yr), or a 23,834 ton/year reduction from the baseline load. This would bring annual, enriched loads of nitrogen enrichment close to 24 thousand tons/year (**Table 10**), a 50 percent reduction from the baseline. Implementation will occur within a 15-year time frame with five-year incremental targets:

August 2004	First 40 percent of the 58.5 percent reduction = 23.4 percent reduction = 9,534 tons/yr removed
August 2009	Total of 75 percent of the 58.5 percent reduction = 43.9 percent reduction = 17,876 tons/yr removed
August 2014	Full 100 percent of the 58.5 percent reduction met = 23,834 tons/yr removed

A complete implementation schedule for the TMDL is provided in **Table 11**. August 1999 marks the beginning of the 15-year implementation schedule. By August 2000, the states will propose modifications to NPDES permits for point sources and commit to appropriate nonpoint source reduction actions to meet the 5-year nitrogen reduction target. This process will be allowed the flexibility to reallocate nitrogen reductions among sources as nonpoint management plans or trading programs are implemented. The total effect of the nitrogen reductions from all the management zones, however, will be the attainment of the 58.5 percent Phase III nitrogen reduction target adopted by the LISS within the 15-year time frame. The enforceable mechanism to ensure reductions are attained will be state and federal permitting programs.

Table 11. Implementation schedule for the Phase III actions.

Date	Action
Upon TMDL Adoption	Implementation schedule begins.
Within one year of TMDL adoption	Propose modifications to NPDES permits for point sources and commit to nonpoint source reduction actions
February 2003	LISS formally evaluates Phase III nitrogen reduction targets
August 2003	CTDEP and NYSDEC review and revise the TMDL, as appropriate
August 2004	Propose modifications to NPDES permits, as appropriate, for point sources
August 2004	Five year nitrogen reduction targets achieved.
February 2008	LISS formally performs second reevaluation of the nitrogen reduction targets
August 2008	CTDEP and NYSDEC review and revise the TMDL, as appropriate
August 2009	Propose modifications to NPDES permits, as appropriate, for point sources
August 2009	Ten year nitrogen reduction targets achieved
August 2014	Nitrogen reduction targets achieved

D. Phase IV

Phase IV actions reflect the fact that attainment of water quality standards is currently predicted to require pollutant reductions from sources outside of the portions of the watershed within New York and Connecticut. However, the degree to which additional pollutant reductions will be necessary has a higher degree of uncertainty than the Phase III in-basin reduction targets. Therefore, the Phase IV actions for the next five years focus on expanding the management framework for addressing these needs and capitalizing on available opportunities, such as reduction of atmospheric deposition. Phase IV also calls for a review of out-of-state air and water sources of nitrogen and, where feasible, nitrogen management actions coordinated by EPA.

As identified earlier as a Phase IV nitrogen reduction scenario (**Table 8**), 1) an estimated 18 percent basinwide reduction in nitrogen deposition is anticipated from implementation of the Clean Air Act, 2) a 25 percent reduction in the point source portion of the tributary nitrogen loads is anticipated from an aggressive out-of-basin point source control program, and 3) a 10 percent reduction of the urban and agricultural nonpoint source nitrogen portion of the tributary loads is anticipated from an aggressive out-of-basin nonpoint source control program. Concomitant TOC reductions are anticipated as part of the tributary nitrogen program. An estimated carbon reduction of 5 percent of the tributary point source load and 10 percent of the tributary nonpoint source load is anticipated. The Phase IV nutrient management effort would yield hourly minimum dissolved oxygen levels for the critical cell in response region 2 in New York of 3.5 mg/l and 4.3 mg/l for the critical cell in response region 6 in Connecticut, according to estimates based on the unit response matrix (**Table 8**).

Many of the actions necessary to achieve Phase IV reductions are based on existing programs. For example, programs required by the federal Clean Air Act (CAA) will yield significant NOx emission reductions from three sectors that contribute substantially to the NOx air pollutant loading. The three sectors are industrial point sources, on-road vehicles, and non-road engines, and the control programs affecting them are briefly described below.

Emissions from large industrial NOx sources will be controlled pursuant to several regulatory programs. The first program required the installation of Reasonably Available Control Technology (RACT) by most large industrial NOx air emitters by 1995. The second program was developed and implemented by States within the Ozone Transport Commission, which includes Connecticut, New York, and ten other eastern states. This program requires additional NOx reductions beyond those required by the NOx RACT program. The reductions from the Ozone Transport Commission program take effect between 1999 and 2003. The third program is commonly referred to as the NOx SIP call. This program consists of a NOx budget and allowance trading programs that caps NOx emissions and requires reductions across industry segments to meet the cap. Importantly, the NOx SIP call affects 22 States located in the eastern U.S., many of which are not members of the Ozone Transport Commission and therefore were not subject to the stringent NOx emission limits that organization has required. EPA has already proposed approval of New York’s plan to reduce nitrogen oxides pollution. In total, implementation of these three major control programs will result in a 75 percent reduction of 1990 baseline NOx emissions from these sources.

EPA recently undertook actions to significantly reduce NOx emissions from on-road vehicles by issuing tougher tailpipe emissions standards that take effect beginning in 2004. These “tier 2" standards represents the first time both cars and light-duty trucks will be subject to the same national pollution control system. The new standards will yield a 77 percent NOx reduction for cars and up to a 95 percent reduction for trucks and sport utility vehicles (SUVs). Although these requirements are phased in between 2004 and 2009, they only apply to new vehicles, and so the emission reduction benefit from the program will accrue incrementally each year as more and more new cars that meet these strict limits become part of the nation’s vehicle fleet.

In addition to the tier 2 program affecting cars, light-duty trucks, and SUVs, EPA issued a final rule in July 2000 for the first phase of its two-part strategy to significantly reduce harmful diesel emissions from heavy-duty trucks and buses. The new standards require diesel trucks to reduce NOx emissions by 40 percent compared to today's models. The second phase of the program will require cleaner diesel fuels and even cleaner engines, and will reduce air pollution from trucks and buses by another 90 percent. EPA expects to issue the final rule, to take effect in 2006-2007, for the second phase of the program by the end of this year.

Lastly, EPA is requiring NOx emission reductions from non-road diesel engines. Non-road diesel engines dominate the large non-road engine market and comprise approximately 25 percent of the current mobile source NOx emissions inventory. Examples of applications falling into this category include: agricultural equipment such as tractors; construction equipment such as backhoes; material handling equipment such as heavy forklifts; and utility equipment such as generators and pumps. Under EPA regulations, diesel engines greater than 50 horsepower (hp) must comply with Tier 1 emissions standards that are being phased in between 1996 and 2000, depending on the size of the engine. Under the Tier 1 standards, EPA projects that NOx emissions from new diesel non-road equipment will be reduced by over 30 percent from uncontrolled levels of unregulated engines.

Table 12. Phase IV actions and schedule.

Action	Schedule
1. EPA will coordinate with Connecticut, Housatonic and Thames River basins, Block Island Sound and NY Harbor states to identify nitrogen sources, evaluate the impact of the loads on DO in Long Island Sound, and establish a nitrogen (and carbon) reduction program and schedule.	Started January 1999
a) affected states, in cooperation with the LISS Management Conference, identify loads; enter into agreement to implement load reduction; assess removal costs on a facility basis; establish load reduction targets and schedule to implement point and nonpoint source reduction.	Finish August 2003
b) assess progress	Finish August 2008
c) assess progress	Finish August 2013
2. EPA and east coast/mid-west states coordinate implementation of reduction in air emissions of nitrogen required by the Clean Air Act. Identify baseline nitrogen loadings, verify the Northeast regional air quality model for transport and deposition of nitrogen, and establish a nitrogen reduction program and schedule. Potential air emission reductions should not be constrained by current CAA commitments, but should consider Long Island Sound needs and technological feasibility.	Started January 1999
a) verify air quality model; estimate air emission reductions under the CAA and estimate further potential reductions based on Long Island Sound needs and technological feasibility; establish schedule for implementation.	Finish August 2003
b) assess progress.	Finish August 2008
c) assess progress	Finish August 20013

Achieving reductions in point and nonpoint source loads from states north of Connecticut will require increased coordination and exchange of technical information between the Long Island Sound

Management Conference and those states. Some reductions in nonpoint source nitrogen loads are anticipated through the ongoing implementation of state nonpoint source management, stormwater permitting, and animal feeding operation (AFO) permitting programs. However, it will be necessary to conduct additional monitoring and assessment to better determine the relative importance of point and nonpoint sources, as well as the role of natural attenuation as the distance from Long Island Sound increases. Based on this assessment, the TMDL revision scheduled for 2003 will describe a framework for managing these out-of-basin sources and a schedule for implementing Phase IV nitrogen reduction actions. Because Phase III and IV overlap and are interrelated, Phase IV nitrogen reductions should be initiated as soon as interstate agreements on specific implementation actions are established. Several steps have been identified to assess and achieve nitrogen reductions from out-of-basin sources (**Table 12**).

E. Phase V

Attainment of water quality standards may require non-treatment alternatives in addition to pollution reductions. Phase V actions include the review, evaluation, and implementation, as needed, of non-treatment alternatives. Initial steps to assess non-treatment alternatives to attain water quality standards are described in **Table 13** and include assessments of the technical feasibility, cost, use conflicts, and adverse environmental consequences. Implementation steps for Phase V actions will be identified in a revised TMDL developed after the five-year evaluation described in the Phase III schedule and after all more traditional in-basin and out-of-basin air and water controls are fully considered.

F. Reassessment

A critical component of phased implementation is the reassessment of management goals and actions based on new information. The LISS *Phase III Actions for Hypoxia Management* also contains commitments to formally evaluate the 58.5 percent reduction target every five years, considering:

- the progress and cost of implementation, including a reevaluation of the knee-of-the-curve analysis used to establish the Phase III nitrogen reduction targets,
- improvements in nitrogen removal technology, including the results of quality controlled pilot projects,
- the feasibility and progress of Phase IV implementation, including potential for more aggressive out-of-state air and water nitrogen controls,
- the regional dissolved oxygen criteria to be published,
- review of states' water quality standards and their possible revision,
- refined information on the ecosystem response to nitrogen reductions,
- the results of peer reviewed modeling, and
- research on the impacts of hypoxia to living resources and their habitats.

As identified in the TMDL schedule (**Table 11**), New York and Connecticut will review and revise the TMDL based on this assessment by August 2003. Based on the analysis performed to date, the regional marine DO criteria and the revision of water quality standards will not affect the necessity of the Phase III nitrogen reduction targets for in-basin sources.

Table 13. Phase V actions and schedule.

Action	Schedule
1.LISS will further assess non-treatment alternatives to control low DO with a focus on model analysis	Start January 2001
a) expand analysis of alternatives using improved water quality models	January 2003
2. New York and Connecticut revise the TMDL, as appropriate, and include an assessment of the degree to which Phase V actions are required and a more detailed schedule for implementation.	August 2004
3. Conduct pilot testing, as appropriate	Start August 2004
a) complete pilot testing where, and as, appropriate	August 2006
4. Refine engineering and design based on pilot testing results	August 2007
5. Implement non-treatment alternatives, as appropriate.	Start August 2008

As discussed in Section III.C., the EPA marine DO criteria research suggests that chronic effects on aquatic life become most significant when DO falls below 3.5 mg/l, though some effects occur at levels between 3.5-5.0 mg/l. To ensure protection, the DO criteria will identify the level and duration of exposure between the 3.5-5.0 mg/l range. The LIS 3.0 model predicted that the Phase III nitrogen reduction targets would achieve hourly minimum DO levels of around 3 mg/l under 1988 conditions. As a result, it is very unlikely that the Phase III nitrogen reduction targets would be overly stringent in regard to protecting Long Island Sound resources, including a margin of safety, or to attaining water quality standards modified based on the regional marine DO criteria. However, the regional marine DO criteria will have major implications on the degree and scope of the Phase IV and Phase V actions necessary to attain water quality standards. Further, in-basin point source management is pushing toward the limit of technology, especially when growth is considered. If revisions in marine DO standards determine adequacy of Phase III actions alone to meet the standards, there still may be an urgent need to implement Phase IV, at least partially, to offset growth or to alleviate other water problems relevant to acid deposition, for example.

As part of the continuing assessment of the nitrogen and carbon loading estimates, the LISS provided fiscal year 1998-99 funding to estimate the trends in nonpoint nitrogen loads over the past ten years. The work will be conducted by the U.S. Geological Survey and will investigate the portion of the total nonpoint source load from direct groundwater flow to Long Island Sound. Additional detail on the steps to the reassessment are described in **Table 14**.

Table 14. Reassessment tasks and schedule for the Long Island Sound TMDL.

Task	Schedule
EPA to promulgate regional marine DO criteria applicable to LIS.	2000
LISS to assess up-to-date information on nitrogen and carbon loadings for point and nonpoint sources, evaluation of progress and cost of nitrogen load reductions, and improvement in technology	Ongoing from 1998-2003
a) LISS, in cooperation with USGS, to assess nonpoint nitrogen load over past ten years and investigate the contribution of direct groundwater flow of nitrogen to total loadings.	Start October 1998
LISS to assess ecosystem response to nitrogen reduction through enhanced water quality models and monitoring data. Complete assessment of the System Wide Eutrophication Model (SWEM), which encompasses all of NY Harbor, the NY Bight Apex, and LIS. Continue improvement of water quality models with new verification data sets.	Ongoing from 1998-2003
New York and Connecticut to revise DO standards for LIS, as appropriate	Finish August 2003
The LISS will assess Phase III in-basin nitrogen reductions against the revised DO standard to validate the Phase III nitrogen reduction targets and the Phase IV out-of-basin reductions, and non-treatment alternatives.	Start January 1999
New York and Connecticut revise the TMDL, as appropriate. More detailed schedules for Phases IV and V, including additional out-of-state actions coordinated by EPA, will be identified in the revised TMDL.	Finish August 2004

VIII. Public Participation

A. Phase III Implementation

There was extensive public participation in the process for developing the *Phase III Actions for Hypoxia Management*, which set the in-basin nitrogen reduction target of 58.8 percent and the approach for this TMDL. In addition to public participation within the LISS Management Conference, a 25-page report describing the proposal was prepared to support broader outreach efforts. The report, along with a standard form for submitting comments, and a public meeting schedule was widely distributed. The report was mailed to:

- The mailing list from *UPDATE*, the LISS Newsletter (3,555 pieces)
- 115 libraries in Nassau/Suffolk Counties
- Long Island Sound Watershed Alliance (LISWA) membership (365 pieces)
- Long Island Association Environmental Committee (60 pieces)
- Long Island Aquarium (50 pieces)
- Municipalities along the Sound shore throughout New York State
- Municipalities throughout Connecticut

Twelve public meetings to present the proposed Phase III Nitrogen Reduction Plan and receive comments from attendees were scheduled and held in September 1997 in New York and Connecticut:

New York	Oyster Bay	2 September
	New Rochelle	3 September
	East Setauket	4 September
Connecticut	Norwalk	9 September
	New Haven	10 September
	Groton	11 September

Afternoon (3:00 - 5:00 p.m.) and evening (7:00 - 9:00 p.m.) meetings were held at each site. Session attendance in New York ranged from a high of 23 attendees at the Oyster Bay and New Rochelle afternoon meetings to a low of 13 at the New Rochelle evening meeting. A total of 125 people attended the New York meetings. Connecticut attendance ranged from 25 at the afternoon meeting in New Haven to a low of seven at the evening meeting in New Haven. A total of 91 people attended the Connecticut meetings.

A substantial effort was made to inform the public of these meetings, including:

- announcement published in *UPDATE* newsletter and mailed to 3,555 addresses
- advertisement by LISWA
- press release sent to 280 on media list
- press release distributed to newspapers and electronic media
- public service announcements distributed to local radio and television stations

- meeting times and locations provided for various published calendars

In addition, the NYSDEC hosted a series of municipal briefings (Towns of Brookhaven, Huntington, Oyster Bay, and Smithtown, and Westchester County). Meetings with towns were with Town Supervisors and/or staff. The meeting with Westchester County was hosted by the Department of Planning, and was attended by Planning Staff and members of their Watershed Advisory Committees. CTDEP hosted five meetings in June 1997 with municipal officials and chief elected officials to introduce nitrogen management needs and the Phase III strategy to municipalities with sewage treatment plants. More than 50 municipalities sent representatives to the meetings and heard presentations by CTDEP and EPA staff on the Phase III strategy and implications for their communities.

B. Draft TMDL Review

This TMDL document was prepared jointly by CTDEP, NYSDEC and the EPA. The draft TMDL was subject to public review and comment separately by each state consistent with their respective public participation requirements.

On November 16, 1999, CTDEP and NYSDEC mailed the draft TMDL to local government representatives and interested parties in the Long Island Sound watershed. In addition, the TMDL document review was public noticed in the New York State Environmental Notice Bulletin (ENB) on 24 November 1999 as Region 1 and 2 notices and on 1 December 1999 as a statewide notice. CTDEP and NYSDEC established a 45-day public review period (ending January 9, 2000). At the request of some of the reviewers, CTDEP extended the comment period to January 28 and NYSDEC extended the comment period until February 9, 2000. The TMDL document was also made available through the CTDEP, NYSDEC and Long Island Sound Study web sites.

As a part of public participation process, CTDEP and NYSDEC held nine public meetings to discuss and answer questions on the TMDL (December 2 in East Setauket, NY; December 6 in Manhasset, NY; a.m. and p.m. sessions on December 7 in Hartford, CT, a.m. and p.m. sessions on December 8 in Groton, CT, a.m. and p.m. sessions on December 14 in Norwalk, CT, and December 15, 1999 in White Plains, NY). Staff from NYSDEC, CTDEP, and USEPA were present at these meetings. CTDEP and NYSDEC personnel discussed the issues relating to hypoxia (dissolved oxygen< 3.0 mg/l), nitrogen as the pollutant primarily responsible for low DO levels in Long Island Sound, listing of the Sound on the states' 303(d) list, and the development of TMDL document.

As a result of these efforts, NYSDEC received 13 comment letters and CTDEP received 20 comment letters. CTDEP and NYSDEC have prepared responses to those comments as a companion to this TMDL. All comments received on the draft have been considered in finalizing this TMDL. NYSDEC and CTDEP have prepared response summaries documenting all comments received on the draft and the response to those comments. The response summaries are part of the package to be submitted to EPA for review and approval.

C. Review of the Marine Waters DO Criteria

The states of Connecticut and New York will consider revision of their respective dissolved oxygen standards consistent with state administrative procedure requirements.

D. 2004 Revised TMDL Analysis

Upon adoption of revised dissolved oxygen standards by both states, the TMDL analysis will be revised. The reassessment supporting any changes was described at length in VII. E. This effort will be assisted by the information gathered during the evaluation of achieving the first five-year nitrogen reduction targets of the Phase III implementation actions, agreements reached to reduce out-of-basin nitrogen loads, and progress in atmospheric emission reductions. Both the assessment of implementation and preparation of the revised TMDL will be conducted with full public participation and stakeholder involvement.

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X. Glossary

Algae: Any organisms of a group of chiefly aquatic microscopic nonvascular plants; most algae have chlorophyll as the primary pigment for carbon fixation. As primary producers, algae serve as the base of the aquatic food web, providing food for zooplankton and fish resources. An overabundance of algae in natural waters is known as eutrophication.

Anoxic: Aquatic environmental conditions containing zero or little dissolved oxygen. See also anaerobic.

Assimilative capacity: The amount of contaminant load (expressed as mass per unit time) that can be discharged to a specific stream or river without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a water body to naturally absorb and use waste matter and organic materials without impairing water quality or harming aquatic life.

Bacterial decomposition: Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.

Best management practices (BMPs): Methods, measures, or practices that are determined to be reasonable and cost-effective means to meet certain generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Biochemical oxygen demand (BOD): The amount of oxygen per unit volume of water required to bacterially or chemically oxidize (stabilize) the oxidizable matter in water. Biochemical oxygen demand measurements are usually conducted over specific time intervals (5, 10, 20, 30 days). The term BOD generally refers to the standard 5-day BOD test.

Calibration: Testing and tuning of a model to a set of field data not used in the development of the model; also includes minimization of deviations between measured field conditions and output of a model by selecting appropriate model coefficients.

Designated use: Uses specified in water quality standards for each waterbody of segment regardless of actual attainment

Discharge permit (NPDES): A permit by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System (NPDES), under provisions of the Federal Clean Water Act

Dissolved oxygen (DO): The amount of oxygen that it dissolved in water. It also refers to a measure of the amount of oxygen available for biochemical activity in a waterbody and as indicator of the quality of that water.

Drainage basin: A part of the land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as watershed, river basin, or hydrologic unit.

Effluent: Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe or other conduit.

Estuary: Brackish-water area influenced by the tides where the mouth of the river meets the sea.

Eutrophication: Enrichment of an aquatic ecosystem with nutrients (nitrates, phosphates) that accelerate biological productivity (growth of algae and weeds) and an undesirable accumulation of algal biomass.

Eutrophication model: Mathematical formulation that describes the advection, dispersion, and biological, chemical and geochemical reactions that influence the growth and accumulation of algae in aquatic ecosystems. Models of eutrophication typically include one or more species groups of algae, inorganic and organic nutrients (N, P), organic carbon, and dissolved oxygen.

Hydrodynamic model: Mathematical formulation used in describing circulation, transport, and deposition processes in receiving water.

Loading, load, loading rate: The total amount of material (pollutants) entering the system from one source or multiple sources; measured as a rate in weight per unit time.

Load allocation (LA): The portion of a receiving water's total maximum daily load that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources.

Margin of safety (MOS): A required component of the TMDL, that accounts for the uncertainty about the relationship between the pollutant load and the quality of the receiving waterbody. This uncertainty can be caused by insufficient or poor-quality data or a lack of knowledge about the water resource and pollution effects.

Mathematical model: A system of mathematical expressions that describes the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one, or more, individual processes and interactions within some prototype\aquatic ecosystem. A mathematical water quality model is used as the basis for TMDL evaluations.

Nonpoint source pollution: Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, agricultural and forestry practices , and urban and rural runoff. Nonpoint source pollution may be transported in surface runoff and in ground water.

Nutrient: A primary element necessary for the growth of living organisms. Nitrogen, and phosphorus, for example, are nutrients required for phytoplankton growth.

Nutrient limitation: Deficit of nutrient (e.g., nitrogen an phosphorus) required by microorganisms in order to metabolize organic substrates.

Point source: Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities.

Three-dimensional (3-D) model: Mathematical model defined along three spatial coordinates (length, width, and depth) where the water quality constituents are considered to vary over all three spatial coordinates.

Waste load allocation (WLA): The portion of a receiving water's total maximum daily load that is allocated to one of its existing or future point sources of pollution.

Water quality: The biological, chemical, and physical conditions of a waterbody; a measure of the ability of a waterbody to support beneficial uses.

Water quality criteria (WQC): Water quality criteria are composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

Water quality standard (WQS): A law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

Watershed: The area of land from which rainfall (and/or snowmelt) drains into a stream or other waterbody. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground generally form the boundaries between watersheds.

Appendix A. Estimation of In-Basin Nonpoint Nitrogen Load and Load Allocation

Estimation of In-Basin Nonpoint Nitrogen Load

As described in Section V.B.2., the total nonpoint nitrogen load is composed of three categories: pre-colonial, terrestrial, and atmospheric sources. Estimates for each category were based on nitrogen runoff coefficients (for average rainfall years) applied to three general land covers (urban, agriculture, and forest) in the watershed. For Connecticut, the land cover data were generated by Civco et al. (1992) and were further refined by the Connecticut Department of Environmental Protection. Data for New York were from the Long Island Regional Planning Board (1978). The runoff coefficients were developed by calibrating export coefficients from the literature to monitored loads in test watersheds. This process was also used to develop attenuation rates for noncoastal tiers in the watershed. Included in the estimates is the enriched component of atmospheric deposition based upon the work done by Jaworski et al. (1992) and Miller et al. (1993). It is estimated that approximately 70 percent of nitrogen (nitrate component) deposition is enriched. The exceptions to this approach were in Management Zones 8 and 9, which were considered entirely CSO areas and were included in point sources.

Export coefficients (kg/ha/yr) used to derive pre-colonial, atmospheric, and terrestrial nonpoint estimates for three land cover types.

Land Cover	Pre-Colonial	Terrestrial	Atmospheric	Total
Forest	2.9	0.0	1.4	4.3
Agriculture	2.9	3.3	1.4	7.6
Urban	2.9	5.0	5.5	13.4

Calculation of Load Allocation

As described in Section V.A.1., the Load Allocation was calculated based upon achieving a 10 percent reduction in the total nonpoint source load of nitrogen from urban and agricultural land covers. Forested land was not included because opportunities for applying structural and nonstructural best management practices within this land cover are considered to be limited. The resulting reductions are listed below in Col. 4. The load allocation (LA) reduction target has been identified by subtracting Col.4 from Col.2 for each management zone.

Calculation of Load Allocation (tons/year)				
Management Zone	Nonpoint Total Load	Urban + Agriculture Load	10% of Urban + Agriculture Load	LA Target Load
1	1852	648	65	1787
2	2473	1231	123	2350
3	999	615	62	937
4	1652	772	77	1575
5	475	319	32	443
6	545	387	39	506
7	190	184	18	172
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	275	226	23	252
11-west	393	356	36	357
11-east	34	31	3	31
Total	8888	4769	478	8410

Appendix B Literature Cited

Civco, D.L., D.R. Miller, J.D. Hurd, and Y. Wang. 1992. Connecticut statewide land use and land cover mapping. Long Island Sound Research project CWF 219-R, Technical Completion Report. Dept. Nat. Resour. Mgmt. Engr., Univ. Conn., Storrs, CT. 44 p.

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Miller, D.R., N.P. Nikolaidis, L.H. Yang, M.A. Geigert, J. Heitert, and H.M. Chen. 1993. Technical report on the Long Island Sound atmospheric deposition project. Univ. Conn., Storrs, CT. 12 p.

Appendix B. Analysis of WLA and TMDL reduction effects through reallocation using equivalency factors.

One revision of the draft TMDL required by EPA, and suggested in many of the public comments received on the draft TMDL, was to include an individual WLA for all affected dischargers. CTDEP also received many comments on the uneven percent reduction requirements among Connecticut's six management zones, which appeared to unfairly apportion higher percent reductions to point sources in the east compared to the western part of the state. To address these concerns, CTDEP elected to identify both baseline nitrogen loads and the final WLA for each individual point source discharger located in Connecticut (**Appendix C**). The WLA process involved reapportioning both the zone baseline and WLA nitrogen loads. To preserve the integrity of DO response expected from the nitrogen loads reductions proposed by the LISS participants and presented in the October 1999 draft TMDL, the LIS Transport Efficiency Factors (**Table 7**) were first applied to the respective loads from all six zones. In order to equally assign this calculated load "equalized to DO impact," without bias caused by treatment efficiency differences from plant to plant, the "equalized" load was distributed proportionately to each treatment plant's average flow for the years 1997 through 1999. Calculated back to end-of-pipe, this resulted in about a 15.37 mg TN/l concentration for every sewage treatment plant in Connecticut included in the WLA. A similar distribution of the final WLA loading was made, which resulted in an equal percent reduction (about 63.5 percent) for each discharger in the state. By applying the delivery and transport factors to the reallocations, there is no significant alteration of DO benefit to Long Island Sound. However, the "edge of Sound" loading, upon which the TMDL is based, did change with the reallocation between management zones both as a baseline and a TMDL value, as it will when a trading program or other inter-zone exchanges are made as implementation proceeds.

To proactively address questions about whether the change in "edge of Sound" loading imperils the Phase III DO target, and to provide insight into how the TMDL might change as trades are implemented, a review of the effects of the adjusted WLA in Connecticut on the "edge of Sound" nitrogen load is appropriate. The original Phase III nitrogen loads by zone are presented in **Table B-1**. The "edge of Sound" baseline and reduction are presented for both Connecticut and New York contributions as well as the percent reduction achieved. The percent reduction is about 58.5 percent, which is the result of the cost-effective, Phase III reduction analysis. It is applied to the point sources listed in **Appendix C** plus the terrestrial nonpoint source baseline nitrogen load estimate from **Table 1** and the LA in **Table 6** and **Appendix A**. As shown in **Table B-1,** the Connecticut and New York reductions based on the loads presented in the draft TMDL came to 58.5 percent as did the aggregate loading.

The loads were "equalized" to DO effect by applying Long Island Sound Transport Efficiency factors to these numbers (**Table B-1**) to show the potential benefit to DO in Long Island Sound. Note that River Delivery Factors do not need to be applied again, as the data reflect "edge of Sound" nitrogen loads that already account for river attenuation. As expected, both the New York and Connecticut DO benefits equal the 58.5 percent reduction target as does the combined loading for the two states.

Table B-1. Original TMDL nitrogen load reduction and "equalized" TMDL nitrogen load reduction calculated by applying the Long Island Sound Transport Efficiency Factor.

Management Zone	Edge of Sound Baseline Nitrogen Load [a]	Edge of Sound TMDL Load Reduction for Nitrogen	Long Island Sound Transport Efficiency Factor	Baseline Nitrogen Load Equalized to DO Impact	TMDL Load Reduction for Nitrogen Equalized to DO Impact
Connecticut					
Zone 1	1540	901	0.17	260	152
Zone 2	3482	2037	0.20	703	411
Zone 3	2308	1350	0.55	1274	745
Zone 4	2275	1331	0.62	1415	828
Zone 5	1022	599	0.79	809	474
Zone 6	1056	618	0.93	979	573
Subtotal	11683	6836		5441	3184
Percent		58.5			58.5
New York					
Zone 7	906	530	0.83	748	438
Zone 8	18081	10577	0.21	3797	2221
Zone 9	9417	5509	0.11	1026	600
Zone 10	568	332	1.00	568	332
Zone 11-west	325	190	0.94	304	178
Zone 11-east	26	15	0.55	14	8
Subtotal	29323	17153		6458	3778
Percent		58.5			58.5
TOTAL	41006	23989		11899	6962
PERCENT REDUCTION		58.5			58.5

[a] The enriched nitrogen load from in-basin sources; defined as the point source load plus the terrestrial nonpoint source load.

The effects of the Connecticut reallocation of point sources is summarized in **Table B-2**. The WLA adjustment process altered numbers slightly, but did not violate overall percent reductions for Connecticut and did not reduce "effective" DO benefit expectations for Long Island Sound. As the data show, the "edge of Sound" baseline load in Connecticut fell by 261 tons of nitrogen/yr and the expected "edge of Sound" reduction fell by 167 tons of nitrogen/yr. This minimally affected the overall "edge of Sound" reduction for Connecticut, which fell to 58.4 percent, about 0.1 percent below the target. However, the TMDL allows adjustments in these loads and targets from the original draft TMDL estimates for reallocation and trading purposes, provided that the effect on DO is unaltered. Applying the Long Island Sound transport efficiency factors to the revised nitrogen TMDL for Connecticut, the baseline "effective" nitrogen load increased by about 5.5 tons of effective nitrogen/yr, but this was more than offset by the increase in effective nitrogen removed, which amounted to about 14 tons of effective nitrogen/year. This proves to be an overall reduction in nitrogen of 58.7 percent, more than 0.2 percent above the Phase III agreement level. Clearly, redistribution of the WLA in

Connecticut did not negatively impact anticipated DO benefits for the Sound, and in fact has slightly increased the benefit. This also demonstrates that future use of the appropriate adjustment factors in a reallocation or trading exercise will not affect the "effective" nitrogen reductions and the anticipated improvements in Long Island Sound oxygen concentrations and will not require continual revisions in the TMDL.

Table B-2. TMDL nitrogen load reduction adjusted for Connecticut WLA changes and "equalized" TMDL nitrogen load reduction calculated by applying the Long Island Sound Transport Efficiency Factor.

Management Zone	Edge of Sound Baseline Nitrogen Load [a]	Edge of Sound TMDL Load Reduction for Nitrogen	Long Island Sound Transport Efficiency Factor	Baseline Nitrogen Load Equalized to DO Impact	TMDL Load Reduction for Nitrogen Equalized to DO Impact
<u>Connecticut</u>					
Zone 1	1499	854	0.17	253	144
Zone 2	3285	1904	0.20	664	385
Zone 3	2339	1397	0.55	1291	771
Zone 4	1975	1137	0.62	1228	707
Zone 5	1069	634	0.79	847	502
Zone 6	1255	743	0.93	1163	689
Subtotal	11422	6669		5447	3198
Percent		58.4			58.7
<u>New York</u>					
Zone 7	906	530	0.83	748	438
Zone 8	18081	10577	0.21	3797	2221
Zone 9	9417	5509	0.11	1026	600
Zone 10	568	332	1.00	568	332
Zone 11-west	325	190	0.94	304	178
Zone 11-east	26	15	0.55	14	8
Subtotal	29323	17153		6458	3778
Percent		58.5			58.5
TOTAL	40745	23822		11905	6976
PERCENT REDUCTION		58.5			58.6

[a] The enriched nitrogen load from in-basin sources; defined as the point source load plus the terrestrial nonpoint source load.

Appendix C. Wasteload Allocation for Point Source Dischargers in Connecticut and New York by Management Zone.

Total Nitrogen Wasteload Allocation for Connecticut Point Source Discharges.

Facility	Baseline End-of-Pipe (lbs/day)	WLA End-of-Pipe (lbs/day)
Zone 1		
Groton City WPCF	272	99
Groton Town WPCF	420	153
Jewett City WPCF	42	15
Killingly WPCF	359	131
Ledyard WPCF	20	7
Montville WPCF	323	118
New London WPCF	1057	386
Norwich WPCF	550	201
Plainfield North WPCF	94	34
Plainfield Village WPCF	65	24
Putnam WPCF	145	53
Sprague WPCF	20	7
Stafford Springs WPCF	164	60
Stonington Borough WPCF	37	14
Stonington Mystic WPCF	74	27
Stonington Pawcatuck WPCF	66	24
Thompson WPCF	28	10
UConn WPCF	120	44
Windham WPCF	344	125
Pfizer (Industrial)	2900	1059
Subtotal	7100	2591

Total Nitrogen Wasteload Allocation for Connecticut Point Source Discharges.		
Facility	Baseline End-of-Pipe (lbs/day)	WLA End-of-Pipe (lbs/day)
Zone 2		
Bristol WPCF	1091	398
Canton WPCF	66	24
Mattabassett WPCF	2285	834
East Hampton WPCF	148	54
East Hartford WPCF	801	292
East Windsor WPCF	163	59
Enfield WPCF	763	278
Farmington WPCF	486	178
Glastonbury WPCF	268	98
Hartford WPCF	6512	2377
Manchester WPCF	855	312
Middletown WPCF	569	208
Plainville WPCF	277	101
Plymouth WPCF	114	42
Portland WPCF	86	31
Rocky Hill WPCF	789	288
Simsbury WPCF	293	107
South Windsor WPCF	289	106
Suffield WPCF	122	45
Vernon WPCF	504	184
Windsor Locks WPCF	180	66
Windsor Poquonock WPCF	268	98

Total Nitrogen Wasteload Allocation for Connecticut Point Source Discharges.		
Winsted WPCF	175	64
Subtotal	17104	6244

Total Nitrogen Wasteload Allocation for Connecticut Point Source Discharges.		
Facility	Baseline End-of-Pipe (lbs/day)	WLA End-of-Pipe (lbs/day)
Zone 3		
Branford WPCF	526	192
Cheshire WPCF	281	103
Meriden WPCF	1230	449
New Haven East WPCF	4294	1568
North Haven WPCF	433	158
Southington WPCF	557	204
Wallingford WPCF	737	269
West Haven WPCF	967	353
Cytec (Industrial)	2543	928
UpJohn (Industrial)	309	113
Subtotal	11877	4337

Total Nitrogen Wasteload Allocation for Connecticut Point Source Discharges.		
Facility	Baseline End-of-Pipe (lbs/day)	WLA End-of-Pipe (lbs/day)
Zone 4		
Ansonia WPCF	314	115
Beacon Falls WPCF	33	12
Danbury WPC	1211	442
Derby WPCF	195	71
Heritage Village	54	20
Litchfield WPCF	64	24
Milford Beaver Brook WPCF	258	94
Milford Housatonic WPCF	844	307
Naugatuck Treatment Co.	675	246
New Milford WPCF	66	24
Newtown WPCF	115	42
Norfolk WPCF	30	11
North Canaan WPCF	36	13
Salisbury WPCF	58	21
Seymour WPCF	167	61
Shelton WPCF	290	106
Southbury T.S.	41	15
Stratford WPCF	974	356
Thomaston WPCF	114	42
Torrington WPCF	680	248
Waterbury WPCF	2766	1010
Watertown WPCF	106	39
Unknown Industrial	1152	420

Total Nitrogen Wasteload Allocation for Connecticut Point Source Discharges.		
Subtotal	10243	3739

Total Nitrogen Wasteload Allocation for Connecticut Point Source Discharges.		
Facility	Baseline End-of-Pipe (lbs/day)	WLA End-of-Pipe (lbs/day)
Zone 5		
Bridgeport East WPCF	991	362
Bridgeport West WPCF	2852	1041
Fairfield WPCF	1113	406
Westport WPCF	238	87
Subtotal	5194	1896
Zone 6		
Greenwich WPCF	1313	479
New Canaan WPCF	175	64
Norwalk WPCF	1967	718
Ridgefield South St. WPCF	80	29
Stamford WPCF	2536	926
Subtotal	6071	2216
Total Zones 1-6	57589	21023

Total Nitrogen Wasteload Allocation for New York Point Source Discharges.		
Facility	Baseline End-of-Pipe (lbs/day)	WLA End-of-Pipe (lbs/day)
Zone 7		
Mamaroneck WPCF	2135	829
Port Chester WPCF	563	219
Blind Brook WPCF	338	131
New Rochelle WPCF	1516	589
North Castle WPCF	33	13
Subtotal	4585	1780
Zone 8		
Wards Island	43140	17903
Hunts Point	28630	11881
Bowery Bay	17270	7167
Tallman Island	6860	2847
CSOs	3170	1316
Subtotal	99070	41114
Zone 9		
Newtown Creek	45270	18787
Red Hook	4610	1913
CSOs	1721	714
Subtotal	51601	21414
Zone 10		
Belgrave	213	77
Glen Cove	893	323

Total Nitrogen Wasteload Allocation for New York Point Source Discharges.		
Great Neck SD	457	165
Great Neck (Village)	212	77
Oyster Bay	220	80
Port Washington	655	237
Subtotal	2650	958
Zone 11 West		
SUNY (SCSD #21)	208	40
Port Jefferson (SCSD #1)	202	39
Huntington	448	87
Kings Park (SCSD #6)	134	26
Northport (Village)	52	10
Subtotal	1044	202
Zone 11 East		
Greenport (Village)	76	11
Total Zones 7-11	159026	65479