2002 New York Harbor Water Quality Report

Michael R. Bloomberg, Mayor

Christopher O. Ward, Commissioner

July, 2003

The 2002 New York Harbor Water Quality Report represents the 93rd year of comprehensive monitoring of the water quality in New York Harbor, and demonstrates the continued improvements of the City's waterways and the regeneration of their aquatic ecosystems. In fact, the Harbor is in better shape today than it has been in more than thirty years.

Under the management of the Department of Environmental Protection (DEP), the City's advanced wastewater treatment and pollution prevention programs are clearly producing positive results. Largely because of these efforts, our bathing waters are cleaner and our aquatic environment is flourishing. What's more we are committed to do better next year. With further enhancements to our treatment plants and other infrastructure upgrades already underway, the quality of the Harbor, and of City life, will surely continue to improve.

I encourage all New Yorkers to review this report to gain an appreciation for the extensive efforts the City has undertaken to reduce pollution in the Harbor and to protect our wonderful natural resources.

Sincerely,

Michael R. Bloomberg
Mayor

July, 2003

The New York City Department of Environmental Protection (DEP) performs an intensive annual survey of the water quality in New York Harbor. The purpose of the Harbor Survey Program is to assess the effectiveness of the City's various pollution control programs, and their combined impact on water quality.

The 2002 New York Harbor Water Quality Report provides data summaries for the four significant regions of the harbor and includes discussion of our monitoring results as well as trend data dating back to 1970. Additional features, this year, are descriptions of the DEP's pollution control programs and summaries of special studies conducted on harbor-related subjects.

We are continually striving to improve our programs and to enhance the usefulness of this report. Your comments are encouraged. Questions or suggestions may be directed to Mr. Robert Ranheim of the DEP's Marine Sciences Section at (212) 860-9378.

We are proud of the results of our efforts to improve the quality of New York City's waterways. Your interest in the success of our programs is greatly appreciated.

Sincerely,

Christopher O. Ward
Commissioner

Credits and Acknowledgements

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The Special Project Laboratory is supervised by Trikam Patel and Patrick Jagessar, with analyses performed by: Lovely Chacko, Anna Chernyak, Legi Issac and Helen Otteno. The Newtown Creek Micro Lab was supervised by Daphne Sumpter, analyses done by: Shirley Bush, Mona Dave, Lorraine Johnson and Paricher Malakkhani.

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List of Acronyms

BNR	Biological Nitrogen Reduction
CWA	Clean Water Act
DO	Dissolved Oxygen
USEPA	United States Environmental Protection Agency
FC	Fecal Coliform
GNRA	Gateway National Recreation Area
NYS CW/CA	New York State Clean Water/Clean Air Bond Act
NYCDEP	New York City Department of Environmental Protection
NYSDEC	New York State Department of Environmental Conservation
PCB	Polychlorinated Biphenyl
TMDL	Total Maximum Daily Loads
WLIS	Western Long Island Sound
WPCP	Wastewater Pollution Control Plant

Executive Summary

The 2002 New York Harbor Survey provides overview of the long-term trends in water quality in the harbor. Conducted annually by the New York City Department of Environmental Protection (NYCDEP), the survey has been ongoing since 1909. The survey provides a means by which New York City can track the quality of its Harbor waters and gauge the effectiveness of its management practices. This report discusses the trends since the early 1970s during which time much of the public investment into water quality grew in earnest.

New York Harbor has over the past 30 years enjoyed a gradual resurgence in overall quality. The estuary had for many years prior, been the dumping ground for the New York metropolitan region's waste. This dramatic revitalization is due largely to improved management and stewardship of this great public resource as well as the strength of its natural resilience.

Significant public investment in wastewater treatment and enhanced regulatory control over waste discharges has helped to bring about water quality improvements that have stimulated a renewed use and enjoyment of the Harbor. Waterfront parks, promenades, and piers have been constructed and refurbished allowing the public greater access to the water. Public beaches are open more days of the year, affected less and less by water pollution. Ferry traffic has increased rapidly and continues to grow as a viable means of commuting. Aquatic species and birds have grown in numbers and diversity.

The 2002 New York Harbor Survey indicates that many of the improvements of the past 30 years have continued, however there are ongoing challenges to maintaining past gains and making new improvements.

The reduction of fecal coliform, used as an indicator of human pathogens, is one of the most dramatic water quality improvements in New York Harbor over the past 30 years. The Inner Harbor and the Upper East River-Western Long Island Sound have seen reductions by two orders of magnitude – falling from regional summer geometric means between 3,000-4,000 cells/100ml in the early 1970s to well below 100 over the past ten years. (From the 1970s through the early 1990s) Jamaica Bay and the Lower Bay have also improved but never suffered the same impairment as Inner Harbor waters, due to their distance from population centers.

In spite of these dramatic improvements, there continue to be episodic discharges of untreated sewage into New York Harbor. These are generally associated with periods of intense precipitation and runoff. Heavy rainfall has a significant impact on local water quality due to the combined storm and sanitary sewers (CSOs) in and around New York City. Periods of sustained or significant precipitation leads to overflows both in the conveyance system of pipes and sewers as well as overflows at the wastewater treatment plants themselves as volumes become unmanageable. It is at these times that discharges in untreated sewage occur, which can deteriorate water quality. The harbor areas most affected are where outfalls empty into semi-confined basins.

Dissolved oxygen, needed to support respiration by aquatic species, has shown an upward trend throughout the Harbor. On average, New York Harbor is well-oxygenated and generally capable of supporting a variety of aquatic life.

Dissolved oxygen is only problematic in certain areas of the Harbor, particularly in bottom waters around Hart Island in the Western Long Island Sound and in Grassy Bay in Jamaica Bay. These areas are typically in deeper waters where mixing between surface and bottom waters appears to be limited. Summer months are especially challenging for some organisms with dissolved oxygen dropping below criteria minimums in some areas.

Ecological change in Jamaica Bay is of significant concern. Salt marsh loss, critical to the ecological functioning of the Bay, appears to be occurring at a startling pace. A large amount of salt marsh has been lost through historic landfilling along the edges of Jamaica Bay, however in recent years, annual loss has persisted and possibly accelerated in the absence of landfilling. Experts have identified a number of possible factors that may be responsible, ranging from physical causes such as sea-level rise and sediment starvation to biological causes such as ponding caused

by high muscle populations and feeding on marsh grass by birds. Although the extent and rate of marsh loss are still being debated, the diverse potential causes are being examined closely to determine what, if anything, might be done to address this problem.

Paradoxically, while marsh loss continues, algal productivity appears to be growing in Jamaica Bay. Since 1986, data from the Harbor Survey indicates a clear upward trend in algal growth in Jamaica Bay. This has both a positive and potentially negative effect. It improves food sources at the bottom of the food chain and ultimately for the top of the food chain. However, overproduction can depress water clarity and lead to lower dissolved oxygen, particularly in bottom waters.

Building on the gains made in the past 30 years, NYCDEP is continuing with its mission to ensure human and ecological health and maximize the resource value of New York Harbor. Ongoing programs include upgrading and maintenance to wastewater pollution control plants, investment into untreated sewage discharge abatement, and reduction of nutrient discharges. Moving forward, NYCDEP is undertaking several new initiatives. It is partnering with other resource agencies to promote the protection and restoration of ecological habitats along the fringes of New York Harbor. It is also moving towards reducing several types of pollutants that were not eliminated, such as organics.

Introduction

History and Scope of the New York Harbor Survey

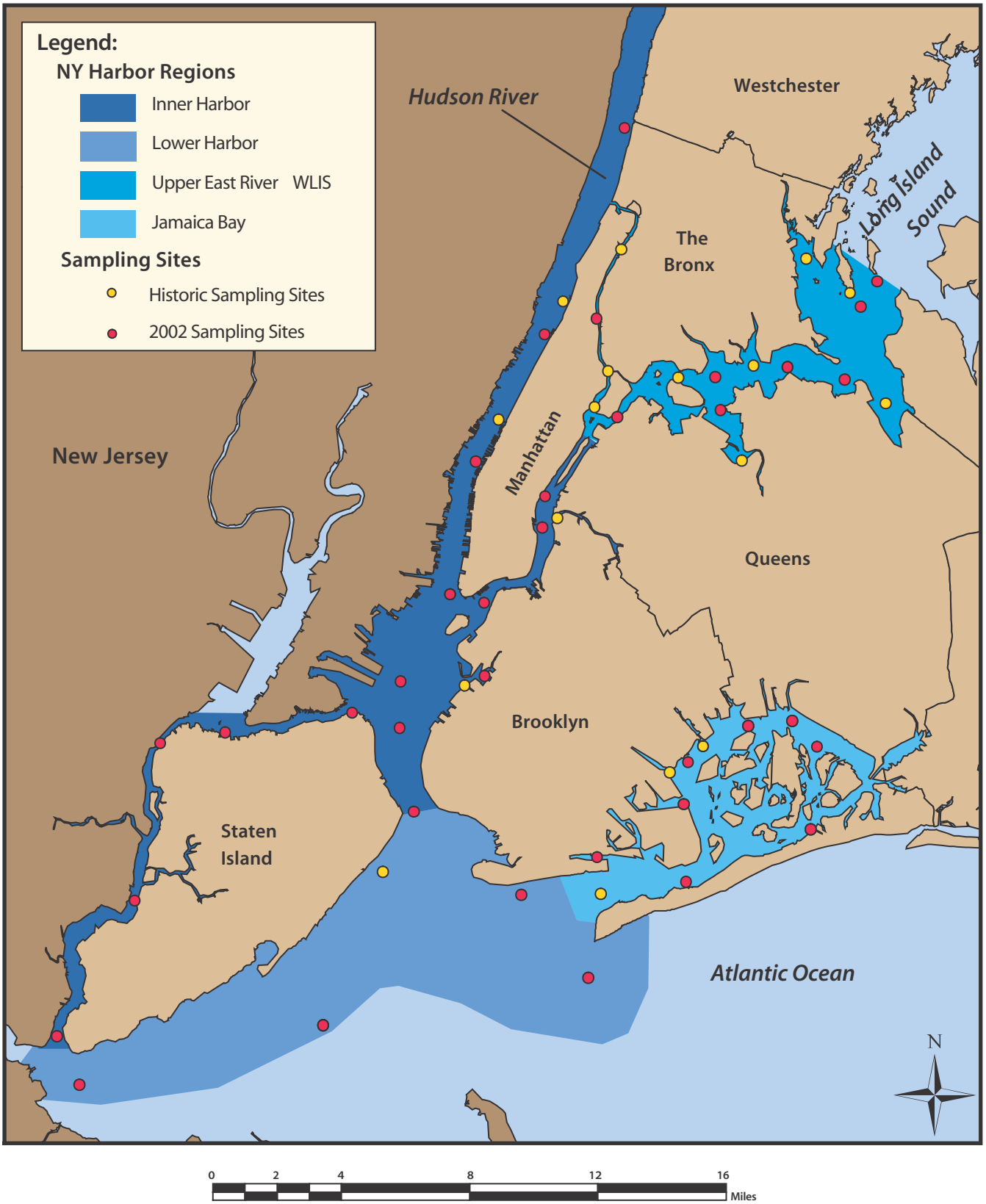
In 2002, the New York City Department of Environmental Protection (NYCDEP) conducted the 93rd annual New York Harbor Survey. Initiated in 1909, this study has conducted water quality analysis at numerous sites throughout the Harbor ranging from 12 stations in 1914 to 53 in 2002. The NYCDEP records variations and trends in water quality in New York Harbor in order to develop a long term dataset. As the operator of the 14 Wastewater Pollution Control Plants (WPCP) and related infrastructure of pipes and outfalls in New York City, NYCDEP can track how investments and upgrades correspond to water quality trends. Indeed, many of the significant improvements seen in the New York Harbor follow the construction, upgrading, and operational improvements at the WPCPs in the region. Increased control of illegal discharges and industrial emissions into the Harbor has further helped to bring about dramatic water quality improvements.

This report divides the Harbor into discussions of four regions, the Upper East River (including the Harlem River) and Western Long Island Sound (WLIS); the Inner Harbor (the Hudson River, Lower East River, Upper New York Bay, Arthur Kill and Kill Van Kull); Jamaica Bay; and the Lower Bay (including Raritan Bay) (Figure 2-1).

NYCDEP sampling occurs throughout the year, however, the results discussed in this report cover the period from May to September. Collectively, this time period is referred to as summer in this report. The summer is analyzed primarily because this is the period of maximum recreational use of the regional waters and also coincides with the greatest impairments to water quality, particularly dissolved oxygen.

Discussion of long-term trends goes back 30 years – corresponding to the passage of the Clean Water Act (CWA) in 1972. Although several of the NYCDEP WPCPs were already constructed at that time, upgrades to secondary treatment and significant operational improvements have occurred subsequently. Certain water quality parameters tracking turbidity (secchi depth) and biomass productivity (chlorophyll a) date back to 1986 while others including dissolved oxygen and fecal coliform go back before 1972.

FIGURE 2-1: Map of New York Harbor with 2002 Sampling Sites and Historical Sampling Sites



Description of Parameters

The New York City Harbor Survey primarily measures four parameters related to water quality; dissolved oxygen (DO), fecal coliform (FC), chlorophyll a, and secchi depth. Individually, these parameters give only a small picture of the health of the harbor. Taken together and over time, they draw a picture of aquatic health. A brief description of each follows:

Dissolved oxygen (DO) is required for respiration by all aerobic forms of life, including fish and invertebrates such as crabs, clams, and zooplankton. As such, DO level gives an indication of a waterbody's ability to sustain aquatic life.

DO is influenced positively and negatively by several variables. Beyond physical mixing from either more or less oxygenated waterbodies, sources of oxygen to a waterbody include atmospheric reaeration at the water surface driven by winds and waves, as well as biological activity (photosynthesis). As a result, DO levels at bottom depths are typically lower than at the surface, with the degree of vertical differentiation dependent on the level of physical mixing, benthic plant activity, and decomposition of biomass.

Biological factors that can deplete DO can be stimulated by high nutrient levels, which can encourage elevated planktonic and other aquatic vegetative growth. This high plant productivity leads to higher daytime surface DO levels, but eventually, the mortality and subsequent decomposition of this biomass leads to declining oxygen levels, particularly at bottom depths. Additionally, decomposing organic material originating from sources such as treatment plants, sewer discharges or surface runoff further adds to oxygen demand, as does the biological nitrification of ammonia released from WPCPs and other sources.

Not only does DO follow a daily pattern based on photosynthetic activity, it also follows a seasonal pattern. In New York Harbor, DO is highest in winter and spring and lowest in late summer.

Expressed in terms of milligrams per liter (mg/l) of water, NYCDEP DO measurements are taken at a fixed depth from the surface (4 ft) and at a variable depth to the bottom (ranging from 11 ft off of Coney Island to 89 ft in WLIS). It should be noted that NYCDEP Harbor Survey measurements are made during daylight hours and may be elevated relative to average daily values.

Fecal coliform (FC) is an indication of the presence of raw or partially treated sewage. Although not harmful to human health itself, FC is found in the intestinal track of all mammals and is correlated with human pathogens, both bacterial, viral, and parasitic, giving an indication of the disease causing potential of affected waters.

Since the passage of the CWA, long-term trends indicate a significant reduction in FC in New York Harbor. A number of factors contribute to this reduction including full secondary treatment of sewage at all but one of NYCDEP's WPCPs, operational improvements at WPCPs that increase dry and wet weather capture and treatment, and continued abatement of illegal discharges.

FC measurements are typically higher following periods of significant precipitation due to direct runoff and sewer overflows. FC measurements often vary by orders of magnitude due to the event-driven nature of the sources. For this reason, summer geometric means are best suited to analysis of temporal and spatial trends. Values are expressed as number of cells per 100 milliliters of water (cells/100ml).

Surface FC results are presented in this report. Bottom samples were taken from 1986-2000 but are not presented, as these values are generally lower than surface FC.

Chlorophyll a is a plant pigment whose concentration in water is used to estimate productivity of phytoplankton. Although there are no regulatory standards for chlorophyll a, it is a useful parameter for determining the biological productivity of a waterbody. Biomass productivity is important for supporting ecological food chains and aeration of water during the daylight hours, but in excess, it can lead to conditions that may deplete bottom dissolved oxygen levels. Abnormally high

chlorophyll a concentrations may suggest that excessive nutrients – possibly from anthropogenic sources – are in the water. This biological phenomenon of excessive nutrient load, heightened vegetative growth, and subsequent low DO is known as eutrophication.

In coastal waterbodies, nitrogen is typically the limiting factor to plant growth. In New York Harbor, organic carbon has also been found to be a limiting factor in phytoplankton growth at different times of the year (JABERRT, 2002).

In the New York Harbor Survey, only surface water measurements are taken for chlorophyll a. Chlorophyll a is measured in micrograms per liter of water (µg/l). Data from 1986 to 2002 are presented in this report.

Secchi depth is a parameter used to determine the clarity of surface waters. The measurement is made with a "secchi" disk, a black and white disk that is lowered into the water and the depth is recorded at which it is no longer visible. Suspended solids found in turbid water may be organic such as humic materials, phytoplankton (algae), as well as inorganic fine-grained sediments. High secchi depth readings indicate clear water that allows sunlight to penetrate to greater depths. Low readings indicate turbid water which can reduce the passage of sunlight to bottom depths. Limited light penetration can be a factor in diminished aquatic plant growth below the surface, thus reducing biological reaeration at lower depths. Secchi depth measurements, in feet (ft), are from 1986 to 2002 in this report.

Summary of Water Quality Trends in New York Harbor

Water quality has significantly improved over several decades throughout New York Harbor, as well as the broader Hudson-Raritan Estuary, primarily as a result of regional abatement of municipal and industrial discharges. These improvements include order-of-magnitude (meaning factors of ten) reductions of fecal and total coliform from concentrations in the thousands to levels in the tens, and significant increases in DO concentrations particularly in surface waters (Figure 2-2).

The most dramatic improvements in water quality typically came after full secondary treatment at local WPCPs was attained and fully optimized operationally.

Secondary treatment refers to the removal of suspended organic solids from effluent by biological means and gravity. Since those milestones were achieved in many of New York Harbor's subbasins by the early 1990s, water quality improvements over the past ten years have been relatively modest to flat with interannual variability sometimes resulting in mildly diminished water quality.

The reduction of fecal coliform is one of the most dramatic improvements in water quality in New York Harbor over the past 30 years. In particular, the Inner Harbor and the Upper East River-WLIS have seen reductions by two orders of magnitude – falling from regional summer geometric means between 3,000-4,000 cells/100ml in the early 1970s to well below 100 over the past ten years (Figure 2-3). In the Upper East River-WLIS region, fecal coliform levels began to fall dramatically in 1978 with the completion of secondary treatment at the Bowery Bay, Tallman Island and Hunts Point WPCPs and in 1979 at Wards Island. In the Inner Harbor, the decline has been similarly steady. This trend, however, does not correspond to specific secondary upgrades at any of the Inner Harbor WPCPs.

During periods of intense precipitation and runoff, fecal coliform is often elevated in certain regions of the Harbor. As explained later in this report, sewers and treatment plants can be overwhelmed by the total flow resulting in discharges of untreated sewage. The result is often a short-term spike in fecal coliform

FIGURE 2-2: 1973-2002 Four Parameters for Entire Harbor

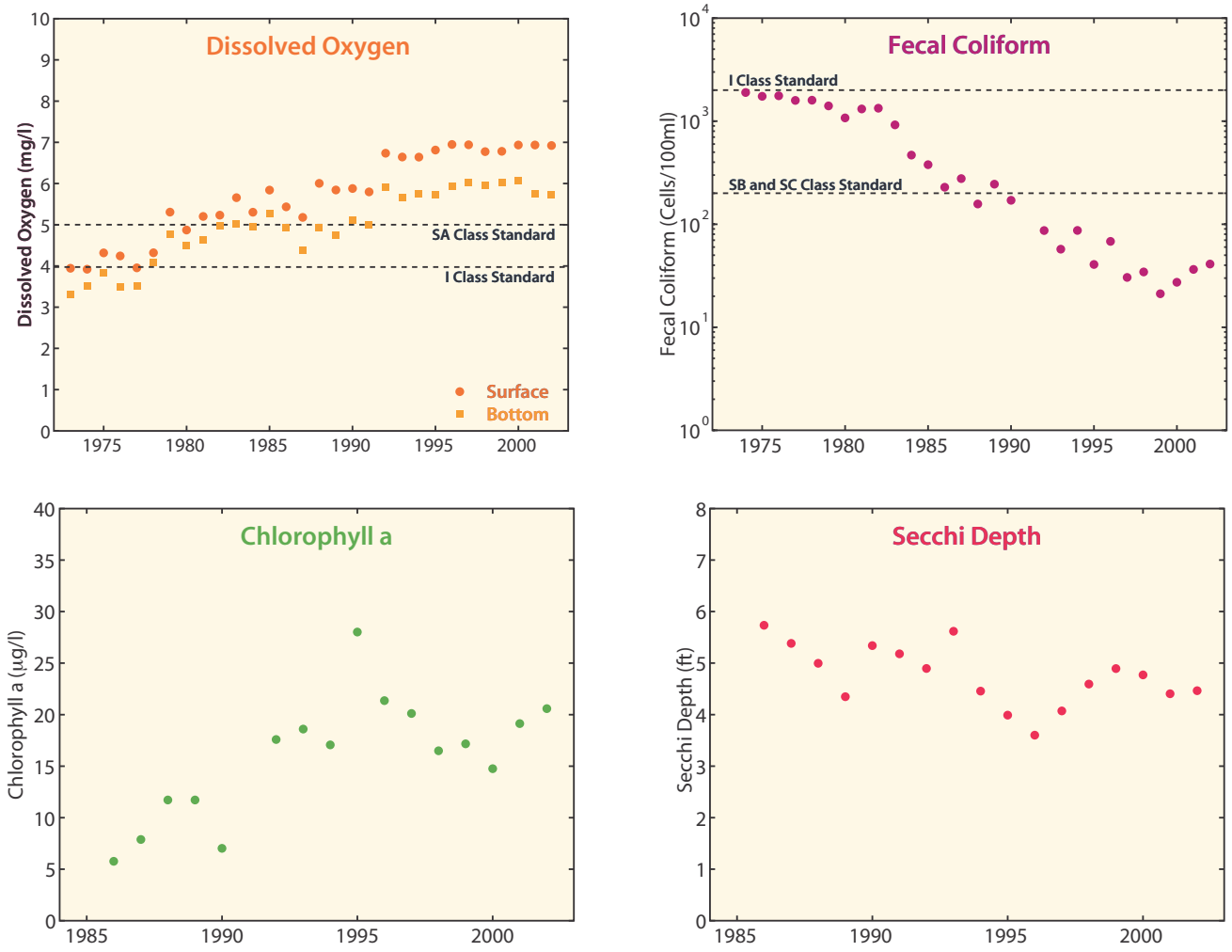


FIGURE 2-3: 1973-2002 Fecal Coliform Trends for Four Harbor Regions: Summer Geometric Means

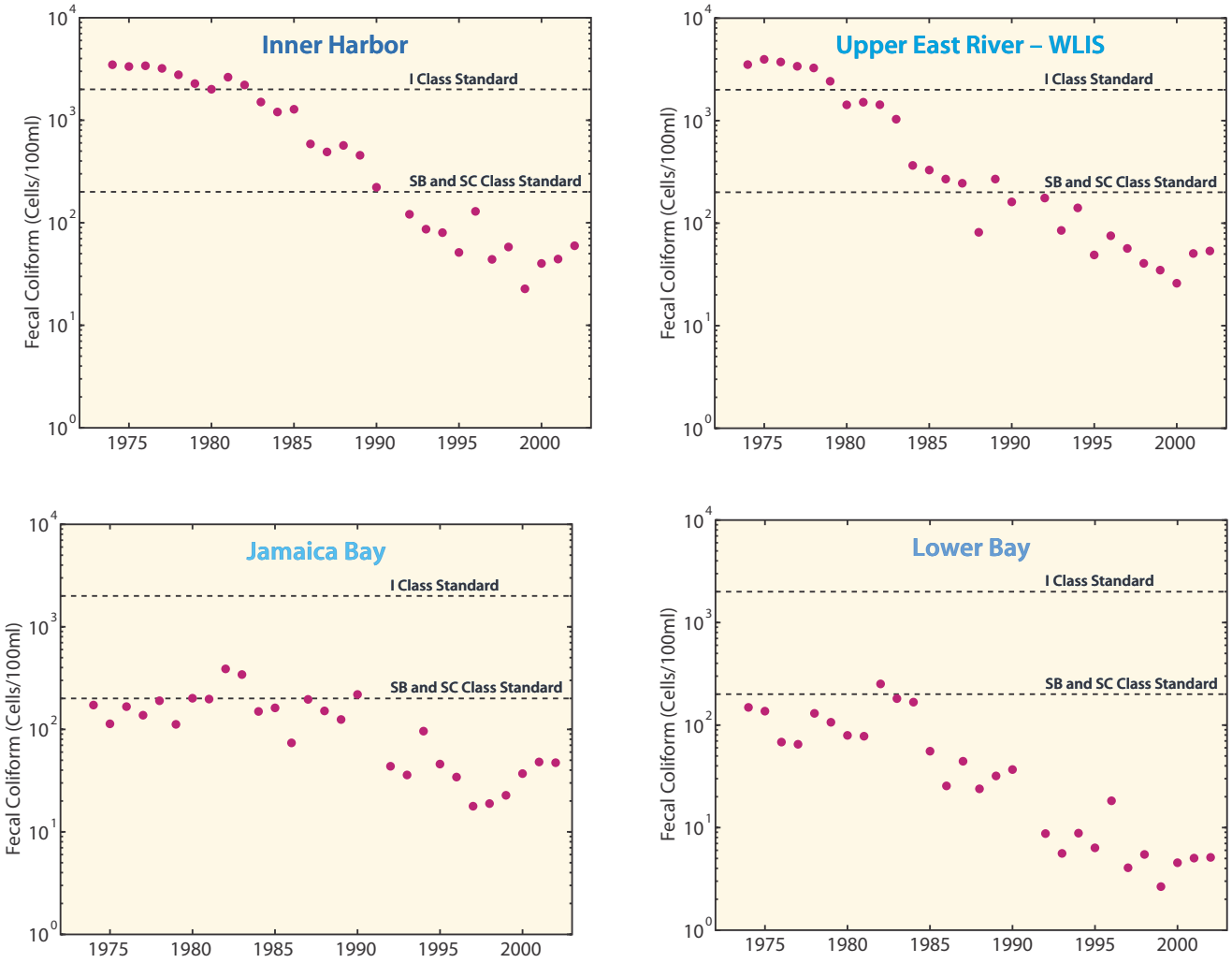


TABLE 2-1: 1974-1990 and 1992-2002 Fecal Coliform Concentrations for New York Harbor Regions

Region	Average Annual Geometric Means (cells/100ml)	
	1974-1990	1992-2002
Upper East River	1600	72
Inner Harbor	1700	64
Jamaica Bay	180	39
Lower Bay	96	7

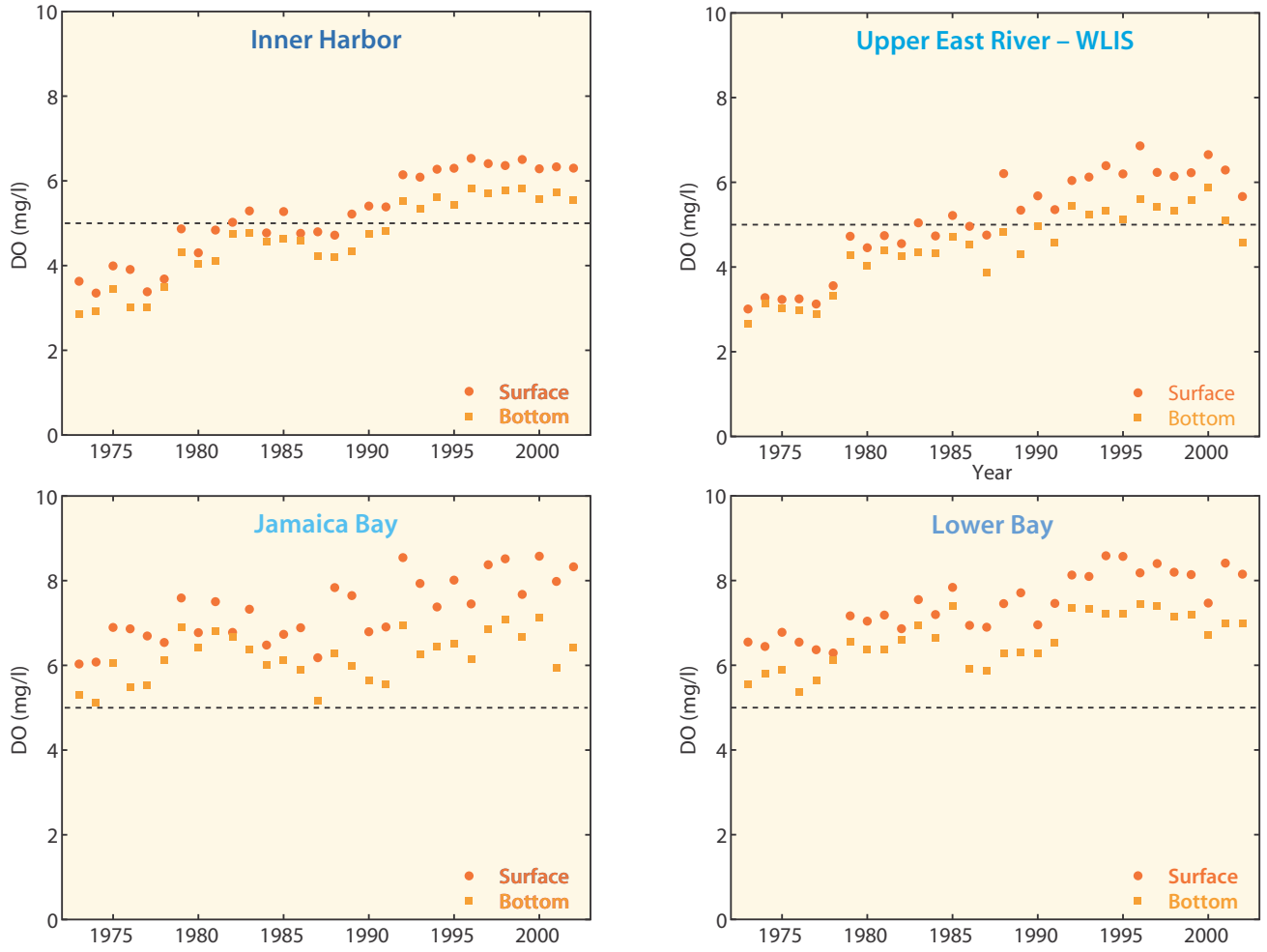
counts. Despite these events, summer geometric means for FC over the past ten years have generally been very low for each of the harbor regions (Table 2-1).

Harborwide, DO levels have exhibited an improving trend since 1973 for both surface and bottom measurements. Summer means for surface waters have exceeded NYS standards for swimmable and fishable waters since the early 1980s (Figure 2-4).

Jamaica Bay and the Lower Bay have exhibited the best summer mean DO concentrations in the harbor; summer mean bottom DO has not fallen below the state standard of 5.0 mg/l over the past 30 years. The Inner Harbor Area and the Upper East River – WLIS have both shown long-term improvement in DO.

Harborwide and regional averages, however, do not tell the entire story. Despite the overall improvement in the health of the harbor, particular areas at particular times of the year continue to be of concern. Several locations within each of the four harbor regions experience depressed bottom DO values during the summer months, particularly August. For example, DO in bottom waters in portions of WLIS during summer months have been extremely low in recent years (1.0–2.0 mg/l). Possible explanations include an increase in eutrophication, increased density stratification, changes in wastewater loads, and possible increases in upstream and nonpoint source loads. Temporal changes in vertical density stratification indicate that surface to bottom temperature differences have increased to a greater extent and have had a more

FIGURE 2-4: 1973-2002 Dissolved Oxygen Trends for Four Harbor Regions: Surface and Bottom Summer Means



significant impact on bottom DO depletion in WLIS than in the shallower Jamaica Bay and Raritan Bay (O'Shea, 2000).

Since 1986, chlorophyll a has remained essentially constant in the Upper East River – WLIS and Inner Harbor. Jamaica Bay, however, has exhibited a clear increasing trend. Jamaica Bay, through the late 1980s had summer means in the 10-20 µg/l range. Since 1992, values have ranged from 30-50 µg/l. The eutrophication of Jamaica Bay may be due to several facts and further investigation is needed. The Lower Bay also has shown an increase in chlorophyll a, however more limited than Jamaica Bay.

Factors Affecting Water Quality In New York Harbor

The heavily urbanized New York metropolitan area puts a tremendous strain on the water quality and ecological health of its waterways. Pollution comes from pipes, streets, streams, and even the air. These multiple pathways are divided simply into point (pipe) and non-point sources (no pipe). Significant point sources include WPCPs, storm overflows, and industrial sources. Non-point sources of pollution – much more difficult to identify and manage – enter into New York Harbor through various pathways. The combined watersheds of the Hudson, Hackensack, Passaic and Raritan Rivers contribute urban and

agricultural runoff containing sediment, nutrients, and chemicals. In sum total, New York Harbor is affected not only by the waste streams generated locally but also by remote sources from northern and western New York State and northern New Jersey.

2002 marked the 30th year since the passage of the CWA. Over the course of this period, New York Harbor as a whole has seen dramatic improvements in many aspects of water quality and ecological health. Prior to the CWA, population and economic growth over the previous decades led to serious declines in water quality and habitat loss in and around New York Harbor. Man-made, or anthropogenic, sources such as sewer outfalls, industrial pollution, coastal development, dredging, landfilling, and non-point sources of pollution are causes of habitat loss, sediment contamination, pathogens and floatables, and eutrophication or excessive nutrient loading.

The expansion in secondary treatment of sewage, overall improved treatment capacities, better monitoring and control of industrial discharges, and abatement of illegal discharges over the past 30 years have marked a significant improvement in harbor water quality. Upgrades in wastewater treatment and enhanced regulation of discharges have led to dramatic reductions in untreated sewage

and other pollutants. The results of this improvement are profound: fish and wildlife populations have rebounded and there has been a renewed public interest in access to and use of the waterways for transportation, commerce, habitation, and recreation.

Point Sources of Pollution

Wastewater Pollution Control Plants (WPCP)

The New York City Department of Environmental Protection's 14 WPCPs treat the sewage of New York City's residents, guests, and businesses (Table 2-2 and Figure 2-5).

Heightened nitrogen discharges, typically a limiting nutrient in marine coastal systems, can stimulate plant growth that can lead to declines in bottom DO. The end of ocean disposal of sewage sludge in 1992 led to a need to dewater sludge at several city WPCPs in order to reduce weight and volume for long-distance transport. The nitrogen-rich water taken from dewatered sewage sludge, known as centrate, is sent back into the WPCPs. This had caused a significant increase in the mean total nitrogen effluent loadings prior to recent retrofits to reduce nitrogen effluent. In place in certain WPCPs, Biological Nitrogen Reduction (BNR) involves the removal of nutrients such as nitrogen and/or phosphorus during wastewater treatment.

The associated infrastructure includes: 6,344 miles of collection systems piping, 130,000 catch basins, and 5,000 seepage basins. Mean dry weather flow in the WPCPs for 2002 was 1,155 million gallons per day (MGD). Mean total flow for the including wet weather periods was 1,220 MGD, well below the permitted capacity of 1,805 MGD. Under dry weather conditions, recovery and treatment from these plants has been steadily improving. However, wet weather, as discussed in the following section, creates problems with untreated sewer discharges into the Harbor.

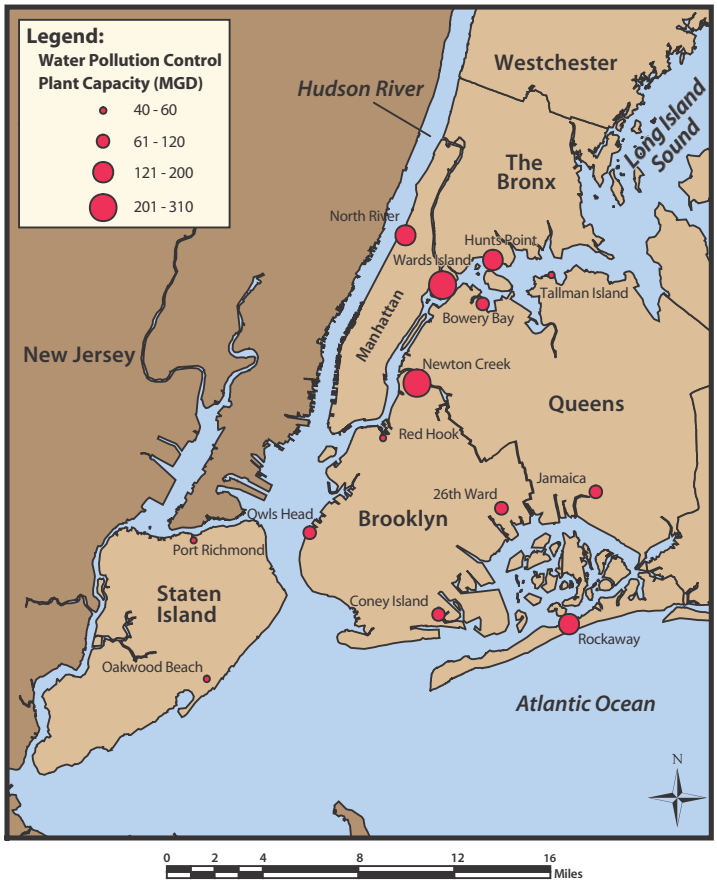
In NYCDEP WPCPs, treatment of wastewater consists of primary and secondary treatment and disinfection. Primary treatment refers to the removal

TABLE 2-2: NYCDEP WPCP Construction Dates and Capacities

Plant	Capacity (MGD)	Initially Built	Upgrade to Secondary	Mean 2002 Dry Weather Flow (MGD)	Mean 2002 Total Flow (MGD)
Newtown Creek*	310	1967	2007	216	229
Wards Island	275	1937	1979	172	179
Hunts Point	200	1952	1978	96	104
North River	170	1986	1991	122	127
Bowery Bay	150	1939	1978	98	105
Owls Head	120	1952	1995	95	101
Coney Island	110	1935	1994	88	92
Jamaica	100	1943	1978	67	71
26th Ward	85	1944	1979	54	58
Tallman Island	80	1939	1978	48	50
Port Richmond	60	1953	1979	29	31
Red Hook	60	1987	1989	28	30
Rockaway	45	1952	1978	18	19
Oakwood Beach	40	1956	1979	24	25

*Currently operating as modified aeration

FIGURE 2-5: Map – Water Pollution Control Plants (WPCP) Capacities and Discharge Rates



of coarse material through screening and settling. Secondary treatment, in place at all WPCPs with the exception of Newtown Creek, refers to the biological and chemical removal of organic matter. Finally, wastewater is disinfected with chlorine before being discharged back into the waterways.

In addition, a number of other WPCPs operate outside of New York City. Along the Hudson River, non-NYC WPCPs include Yonkers, Edgewater, North Bergen, Hoboken, West New York with total discharges of approximately 120 MGD. In the Upper Bay, the Passaic Valley WPCP discharges approximately 285 MGD and along the Kills, Essex, Union, Linden, and Rahway Valley WPCPs in total discharge approximately 110 MGD.

Combined Sewer Overflow

Throughout much of New York City, the sewers collect both sanitary and storm flow. During periods of intense rainfall or snowmelt, local runoff overwhelms the sewer's discharge capacity sending untreated human and industrial waste into local waterways. With over 700 discharge points, Combined Sewer Overflows (CSO) are considered to be the largest single source of pathogens in the New York Harbor region.

NYCDEP has taken several steps to mitigate CSO discharges. Wet weather capture and treatment at WPCPs increased from 18% in 1989 to 41% in 1997 and to 62% in 2002.

Measures to mitigate CSO events vary and may include elimination, where storm and sewer systems are physically separated, or may involve the expansion of WPCPs. Another option (as is being done in Flushing) is to create storage for CSO overflows – pumping the stored water to the treatment plant after the storm event has subsided.

In New York City, the Multi-Year Intended Use Plan of the NYC Municipal Water Financing Authority has

identified several CSO abatement and improvement projects totaling over $500 million with completion dates between 2003 and 2010. These projects include CSO abatement on the East River, Jamaica Bay, Paerdegat Basin, Inner Harbor, and Coney Island Creek (IEC, 2003).

CSOs also convey large, floatable materials into the waterways. Floatables, made up primarily of man-made debris, contribute to beach closures, interfere with navigation, entangle wildlife and impair aesthetics. The NYCDEP Boom and Skim Program began in 1993 and currently consists of 23 booms and nets in the canals and creeks below CSOs. Skimmer boats collect the accumulated floatables.

Non-Point Sources of Pollution

Non-point sources of pollution (NPSP) are contaminants and particulates that flow with rainwater runoff into waterways, or that move through the atmosphere and are deposited onto the land or water. Lawns, roads, agriculture, broken septic tanks, construction sites, and other disturbed ground areas are sources of sediment, fertilizers, pesticides, bacteria, viruses, salt, oils, grease and heavy metals just to name a few examples.

Atmospheric deposition is a significant pathway of NPSP in this region. The atmospheric deposition of mercury, nutrients, soot and particulate matter creates an ongoing source of pollutants that are difficult to track and quantify. Airborne pollutants that make their way into the New York Harbor watershed are generated both regionally and remotely from distant sources.

Summary of NYCDEP Pollution Control Programs

Although water pollution control has been a concern in New York Harbor since the late 1800s, massive plant construction did not begin in NYC until 1931, and accelerated in the 1970s with the CWA. The last of 14 treatment plants, North River and Red Hook, went into operation in 1985 and 1986, respectively. Until North River went on line, sewage from the entire west side of Manhattan, north of Canal Street, went into the Hudson River untreated!

Today, North River treats 127 MGD and the 14 plants treat a total of 1,200 MGD of wastewater. It is important to understand that municipal wastewater treatment systems were originally designed to treat organic material and bacteria during dry weather. During wet weather, the system was designed to overflow to local waterways without treatment; commonly called combined sewer overflows (CSO). Furthermore, the plants are not designed to treat metals or other toxics. Many toxics that enter the sewers end-up in either bio-solids, plant effluent or as air emissions without reduction. In addition, the plants were not designed until recently to treat nitrogen; a nutrient in residential sanitary sewage. These issues (control of toxics, treatment of wet weather flow and nutrients) remain a continuing challenge to improving environmental quality in NYC.

Wastewater treatment program managers are constantly striving to do more with existing resources. For instance, the pollution prevention control program has expanded from 1,000 regulated firms to 30,000 regulated firms over the last 12 years, without an increase in staff.

During that time, metals in wastewater have dropped from 7,800 to 2,800 pounds per day, citywide. In fact, heavy industry now accounts for less than 1% of metals in untreated sewage, citywide. Accordingly NYCDEP strives to shift its resources to other problem

areas including control of Polychlorinated biphenyls (PCBs), mercury, and other toxicants of concern; as well as quality of life issues related to grease, (i.e. sewer backups). New NYCDEP regulations are developed jointly with its Citizens Advisory Committee which has been in place for over 10 years.

Treatment plant operations programs have also expanded dramatically over the last 10 years. The practice of ocean disposal of sludge was banned in 1992. This required construction of eight sludge-dewatering facilities at a cost of about $1 billion and the development of a land-based biosolids program. Nearly 200 staff were required to operate this program. Virtually all were drawn from the operations and maintenance staff of existing plants. At about the same time, the plants began treatment of wet-weather flow though a series of Best Management Practices which have largely been adopted as the standard by EPA for all communities with CSOs. In 1996 NYCDEP state permits were expanded to require BNR.

As a direct result of NYCDEP programs, there is overwhelming evidence that New York Harbor's environment is cleaner and the water quality better than any time since the early 1900s. All public beaches have been open for bathing since 1992. Wet weather beach advisories have been lifted at all but three of these beaches. Priority pollutants are in decline in sediment and benthic creatures.

Shore birds have returned to breed in several areas of the harbor. Fish advisories and shellfish restrictions have been relaxed.

During these next 10 years NYCDEP anticipates a further need to do more with existing resources or with modest increases at best. This challenge results from several developing programs, including:

- more stringent effluent limits due to nutrient restrictions, being addressed by retrofitting the plants for BNR processes
- operation & maintenance (O&M) of several new wet weather treatment facilities, to be built at cost of around $500 million under the CSO program
- plant upgrades, mentioned above, that will modernize these facilities but also add, significant O&M needs for the additional equipment
- trackdown and control of pollutants of concern including mercury, PCBs and various solvents (VOCs) involving potentially thousands of NYC commercial or industrial firms; using innovative regulatory approaches to minimize impact on the regulated community & NYCDEP resources.

Improvements at Water Pollution Control Plants

The challenges that NYCDEP faces in the next 10 years are still evolving, however it is essential to hold on to the water quality gains that have been made. Existing plants must continue to meet state permits requirements thus providing a "platform" for additional improvements. Many of the plants operate with aged and obsolete equipment and will be upgraded as equipment is nearing the end of its life-cycle and stringent treatment requirements dictate improvements.

Of the 14 WPCPs that NYCDEP owns and operates within the City, all but one, the Newtown Creek Plant in Brooklyn, have been upgraded or built to provide full secondary treatment of sewage in accordance with the applicable State and Federal regulations. An upgrade is underway at Newtown Creek to achieve full secondary treatment. Final upgrade construction began in calendar 1998 and will conclude in calendar 2013. Upon completion of the final upgrade, the Newtown Creek Plant will provide secondary treatment levels and improve nitrogen removal, which reduces oxygen deprivation and improves water quality.

Additionally, the following plants are either in the facility planning, design or construction phase of capital projects: Wards Island in Manhattan; Tallman Island, Jamaica and Bowery Bay, in Queens; Hunts Point in the Bronx; and 26th Ward in Brooklyn. The upgrade of these facilities, which includes equipment replacement and the installation of additional controls, will improve performance and reliability. As part of the upgrade, the nitrogen removal capability at these plants will be improved. In fiscal 2002, NYCDEP began the facility planning stage for the Staten Island WPCPs (Port Richmond and Oakwood Beach) and the Rockaway WPCP in Queens.

Shoreline Survey/Sentinel Monitoring Programs

NYCDEP initiated a program to investigate and eliminate the dry weather discharge of untreated sewage into New York Harbor in 1998. This program originally involved a detailed evaluation of the entire 425 miles of shoreline within the City. NYCDEP personnel examined over 3,000 outfalls for a dry weather discharge and conducted sampling of those found to be discharging. The initial survey found over 3 million gallons per day of untreated sewage discharging into the harbor waters during dry weather. To date, NYCDEP has abated 96% of these discharges and continues to work to abate those remaining through capital construction of new sewers and enforcement actions to correct illegal connections to storm sewers.

While the initial shoreline survey was extremely effective in identifying and abating dry weather discharges it reached a point of diminishing returns. NYCDEP thus modified its program by the establishment of the Sentinel Monitoring Program that operates in conjunction with the Shoreline Survey Program. The Sentinel Monitoring Program established 80 stations within New York Harbor and its tributaries. NYCDEP sampled all 80 stations to establish a FC ambient baseline. NYCDEP samples each station on a quarterly basis and compares these results with the baseline fecal coliform readings.

Exceedances trigger a mini shoreline survey to determine the source of the exceedance. This new system has proved successful in not only identifying new dry weather discharges but in also effectively maximizing the productivity of NYCDEP staff resources. NYCDEP recently relocated a number of its Sentinel Stations to further enhance the reliability of this program.

Telemetry

Installation of telemetry at 92 city pumping stations since 1998 has improved monitoring and communications between these facilities and NYCDEP operators. This system enables NYCDEP personnel to view from computers historical or real-time data for all connected pump stations. Automatic alarms for a dozen critical values notify shift engineers as to condition changes, including: force main pressure, wet and dry well liquid level, electric power supply, pump operation, and gate position. In its fourth year of operation, this program has already succeeded in reducing dry weather bypasses, by enabling NYCDEP personnel to respond quicker to malfunction, breakdowns, or other system disruptions.

Enhanced Beach Protection Program

As a response to a series of collection facilities failures and beach closures in June of 1997, on July 2, 1997, the NYCDEP instituted an annual Enhanced Beach Protection Program (EBPP) to implement increased levels of surveillance and improved preventative maintenance procedures for critical pumping stations and regulations.

For 2002, the new program's goals included: 1) a mean bypass response time of eight hours versus 24 hours previously, 2) starting the program on May 25th, prior to the beginning of the bathing season, 3) additional beach sensitive sites to be monitored which have been identified as high maintenance facilities, 4) increase the frequency and locations monitored through the use of Harbor Marine Programs, 5) use of telemetry to monitor virtually all pumping stations.

As a result of the EBPP, the total amount of untreated sewage bypassed during dry weather from all pump stations and regulators during the 2002 season was less than 0.0002% of total dry weather flow treated at the fourteen WPCPs during that period. This represents a 97% decrease from the previous year.

There were no beach closures due to Collection Facilities bypasses during the 2002 EBPP.

Precipitation in 2002

Rainfall can have a significant impact on water quality. As described above, periods of intense precipitation and runoff around New York Harbor lead to CSO events and other untreated discharges. 2002 on the whole saw slightly more precipitation than the 20 year mean – but the total was well within the range of 1 standard deviation (Table 2-3). In addition to total rainfall, the intensity of single events is important as well as short. Intense episodes tend to overwhelm the capacity of the sewer and treatment plant system. There were 13 occurrences in the summer of 2002 in which 48-hour precipitation exceeded 0.5 inches. There were 7 occurrences in which 48-hour rainfall exceeded 1 inch (NCDC, 2002).

Marine Resource Management Standards

Water Quality Standards

New York State classifies freshwater and marine waterbodies on their highest and best uses based on historic and current water quality. Uses are classified for recreational and commercial purposes as well as for fish health. Recreational uses include swimming, fishing, and boating. Commercial uses include shellfishing. Fish survivability and propagation fall into the next lowest use standard. Standards are based on a number of factors including total coliform, fecal coliform, and dissolved oxygen (Table 2-4).

The use classification south of Staten Island and on the ocean side of the Rockaways is high enough such that waters are suitable for commercial shellfishing. This classification – SA – establishes that water quality is good enough for commercial shellfishing, primary and secondary recreational contact, and fish survival and propagation. As waters become more affected, the allowed uses decline. New York Harbor waters including Jamaica Bay and the Lower Bay are classified as SB, or suitable for primary and secondary contact such as fishing, swimming, and boating as well as fish survival and propagation. Many more of the regional waters are classified as being suitable only for fish survival and propagation (classification I). The lowest use classification, SD,

TABLE 2-3: 2002 Total Rainfall and 20 Year Annual Means and Standard Deviation

Weather Station	2002 Precipitation (inches)	20 Year Annual Rainfall Mean and S.D.
Central Park	45.2	43.3±10.7
JFK Airport	43.1	41.6±7.3
LaGuardia Airport	44.8	43.1±6.9

Source: National Climate Data Center

TABLE 2-4: New York State Saline Surface Water Quality Standards

Class	Coliform		Dissolved Oxygen
	Total	Fecal	
SA	Median <70 MPN/10 mL	---	>5.0 mg/l
SB	Monthly median <2,400/100ml 80% <5,000/100 ml	Monthly geometric mean <200/100 ML	>5.0 mg/l
SC	Monthly median <2,400/100ml 80% <5,000/100 ml	Monthly geometric mean <200/100 ML	>5.0 mg/l
I	Monthly geometric mean <10,000/100ml	Monthly geometric mean <2000/100 ML	>4.0 mg/l
SD	---	---	>3.0 mg/l

Adapted from NYCDEP Use and Standards Attainment Project

is suitable only for fish survival and is found in Kill Van Kull, Arthur Kill, Gowanus and Newtown Creeks.

In state classified SB waters the state standard says that FC monthly geometric mean, with a minimum of five measurements, will not exceed 200 cells/100ml. In state I classified waters, the standard is set at a monthly geometric mean below 2,000 cells/100ml.

The New York State use standards also take into account DO levels. For those waters classified as being suitable for primary and secondary contact recreation, DO is not to fall below 5.0 mg/l at any time. 5.0 mg/l is considered a healthy level for marine vertebrates. For those areas of the harbor classified for secondary recreation, fish survival and propagation (I), no DO value is to fall below 4.0 mg/l at any time. The few waterbodies in the New York Harbor are classified as SD, or suitable only for fish survival. In these cases, the state standard proscribes that DO at no time will fall below 3.0 mg/l. SD classified bodies of water include Gowanus Canal, the Kills, and Newtown Creek. However, in each standard described above, the duration and intensity of any dip below levels is taken into account.

Fish Consumption Advisories

Good water quality and preservation of essential fish habitat within New York Harbor is critical to the marine fishing industry in New York State. The total economic contribution of marine sport fishing in New York, including the Atlantic Ocean, Long Island Sound, various estuaries and embayments, and the tidal portion of the Hudson River is estimated at $1.33 billion. The economic contribution of commercial fishing industry lags the recreational, generating an estimated $150 million (Techlaw, 2001).

Despite the vibrancy of the New York marine fishing industry, historical sources of pollution, specifically PCBs, have lead to several fish consumption advisories for New York waters (Table 2-5).

In general, New York State recommends that people eat no more than one meal (one half pound) per week from the state's freshwaters, the Hudson River estuary, Upper Bay of New York, Arthur Kill, Kill Van Kull, and the East River to the Throgs Neck and Harlem River.

It is currently outside of the scope of the New York Harbor Survey to study or address organic pollutants.

TABLE 2-5: 2002-2003 Health Advisories for Sportfish

Area	Species	Chemicals of Concern	Advisory
Harlem River	American eel	PCBs	Eat none
	Bluefish, striped bass, Atlantic needlefish, white perch	PCBs	No more than one meal per month
Upper Bay of New York Harbor, Arthur Kill and Kill Van Kull	American eel, Atlantic needlefish, bluefish, carp, channel catfish, goldfish, largemouth bass, smallmouth bass, rainbow smelt, striped bass, walleye, white catfish, and white perch	PCBs	No more than one meal per month
	Gizzard shad	PCBs	Eat none
	Blue Crab	PCBs	Eat no more than six crabs per week. Do not eat the hepatopancreas.
East River	American eel	PCBs	Eat none
	Bluefish, striped bass, Atlantic needlefish, white perch	PCBs	Eat no more than 1 per month

Source: NYS Department of Health

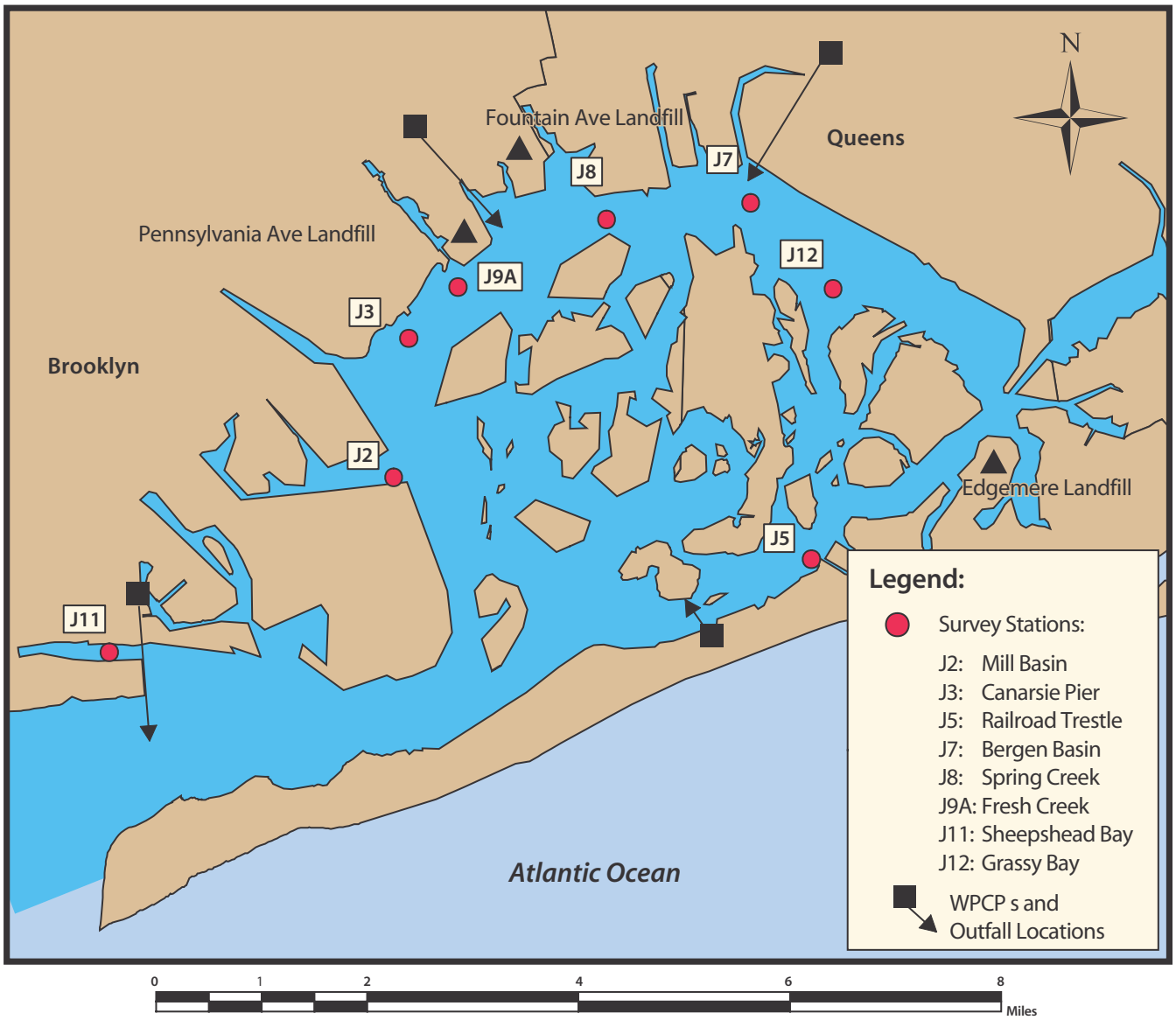
Jamaica Bay

Jamaica Bay is an embayment of tidal wetlands created by the Rockaway Barrier Beach, the westernmost part of a barrier beach system that extends for over sixty miles along the south shore of Long Island. In addition to broad open waters and expanse of tidal wetlands, Jamaica Bay possesses important upland meadows, shrublands, and even fragments of coastal forest. Jamaica Bay is a significant recreational area for New York City as well as seasonal home to thousands of birds migrating along the Atlantic Flyway.

Factors Affecting Water Quality in Jamaica Bay

Jamaica Bay faces intense human use pressures. In addition to recreation and transportation uses, Jamaica Bay serves as the outlet for four WPCPs (Figure 3-1), and numerous storm drains and CSOs. During dry weather, treated effluent from NYCDEP WPCPs in 2002 was approximately 226 MGD with 330 MGD of permitted capacity available. Mean total flow – including wet weather periods – for 2002 was

FIGURE 3-1: Map of Jamaica Bay Including 2002 Sampling Sites and WPCP Locations



239 MGD (IEC, 2003). Although solids and pathogens are generally removed by the WPCPs, storm events in the Jamaica Bay watershed lead to overflows including pathogen and floatable releases.

Natural freshwater stream flow into Jamaica Bay is negligible in comparison to the discharge from four sewage treatment plants and numerous CSO outfalls along the Bay. These treatment plants are the largest source of fresh water to Jamaica Bay as natural flow has been greatly diminished due to urbanization (Table 3-1). Mixing from the Hudson River and groundwater flow also contribute freshwater to the Bay.

Estimates on residence time for Jamaica Bay vary. Some estimates had put residence times at 10 to 35 days (West-Valle, 1992). Recent estimates have been much lower in the range of 7 days to flush peripheral channels and the top 5 meters of Grassy Bay (Houghton, 2002).

Hydrology of the Bay has been affected as dredging and filling have drastically altered the shallow water ecology of the Bay. Prior to modern settlement, the Bay's deepest water depth was an estimated eleven feet. Many formerly shallow areas have been dredged while shore areas have been filled not only with dredged materials but also with municipal waste, incinerator ash, and other historic fill. Throughout NYC, residue from incinerators was disposed of in landfills throughout the city that now account for as much as 10% of the current city surface area (Walsh, 1996).

Dredged channels around the periphery of Jamaica Bay may also be a sink for sediments – deprive marshes of the sediment needed for natural marsh accretion. Infrastructure projects including navigation and removal of fill for JFK airport construction has resulted in numerous pits and channels with depths up to 60 ft deep.

Pollutant loadings into Jamaica Bay have declined over time. Sediments dating from the early 1950s through the late 1980s have been found to have trace metals, including copper, lead, chromium, zinc, and mercury, elevated to levels several times those of pre-industrial concentrations. These metals decreased by about 50% between the mid 1960s and the late 1980s. Chlorinated hydrocarbons – such as PCBs and chlordane – concentrations decreased by a factor of five to ten between the late 1960s and the late 1980s (Bopp, 1993).

Water Quality in Jamaica Bay

Dissolved Oxygen

Long-term Trends

Jamaica Bay surface waters oxygen levels have been broadly supportive of aquatic species over the past 30 years. For the region, DO results for Jamaica Bay are consistently above 5 mg/l and have shown an upward improvement over time (Figure 3-2). Increasing surface DO values may be a function of increased planktonic growth in Jamaica Bay as their daily photosynthesis enriches the DO in the surface waters.

However, bottom DO values remain a concern with numerous periods of non-compliance with NYS standards every year, including 2002. Jamaica Bay on the whole is classified by New York State as being suitable for primary and secondary recreational contact.

TABLE 3-1: Jamaica Bay WPCPs – Capacities, Construction Dates, and 2002 Flows

Plant	Capacity (MGD)	Initially Built	Upgrade to Secondary	Mean Dry Weather Flow (MGD)	Mean Total Flow (MGD)
26th Ward	85	1944	1979	54	58
Coney Island	110	1935	1994	88	92
Jamaica	100	1943	1978	67	71
Rockaway	45	1952	1978	18	19

Therefore, no individual sample is to fall below 5.0 mg/l. Some of the basins in Jamaica Bay including Paerdegat Basin, Bergen Basin, Coney Island Creek, and Spring Creek are classified as I. As such, the state standard for minimum DO is 4.0 mg/l. Jamaica Bay has historically exhibited differences in surface and bottom DO values and in the past 15 years, these differences appear to have grown – suggesting a possible increase in stratified conditions. With both chlorophyll a and turbidity increasing in recent years, the amount of sunlight reaching bottom depths may be declining thus resulting in increasing difference between surface and bottom DO values in Jamaica Bay.

2002 Results

Across Jamaica Bay, summer 2002 surface and bottom DO means were 8.3 and 6.9 mg/l, well above minimum levels to support aquatic life. Summer monthly DO means for Jamaica Bay on the whole were slightly above ten year monthly means, with the exception of August during which time mean bottom DO fell to 4.2 mg/l (Figure 3-3).

Eight out of the ten stations sampled in Jamaica Bay in 2002 had summer mean bottom DO concentrations above 5.0 mg/l. Only Bergen Basin (J7) and Grassy Bay (J12) fell below this level (Figure 3-4 and Table 3-2). 24% of the 141 samples taken in Jamaica Bay in summer 2002 fell below 5.0 mg/l.

The lowest summer bottom DO values were recorded at station J12 at the eastern end of Grassy Bay. Summer mean bottom DO for this site was 2.8 with the lowest value recorded on August 20th of 0.35. The bottom of Grassy Bay has also been found to be the most vertically stratified part of Jamaica Bay (Rubenstone, 2002). Grassy Bay water quality is problematic because it has become almost a closed system due to deepening by dredging, constricted in the north and south by construction of Cross Bay Boulevard in the 1940s, and blocked by the JoCo marsh runway (JFK Airport) to the east. Long-term trends for this location are impossible to assess as NYCDEP measurements for this site only go back to 2001.

Stations J7 at Bergen Basin and J8 at Spring Creek experienced the next lowest summer bottom DO means, 4.6 and 6.2 mg/l, respectively. Of note, the Bergen Basin station is located 500 meters from the Jamaica WPCP outfall. From mid-July through late August, bottom DO levels at these locations were below 5.0 mg/l. Bergen Basin's lowest reading of 1.0 was recorded on July 30th. Spring Creek reached its lowest level of 2.8 on August 27th. Several other stations fell below 5.0 for several weeks during the summer including Canarsie Pier (J3), Fresh Creek (J9A) – as did Railroad Tressle (J5) and Mill Basin (J2) on one occasion, August 27th.

FIGURE 3-2:
1973-2002 Surface and Bottom Summer DO Means and +/- 2 Standard Errors with 30 Year Regression for Jamaica Bay

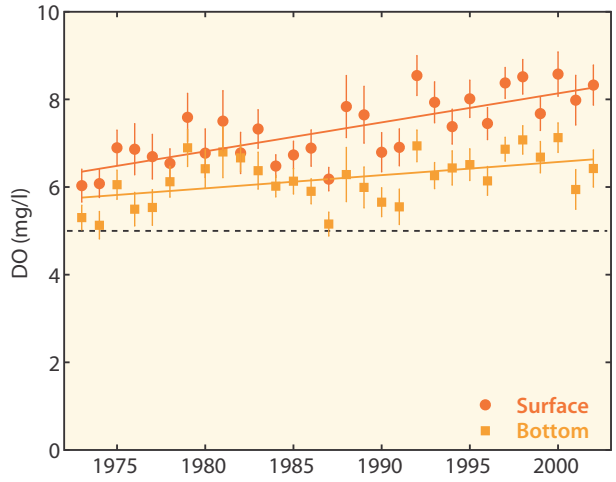


FIGURE 3-3:
2002 Surface and Bottom Monthly DO means and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Jamaica Bay

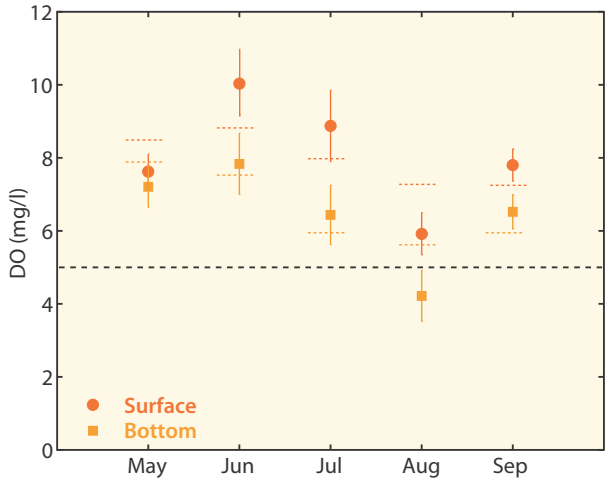
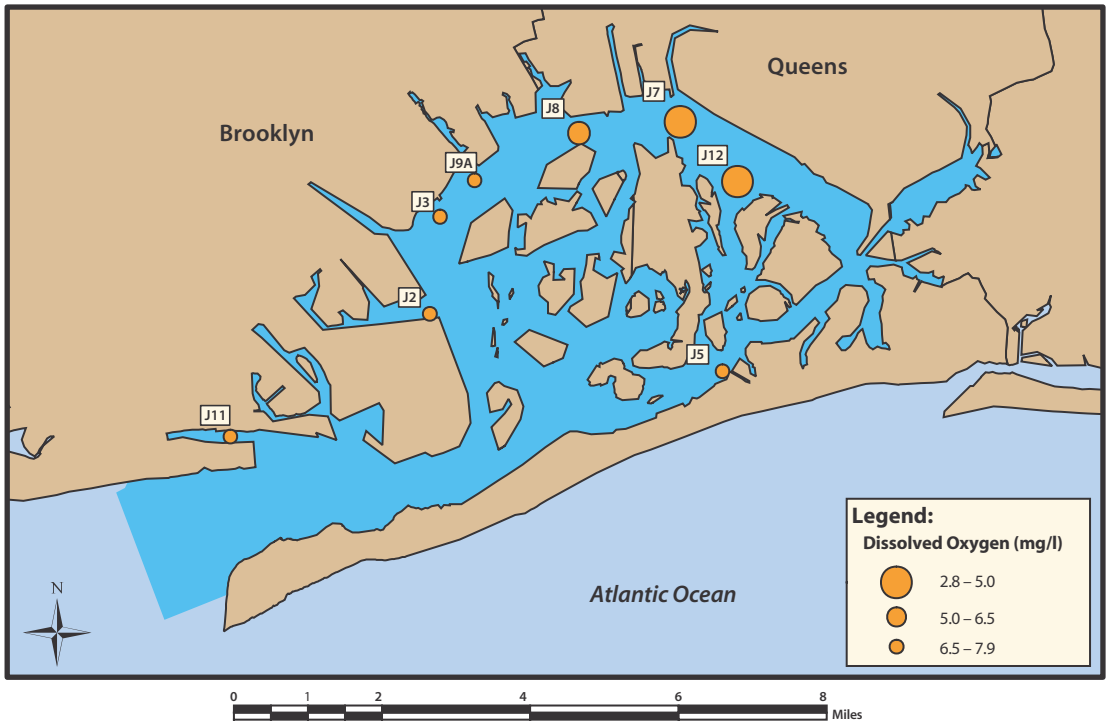


FIGURE 3-4: Map of 2002 DO Values for Jamaica Bay



Fecal Coliform

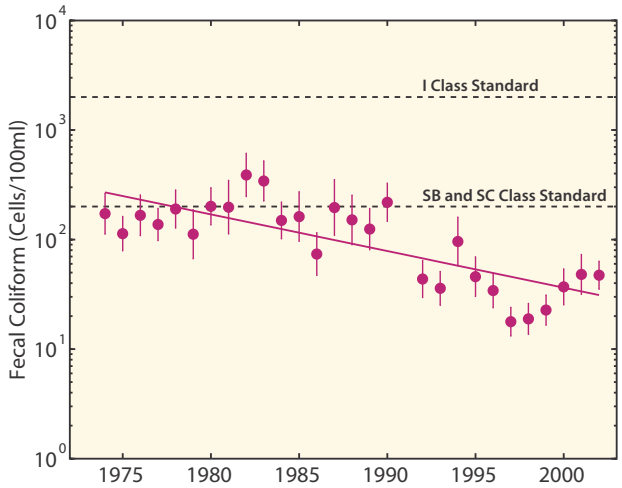
Long-term Trends

Fecal coliform in Jamaica Bay has declined considerably over the past 30 years, due in large part to upgrades and improvements in the performance of WPCPs. From the early 1970s through 1990, summer geometric means were around 200 cells/100ml. Since the early 1990s, summer geometric means declined to below 40 cells/100ml and leveled off since then with the exception of 1994 which climbed to over 100 cells/100ml (Figure 3-5).

2002 Results

The average of FC summer geometric means across Jamaica Bay in 2002 was 45 cells/100ml, consistent with the ten year mean (40 cells/100ml). Due to the numerous basins and CSOs bordering Jamaica Bay, significant variability between stations is to be expected. Stations J7 (Bergen Basin) and J11 (Sheepshead Bay) had the highest summer geometric means in Jamaica Bay, 168 and 126 cells/100ml, respectively (Figure 3-6).

FIGURE 3-5:
1973-2002 Fecal Coliform Summer Geometric Means and +/- 2 Standard Errors with 30 Year Regression for Jamaica Bay



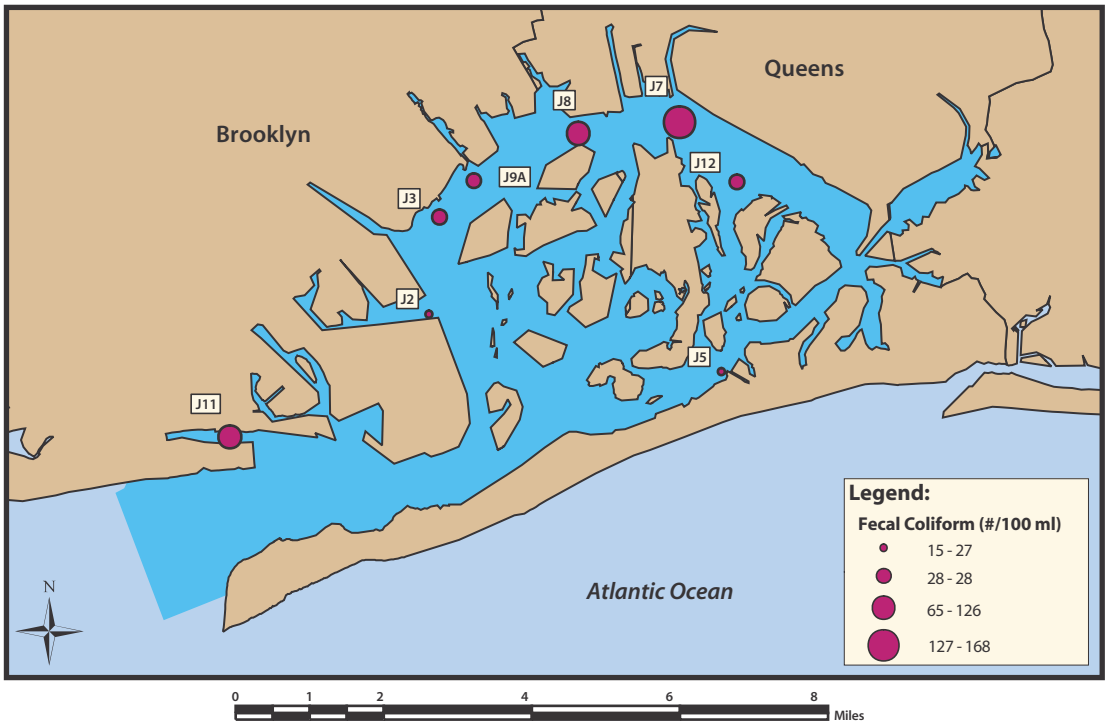
August and September saw unusually high FC monthly geometric means (~152 cells/100ml) relative to ten year monthly means ~40 cells/100ml (Figure 3-7). This may be explained by particularly high rainfall amounts, nearly 14 inches of rain were recorded at JFK Airport for those

TABLE 3-2: Jamaica Bay 2002 DO and Fecal Coliform Means, Minimums and Maximums

Station Code	Location	Dissolved Oxygen				Fecal Coliform	
		Mean		Minimum		Summer Geometric Mean	Maximum
		Surface	Bottom	Surface	Bottom		
J1	Rockaway Inlet	8.4	7.7	5.5	5.7	10	400
J2	Mill Basin	8.0	6.9	4.7	4.4	15	400
J3	Canarsie Pier	8.7	7.0	5.0	3.9	55	800
J5	Railroad Tressle	8.0	7.5	4.1	4.2	27	800
J7	Bergen Basin	8.0	4.7	3.1	1.0	168	948
J8	Spring Creek	7.2	6.1	3.7	2.8	95	1,108
J9A	Fresh Creek	8.1	6.9	4.2	3.1	64	800
J11	Sheepshead Bay	9.4	7.9	6.0	5.3	126	588
J12	Grassy Bay	9.1	2.8	3.6	0.4	49	772

two months. Much of the August rainfall was localized to the Jamaica Bay region as JFK (7.1 inches) received almost 2.5 inches more than either Central Park (4.9 inches) or LaGuardia Airport (4.7 inches) weather stations. The highest individual reading of 1,108 cells/100ml was taken at J8 (Spring Creek) on September 10th. Although no rainfall had immediately preceded this measurement, nearly three inches of rain were recorded at JFK Airport nearly a week prior.

FIGURE 3-6: Map of 2002 FC Summer Geometric Means for Jamaica Bay

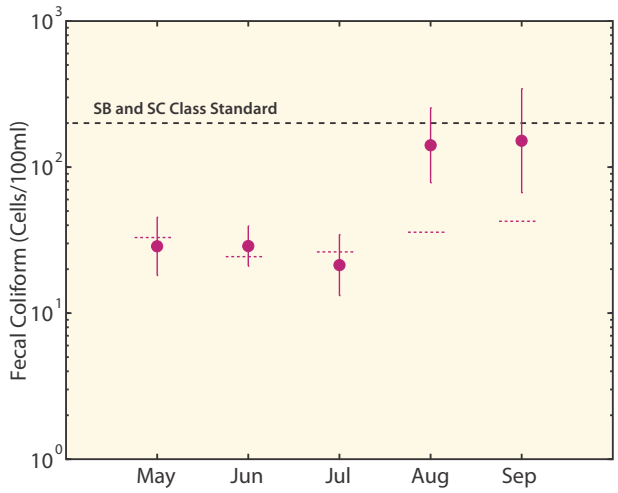


Chlorophyll a

Long-term Trends

Jamaica Bay has the highest algal activity in the New York Harbor region. Since 1986, chlorophyll a in Jamaica Bay has steadily increased (Figure 3-8). In the late 1980s values ranged from 10-26 µg/l. Since 1995, however, chlorophyll a has ranged from 32-52 µg/l.

FIGURE 3-7:
2002 Fecal Coliform Monthly Geometric Means and +/- 2 Standard Errors with Comparison to 10-Year Monthly Means for Jamaica Bay



Although a significant level of interannual variability exists, the rise in phytoplankton growth has been dramatic and may be indicative of eutrophic conditions. Significant bloom events typically occur at two times in Jamaica Bay, a large one in February to March and a weaker bloom in summer (June-July). The summer bloom is more spatially variable with areas at the eastern end of the Bay seeing the highest phytoplankton production (Figure 3-10).

2002 Results

The chlorophyll a 2002 summer mean of 44 µg/l in Jamaica Bay was well above the other regions in the Survey. Relative to prior years, 2002 chlorophyll a monthly means were in line with ten-year means – peaking in June at 58 µg/ml, remaining elevated through July, August, and September with monthly means of 51, 46, and 37 µg/l, respectively (Figure 3-9).

Significant algae blooms occurred in Jamaica Bay in 2002, particularly around July 9th on the northern end of Jamaica Bay. On this day, samples taken from northeastern part of the Bay (Bergen Basin (J7), Spring Creek (J8), and Grassy Bay (J12)) had a mean of 143 µg/l.

FIGURE 3-8:
1986-2002 Chlorophyll a Summer Means and +/- 2 Standard Errors with 17 Year Regression for Jamaica Bay

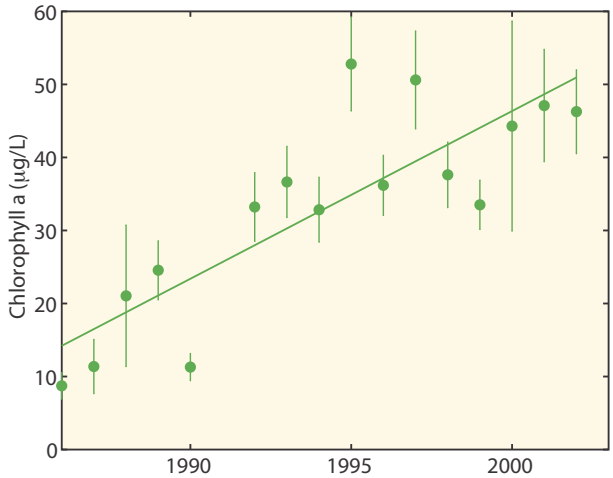
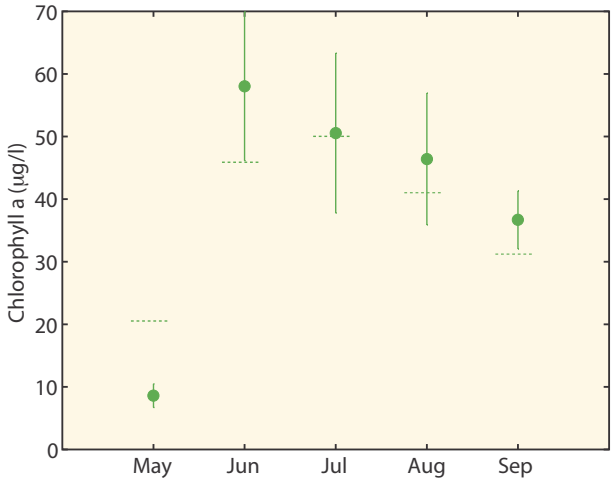


FIGURE 3-9: 2002 Chlorophyll a Monthly Means and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) For Jamaica Bay



Turbidity

Long-term Trends

Water clarity has been declining over the past 16 years in Jamaica Bay (Figure 3-11). From 1986 to 1993, mean secchi depths were 5.6±0.6 ft, and from 1993-2001 were 4.3±0.4 ft. In 2001 and 2002, mean secchi depth were 3.9 and 3.5 ft, respectively.

2002 Results

2002 was significantly more turbid than in previous years in Jamaica Bay. Jamaica Bay had mean secchi depth in 2002 of 3.5 ft, compared with 4.9±0.8 ft for the region from 1986-2001. For many sites in Jamaica Bay, particularly on the north end, water clarity hit its low point around July 9th, the same time as the major algal bloom event of the summer in Jamaica Bay.

Monthly means fell from 5.6 ft in May to just above three feet throughout the summer (Figure 3-12). Ten year monthly means are typically 4-5 ft through the summer months in Jamaica Bay.

Research Initiatives in Jamaica Bay

Ecological Change in Jamaica Bay: Salt Marsh Loss

Prior to colonial settlement, Jamaica Bay possessed an estimated 16,000 acres of wetlands. Today, only 4,000 remain, still representing 1/5 of the entire Bay. Much of the loss can be attributed to human development, most notably by wetland filling for garbage disposal, marina communities built on filled land in its Brooklyn portions, the Belt Parkway, and JFK Airport. From 1900 to 1970, nearly 100 million cubic meters (Mm^3) of sediment were dredged from the Bay and used to fill shoreside marshland. In 1946 47 Mm^3 were removed from Grassy Bay to build Idlewild Airport (later to be named JFK).

NYSDEC and others believe that salt marsh loss continues today even in the absence of landfilling. Recent studies by NYSDEC estimate that since 1975 10-20% of the Bay's remaining wetlands have disappeared.

FIGURE 3-10: Map of 2002 Chlorophyll a Summer Means for Jamaica Bay

FIGURE 3-11:
1986-2002 Secchi Depth Summer Means
and +/- 2 Standard Errors
with 17 Years Regression for Jamaica Bay

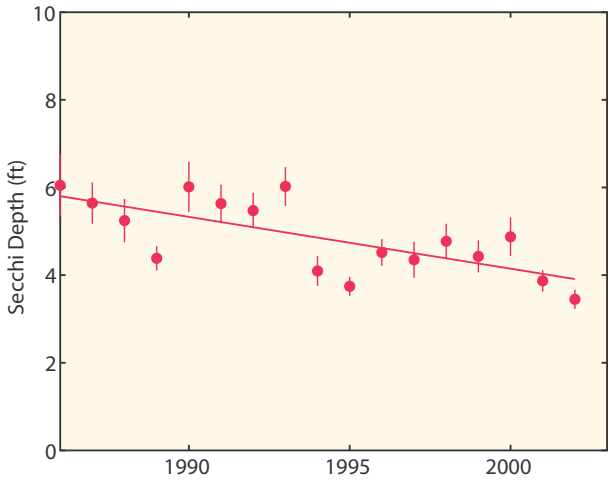
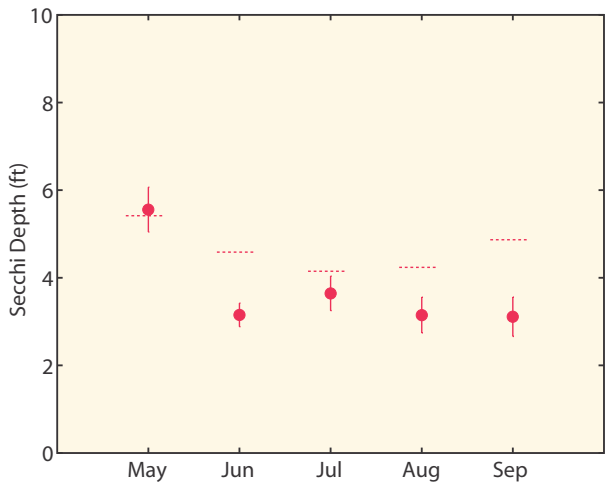


FIGURE 3-12:
2002 Secchi Depth Monthly Mean
and +/- 2 Standard Error
with 10 Year Monthly Means for Jamaica Bay



Opinions as to the nature, extent, and cause of salt marsh loss vary. Sea-levels have indeed risen over time, but marshes also naturally accrete and in many locations can keep pace with changes in sea-level. Indeed, accretion rates for Jamaica Bay range from 0.5 cm/year for high marsh to 0.8 cm/year for low marsh while observed sea-level rise in the region is only 0.27 cm/year (Hartig, 2002). Jamaica Bay and southern Brooklyn are on the 'peripheral-bulge' or terminus of the last glaciation and relative to land to the north, has not undergone comparable rebound from the glacial retreat. As a result, sea level changes recorded at the Battery may not be appropriate for Jamaica Bay. Sandy Hook, perhaps a better comparison, shows sea-level rise of 0.44 cm/year.

As ecological systems are dynamic and prone to change, the question for the region is whether salt marsh loss is part of a natural process for the region or if it is due largely to man-made stressors that can and should be mitigated. A number of studies and groups have been formed to examine this question.

The Jamaica Bay Blue Ribbon Panel was convened to examine numerous factors that are believed to be contributing to this wetland loss. Areas of current exploration include:

Lateral erosion

- Dredged channels and pits acting as sinks for soils eroded from islands
- Lack of sand and silt within the bay for replenishment due to dredged material removal
- Lack of sand and silt transport from the ocean due to the extended littoral drift of Rockaway and the stabilized inlet
- Diminished sand and silt transport from uplands given the negligible natural flow
- Increased fetch, boat wakes and steeper slopes from a deeper bay.

Internal vertical erosion

- Wrack studies (salt marsh straw) smothering and abrasion
- Ulva (sea lettuce) mats smothering
- Ponding within marshes due to increased mussel growth
- Avian foraging
- Contaminants from landfills, direct effects and increased susceptibility to pathogens
- Nutrient overloads from wastewater treatment plants
- Sea-level rise and ground subsidence.

Wildlife Studies

Jamaica Bay is one of North America's most important estuaries for migrating birds. The Jamaica Bay Wildlife Refuge occupies a key position along the Atlantic flyway. Over 350 bird species have been recorded in Jamaica Bay –and is annually visited by over 1/5 of all North American bird species during migratory periods. Within the wildlife refuge, several species have seen increases over the past 25 years including the Laughing Gull, Great Black-backed Gull, Forster's Tern Nuttall, while others decreased including Herring Gull, Coues, and the Snowy Egret. Cattle Egrets have disappeared from the refuge altogether. Common Tern, Least Tern, Roseate Tern, Black Skimmer, Black-crowned Night Heron and Great Egret populations all increased on Long Island over the sampling period although the Common Tern colonies in JBWR have been declining since 1986 (Brown, 1998).

Jamaica Bay supports 49 species of finfish, numerous shellfish and invertebrates, and a thriving eel population. Among the finfish, the most commonly found species are Atlantic Silversides, Atlantic Killifish, Striped bass, Alewife, Atlantic menhaden, Bluefish, and Windowpane flounder (JABERRT, 2002).

There is an increasing concern over classes of contaminants referred to as 'environmental estrogens' – suspected of causing health effects in both humans and wildlife through disruption of the endocrine system. Organic contaminants such as those in sewage effluent have been shown to elicit an estrogenic response in juvenile fish. In Jamaica Bay, concentrations of Alkylphenol Ethoxylate metabolites such as Nonylphenol (NP) in both sediments and water showed a strong correlation with conventional sewage tracers (Ferguson, 2001).

Comparatively little emphasis has been placed on assessing these effects in marine invertebrates, particularly benthic organisms inhabiting sediment where lipophilic contaminants tend to persist. In one study on the impact on sediment inhabiting invertabrates, sewage-affected sediments from Jamaica Bay produced a modest reduction in reproductive output despite exceedingly high concentrations of NP (Zulkowsky, 2002).

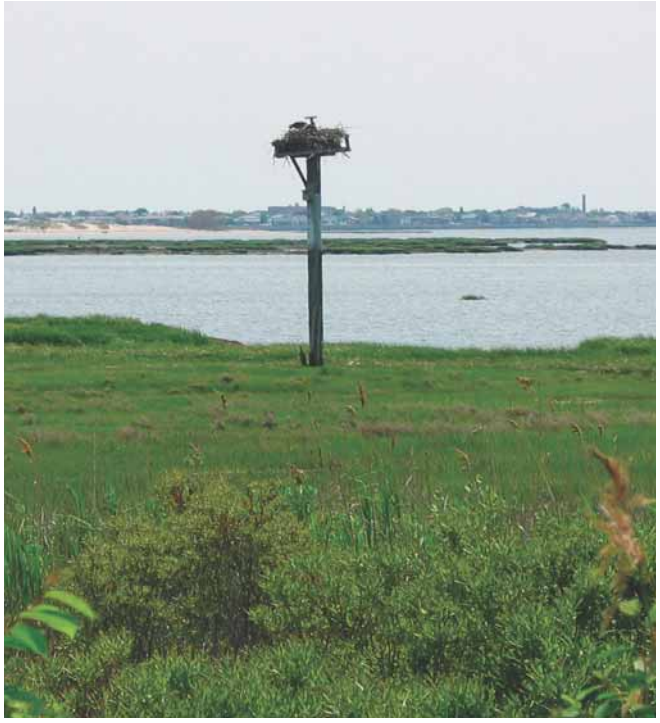
Habitat Preservation in Jamaica Bay

Many, but not all, of the wetland and shallow water habitats of Jamaica Bay are part of the Gateway National Recreation Area (GNRA) administered by the National Park Service. Significant habitat resources outside of GNRA fall under either New York City of New York State jurisdiction. Most of these lands were assembled into permanent preservation during the late 1980s and early 1990s by numerous habitat restoration projects.

NYC Parks and Recreation has been particularly active in investigating and remediating several sites, including:

- Coney Island Creek/Dreier-Offerman is a 4 acre, $3 million dollar project funded by the NYS Clean Water/Clean Air Bond (NYS CW/CA). Currently in design, this project includes excavation and planting for salt marsh restoration, upland planting with grasses, and additional restoration of marsh and beach
- Marine Park is a 30 acre, $6 million project jointly funded by NYS CW/CA and the US Army Corps of Engineers (USACE). Currently in monitoring, this proposal is within NYC parkland that contains both active and passive recreational activities. NYC Parks is currently undertaking a wetland restoration project and has completed construction of an environmental center
- Gerritsen Inlet is a 20 acre site slated for remediation in 2003-2004. This $1.3 million project is funding through NYS CW/CA, the City of New York, and the USACE
- Four Sparrow Marsh is a 4 acre remediation project currently in construction funded by $800,000 from 1997 NYS CW/CA and the City of New York.

The USACE and the NYSDEC are significant sponsors of habitat restoration in Jamaica Bay, including ongoing design work on eight sites, including Dead Horse Point, Fresh Creek, Paerdegat

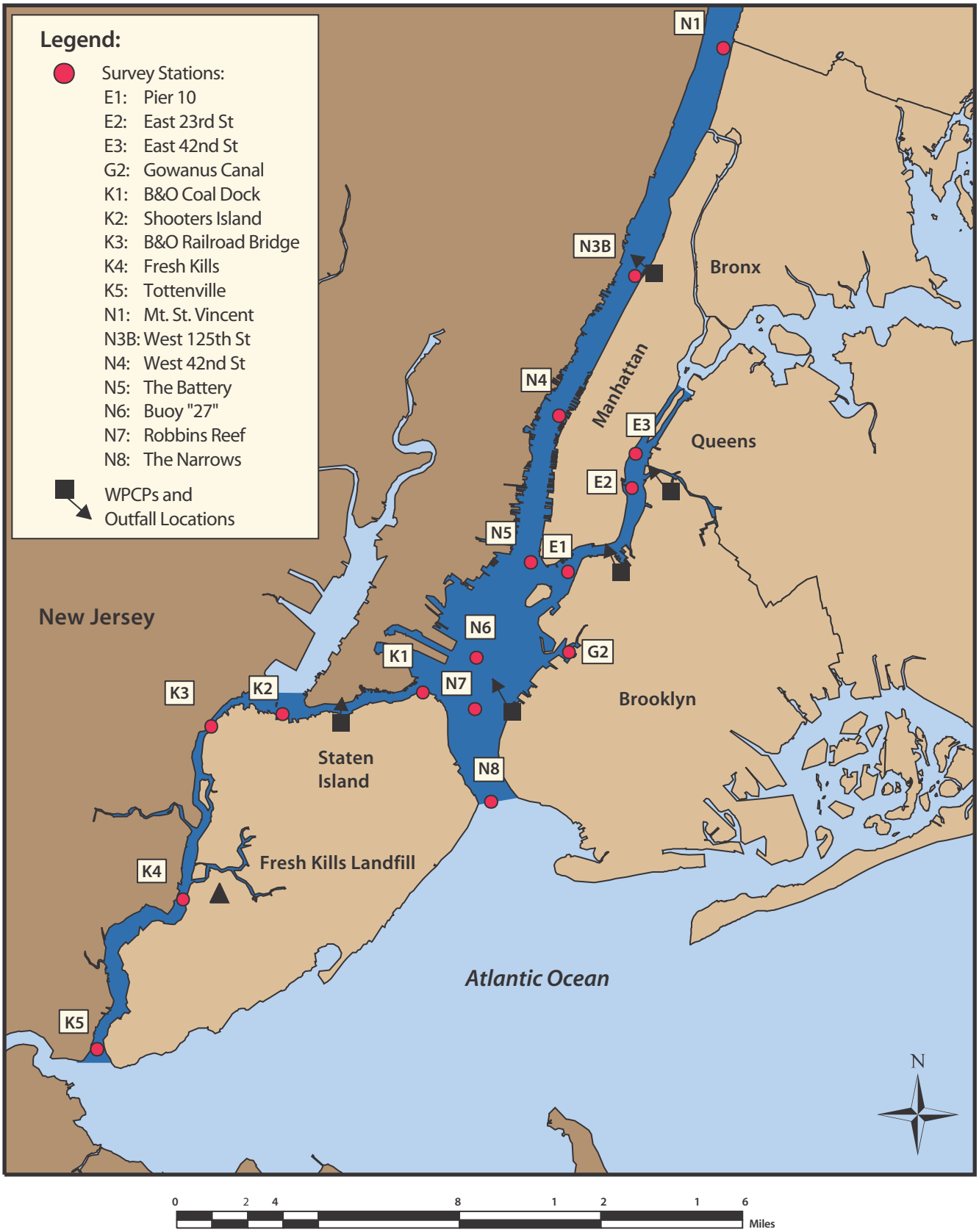


Basin, Dubois Point, Brant Point, Spring Creek, Hawtree Basin and Baywater.

In a joint habitat restoration project between the USACE and the NYCDEP, the Pennsylvania and Fountain Avenue landfills are being converted into traditional coastal habitat through marsh restoration and softening of shorelines.

In Norton Basin, the USACE and NYSDEC are evaluating the restoration potential from filling in former borrow pits originally dug for the construction of JFK. This project will first assess the degree of degradation in the pit and then consider the benefits of restoration and the best method of restoration – which may involve beneficial use of dredged materials from other parts of the harbor. A marsh restoration pilot project is set to begin in 2004 with NYSDEC and NYCDEP in which sediment will be deposited on a salt marsh to determine if this will have an impact on marsh accretion rates.

FIGURE 4-1: Map of Inner Harbor Including 2002 Sampling Sites and WPCP Locations



The Inner Harbor is composed of four subregions, including: the Hudson River (Westchester County line to the Battery); the Upper Bay (Battery through Verrazano Narrows); the Lower East River (the north end of Roosevelt Island south to the Upper Bay); and the Kills (comprised of Arthur Kill and Kill Van Kull, both tidal straights bordering New Jersey) (Figure 4-1).

The greatest water quality improvements in the Hudson River and Upper Bay come at around the time of the construction in 1986 and upgrade to secondary treatment in 1991 of the North River WPCP. Continued progress since 1991 appears to have resulted from other NYCDEP programs, including increases in capture and treatment of stormwater, abatements of illegal discharges, and better engineering management and operational controls on the sewage processing system as a whole. The construction (1987) and upgrade (1989) of the Red Hook WPCP eliminated disposal of untreated wastewater into the East River, also an important part of improving overall water quality in the Inner Harbor.

The various subregions of the Inner Harbor have varying water quality, uses and classifications. Much of the Hudson River is classified primary and secondary contact recreation as well as fish survival and propagation. The Upper Bay and north river portion of the Hudson are classified for secondary contact (I classification) and fish survival and propagation. The Kills meanwhile are classified as SD, or suitable for fish survival.

Factors Affecting Water Quality

The Inner Harbor is the most intensively exploited region in the entire harbor region. The primary shipping channels servicing ports throughout the region are maintained here. To support the significant volume of harbor traffic, dredging operations are ongoing for both maintenance and deepening purposes. The five city owned WPCPs emptying into the Inner Harbor have a combined capacity of 590 MGD (Table 4-1). Further, the waters are heavily affected by CSOs, storm sewer discharges, and general urban runoff. The Hudson, Passaic, and Hackensack Rivers all drain into the Inner Harbor, bringing with them nutrients, sediments, waste discharges and historic upstream pollutants of the inland region.

TABLE 4-1: Inner Harbor WPCPs – Capacities, Construction Dates and 2002 Flows

Plant	Waterbody	Capacity (MGD)	Initially Built	Upgrade to Secondary	Avg. Dry Weather Flow (MGD)	Avg. Total Flow (MGD)
North River	Hudson	170	1986	1991	122	127
Owls Head	Upper Bay	120	1952	1995	95	101
Newtown Creek*	Lower East River	310	1967	2007	216	229
Red Hook		60	1987	1989	28	30
Port Richmond	Kill Van Kull	60	1953	1979	29	31

*Currently operating as modified aeration

Water Quality in the Inner Harbor

Dissolved Oxygen

Long-term Trends

DO for the Inner Harbor has shown consistent, gradual improvement over the past 30 years with all of the subregions showing similar positive patterns. Bottom DO values have risen from approximately 3.0 mg/l in the early 1970s to well above 5.0 mg/l at present. Since 1992, surface summer means have ranged from 6.1-6.5 mg/l while bottom summer means have ranged between 5.3 and 5.8 mg/l (Figure 4-2).

In the Lower Hudson, DO has a spatial distribution based on distance from the Battery and salinity. DO minimums typically occur in the Manhattan portion of the Hudson. High freshwater discharge and associated reduction in salinity, as measured at the Battery, has been found to have a profound effect on DO in this region (Clark, 1995).

Over the past 10 years, surface and bottom summer mean DO values taken in the New York Harbor Survey have been consistently good, however the gains of the prior 20 years leveled out in the 1990s – and are substantially unchanged for the entire region since that time. Despite the good overall numbers, late summer in the Inner Harbor tends to have reduced DO.

In the Inner Harbor, the Hudson River sites have consistently had the highest surface DO values with the last significant improvement occurring in 1992 after the upgrade of the North River WPCP. However, bottom DO values in the Hudson have been substantially lower than surface levels suggesting a degree of stratification.

2002 Results

Ten-year August bottom DO means for the Inner Harbor are slightly below 5.0 mg/l while July and September ten year bottom DO means are slightly above August levels. Summer mean surface and bottom water DO concentrations in 2002 were 6.3 and 5.6 mg/l, respectively. However, in August both surface and bottom DO monthly means fell slightly below 5.0 mg/l (Figure 4-3).

FIGURE 4-2:
1973-2002 Surface and Bottom Summer DO Means and +/- 2 Standard Errors with 30 Year Regression for Inner Harbor

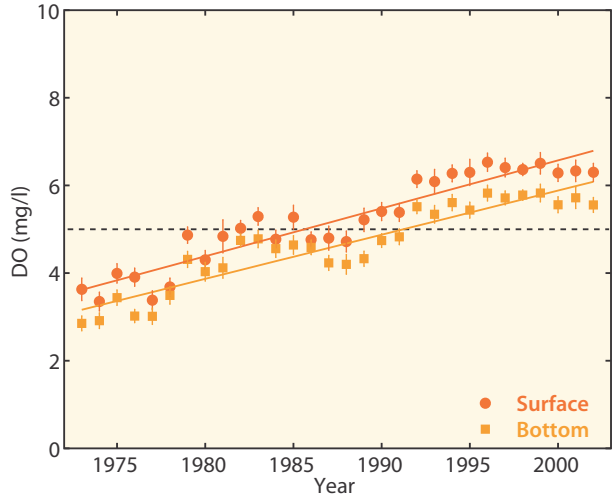


FIGURE 4-3:
2002 Surface and Bottom Monthly DO Means and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Inner Harbor

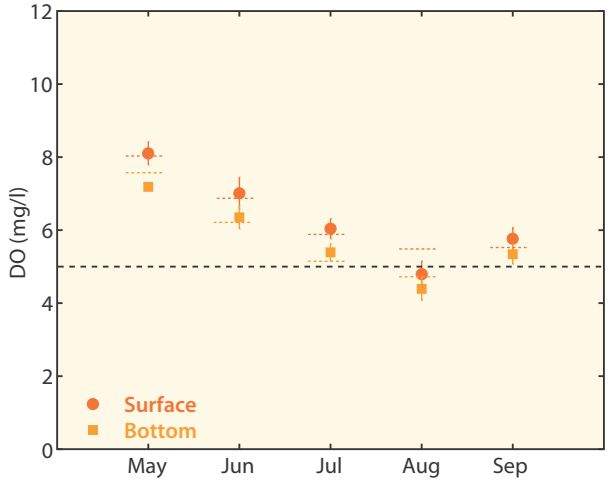
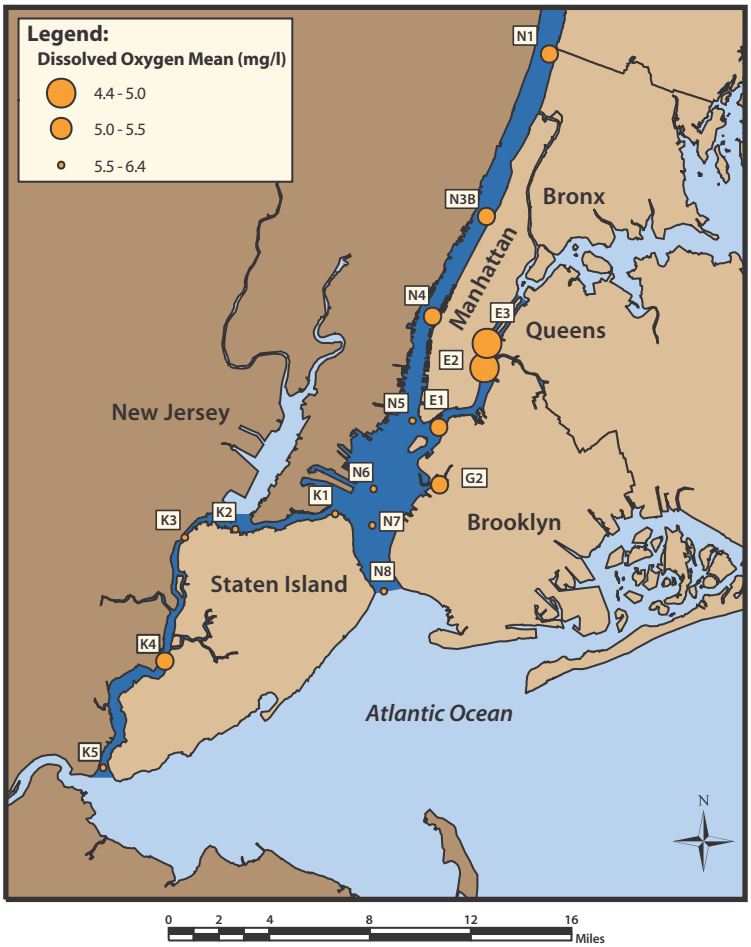


TABLE 4-2: Inner Harbor 2002 DO and Fecal Coliform Means, Minimums and Maximums

Station Code	Location	Dissolved Oxygen				Fecal Coliform	
		Mean		Minimum		Summer Geometric Mean	Maximum
		Surface	Bottom	Surface	Bottom		
N1	Mt. St. Vincent	6.9	5.3	5.0	3.1	53	540
N3B	W. 125th St.	6.4	5.2	5.0	3.7	79	940
N4	W. 42nd St.	6.2	5.4	4.6	3.8	84	820
N5	The Battery	5.8	5.9	4.2	4.0	52	565
E1	Pier 10	5.5	5.0	4.4	4.3	–	–
E2	E. 23rd St.	4.7	4.5	2.9	2.9	62	830
E3	E. 42nd St.	5.1	4.4	3.3	3.2	–	–
G2	Gowanus Canal	6.0	5.1	2.5	2.8	249	>4000
N6	Buoy "27"	6.8	6.1	5.1	4.9	55	241
N7	Robbins Reef	6.6	6.3	4.9	4.7	40	340
N8	The Narrows	7.3	6.4	5.3	5.1	26	169
K1	B&O Coal Dock	6.6	6.1	5.1	5.0	67	490
K2	Shooters Island	6.5	6.1	5.2	5.0	47	355
K3	B&O Railroad Bridge	6.3	5.7	4.8	4.6	71	>4000
K4	Fresh Kills	5.9	5.1	3.7	3.4	77	630
K5	Tottenville	7.0	5.7	4.2	3.7	26	204

Summer mean bottom DO concentrations met the state standard at 17 stations out of 18. Of all 187 samples taken in the Inner Harbor during 2002, 32% fell below 5.0 mg/l. This is within the range of typical exceedances since 1992, a dramatic improvement from the early 1970s when over 90% of samples did not meet the state standard. Station E2, located in the East River south of Newtown Creek, had the lowest DO values for the Inner Harbor region with surface and bottom summer means of 4.7 and 4.6 mg/l (Figure 4-4 and Table 4-2). The minimum value recorded at E2 of 2.9 mg/l was found for both surface and bottom water.

FIGURE 4-4: Map of 2002 DO Values for Inner Harbor

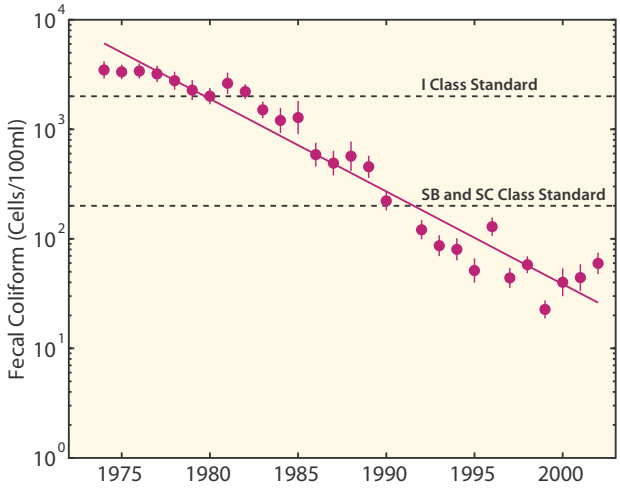


Fecal Coliform

Long-term Trends

Fecal Coliform levels in the Inner Harbor have dramatically declined over the last three decades – from summer geometric means over 2,000 cells/100ml in the early 1970s to well below 100 cells/100ml currently (Figure 4-5). As with DO, FC values have been essentially flat over the past ten years, well below the regulatory standard of 200 cells/100ml. In 1999, summer geometric mean declined as low as 20 cells/100ml. Since then, levels have risen gradually up to 60 cells/100ml in 2002 – still well below the state limit for fishing and swimming.

FIGURE 4-5:
1973-2002 Fecal Coliform Summer Geometric Means and +/- 2 Standard Errors with 30 Year Regression for Inner Harbor



2002 Results

Monthly FC geometric means for 2002 were generally consistent with ten-year monthly means, and were well below 100 cells/100ml (Figure 4-6). The exception was August which saw slightly elevated FC levels of 129 cells/100ml compared with a ten year August mean of 59 cells/100ml. Station G2 in the Gowanus Canal continues to see elevated FC levels. The summer geometric mean was 250 cells/100ml with the maximum of >4,000 cells/100ml occurring July 10th. (Figure 4-7 and Table 4-2)

FIGURE 4-6:
2002 Monthly FC Geometric Mean and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Inner Harbor

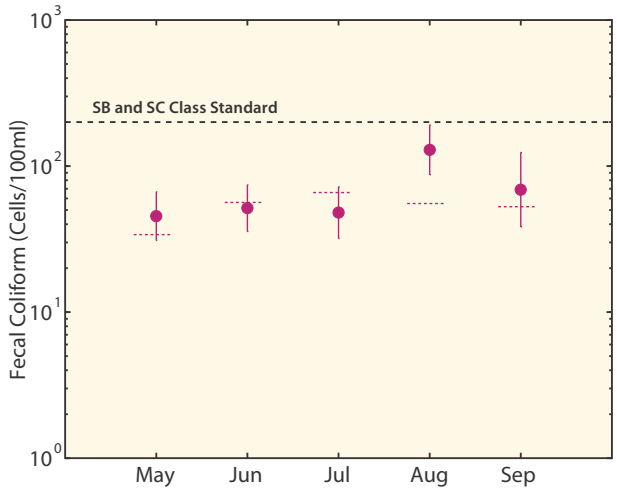
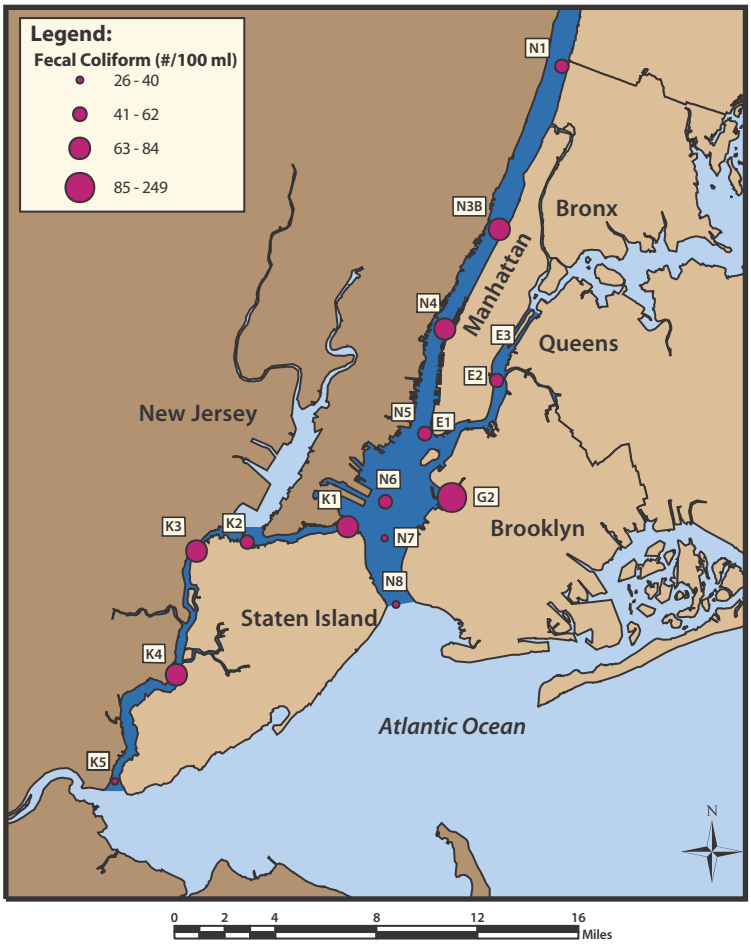


FIGURE 4-7: Map of 2002 FC Summer Geometric Means for Inner Harbor



Chlorophyll a

Long-term Trends

The Inner Harbor has had comparatively low levels of chlorophyll a since 1985, showing little discernible trend. Values have typically been below 10 µg/l with occasional values during the mid-1990s slightly higher (Figure 4-8). The Lower East River and the Upper Bay have consistently recorded the lowest chlorophyll a levels while The Kills and the Hudson River are comparatively higher.

2002 Results

2002 monthly chlorophyll a means in the Inner Harbor did not exceed 10 µg/l for the entire summer and were generally slightly below the ten-year monthly means (Figure 4-9). The highest chlorophyll a levels occurred at station K5 at the southern end of the Arthur Kill, which had a summer mean of 21 µg/l and a maximum value of 38 µg/l. Chlorophyll a concentrations increased southwards through the Hudson River into the Upper Bay.

FIGURE 4-8:
1986-2002 Chlorophyll a Summer Means and +/- 2 Standard Errors with 17 Year Regression for Inner Harbor

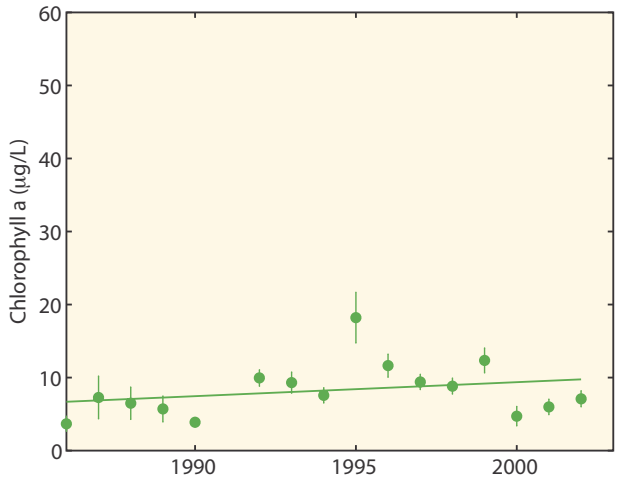
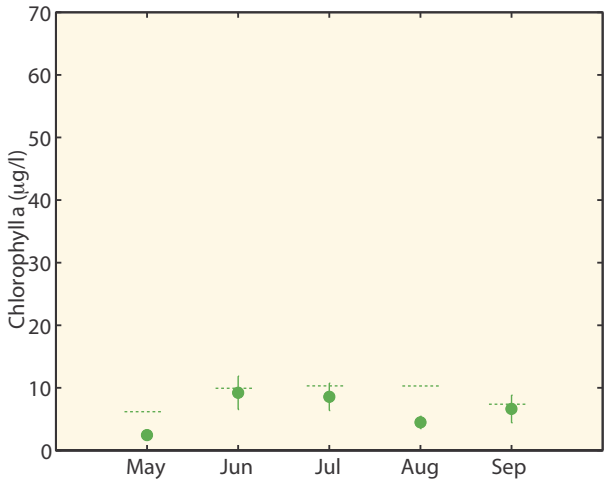


FIGURE 4-9:
2002 Chlorophyll a Monthly Means and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Inner Harbor



Turbidity

Long-term Trends

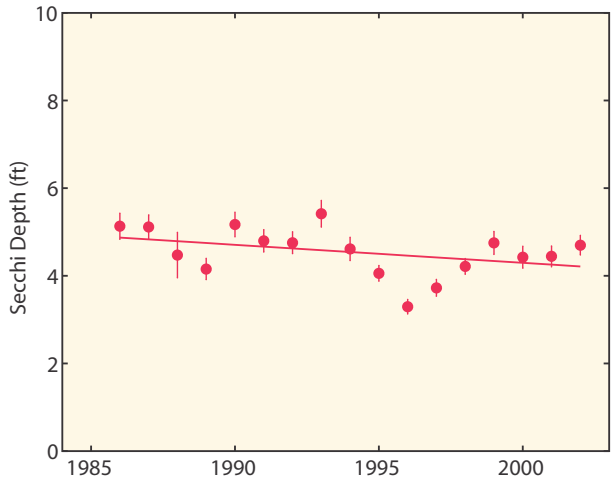
Turbidity in the Inner Harbor shows little discernible trend since 1986 with perhaps a minor deterioration in water clarity (Figure 4-10). In general, interannual swings between the subregions tend to agree, however there is variability in turbidity between subregions. The Hudson River stations have exhibited the most turbid waters with mean secchi depth values in the 2-4 ft range. The Lower East River and the Upper Bay have had summer means in the 4-7 ft range. The Kills tend to show less variability between years and have been in the 4-5 ft range.

2002 Results

Turbidity in the Inner Harbor decreases from north to south in New York Harbor. Station N1 (Mt St Vincent) at the northern end of the study area had a summer mean secchi depth of 3.3±1.0 ft. Water clarity increases going southwards where station N8 (The Narrows) had a summer mean secchi depth of 5.5±2.1 ft. The broadening of the channel towards the south helps to slow the flow and allow for sediment to settle out of the water column.

The Lower East River had water clarity similar to the Upper Bay in the five foot range. The Kills had slightly lower water clarity ranging from 4.2±1.1 to 4.9±1.4 ft.

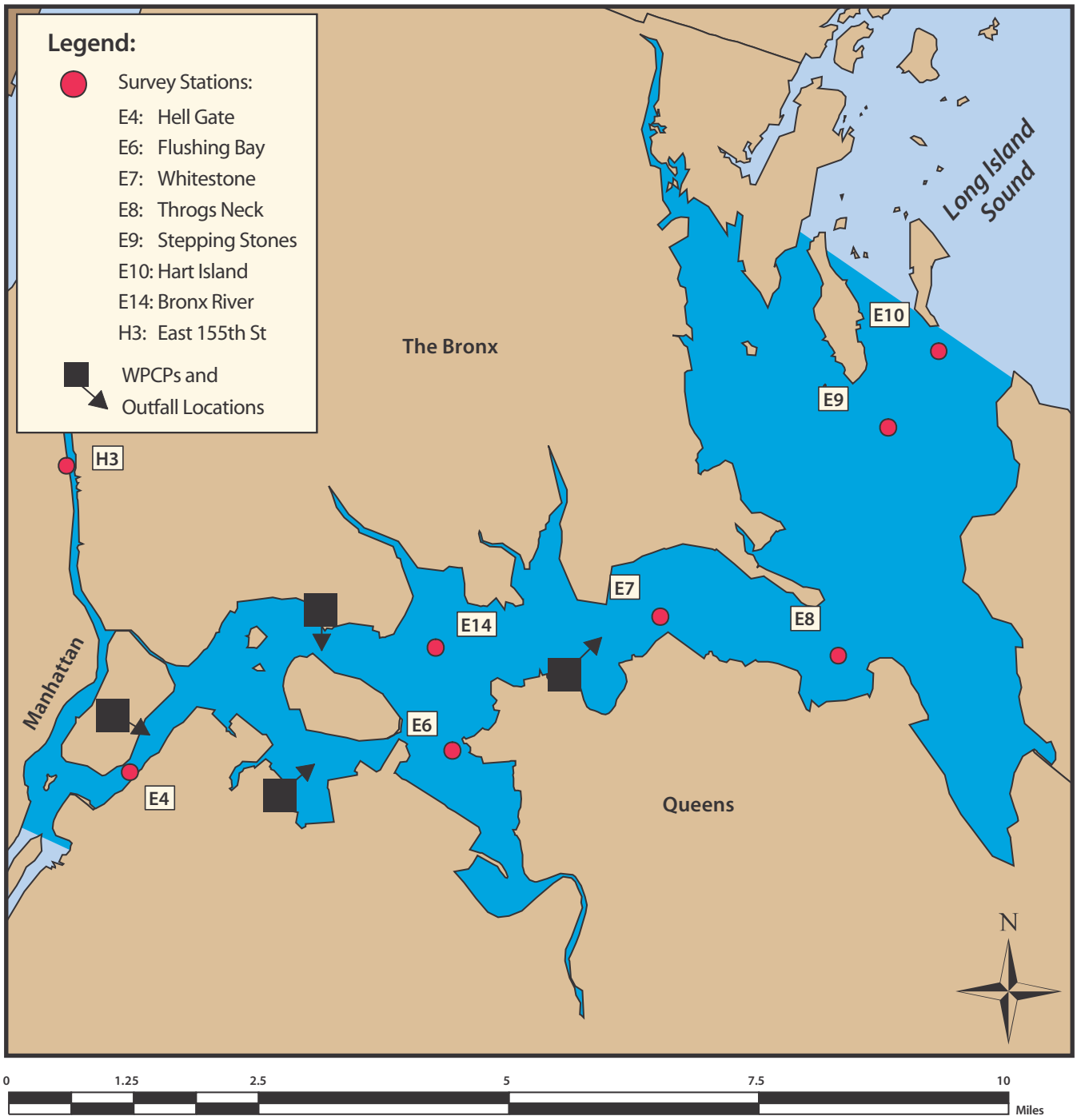
FIGURE 4-10:
1986-2002 Secchi Depth Summer Means and +/- 2 Standard Errors with 17 Year Regression for Inner Harbor



Upper East River – Western Long Island Sound

The Upper East River – Western Long Island Sound region is the northeastern portion of the Harbor and includes the East River north of Roosevelt Island, the Harlem River, and the Western Long Island Sound to Hart Island. The passage through Hell Gate is unique in that New York Harbor connects to the Atlantic Ocean in two significantly distinct places.

FIGURE 5-1: Map of Upper East River – WLIS including 2002 Sampling Sites and WPCP Locations



New York State has determined that the best use classifications for most of the Upper East River is Class I, suitable for boating and fishing but not swimming or shellfishing. The Upper East River east of Throgs Neck and Western Long Island Sound are classified for swimming and primary contact.

The use of these waters has been primarily affected by the success of water quality improvements over the past thirty years. Fecal Coliform reductions have been dramatic and summer geometric means in recent years have consistently been well below regulatory thresholds. Of note, the number of sampling stations in Upper East River – WLIS has declined significantly over the past several years. In 2002, only eight stations were sampled regularly whereas in previous years, up to 18 stations had been sampled (Figure 5-1).

Factors Affecting Water Quality

Flow into and out of the Upper East River – WLIS is very complex. Significant tidal flows entering New York Harbor and Long Island Sound meet in this middle ground. Water and contaminants flow in both directions, towards Long Island Sound and in the opposite direction towards the Upper Bay. Residence time for water is several days in the East River. As a result, discharges into the East River tend to be dispersed rapidly into either the Upper Bay or Long Island Sound.

As surface water from the East River enters the Sound, relatively saline bottom water flows east to west with the net flux of water from Long Island Sound into New York Harbor (Blumberg and Pritchard, 1997).

Several major WPCPs discharge into the waters of the Upper East River – WLIS (Table 5-1). Mean dry weather flow from the four WPCPs in this region in 2002 was 414 MGD. This does not include discharges from WPCPs on the Lower East River and other municipal WPCPs further east on the Long Island Sound.

The Long Island Sound Study has identified low DO as the most significant water quality issue in the region. Nitrogen, thought to be a primary cause of low DO in WLIS, has been declining from both point sources and nonpoint sources over the past ten years. Nonetheless, in 2001 the states of New York and Connecticut in conjunction with the EPA approved the nitrogen Total Maximum Daily Load which may lead to a 58.5% reduction in nitrogen loads to the Sound through 2014.

Water Quality in the Upper East River – WLIS

Dissolved Oxygen

Long-term Trends

Surface DO summer means in Upper East River – WLIS show significant improvement over the past 30 years – nearly doubling from means in the 3.0-3.5 mg/l range in the 1970s to above 6.0 mg/l in the past decade (Figure 5-2). However, the past two years mark a significant departure from the improving pattern. Both 2002 and 2001 DO levels in Upper East River – WLIS were significantly below prior trend lines.

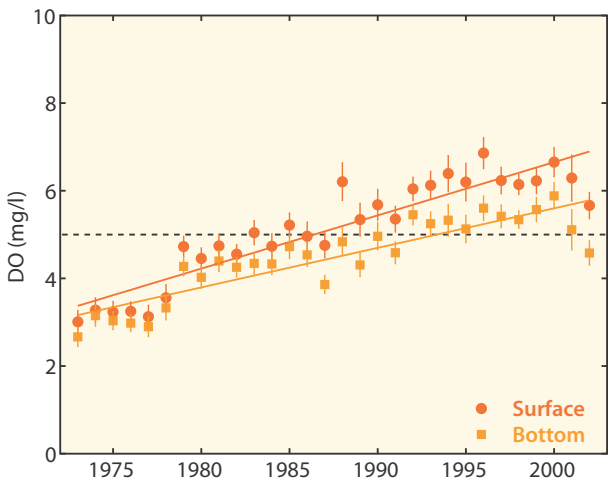
WLIS has historically had a problem with low bottom DO. Since the mid-1980s bottom minimum DO has decreased, and vertical DO stratification has

TABLE 5-1: Upper East River – WLIS WPCPs – Capacities, Construction Dates and 2002 Flows

Plant	Capacity (MGD)	Initially Built	Upgrade to Secondary	Mean Dry Weather Flow (MGD)	Mean Total Flow (MGD)
Wards Island	275	1937	1979	172	179
Hunts Point	200	1952	1978	96	104
Tallman Island	80	1939	1978	48	50
Bowery Bay	150	1939	1978	98	105

increased in WLIS (O'Shea, 2000). Over the past ten years, annually between 40% and 60% of DO samples in the Upper East River and WLIS have fallen below 5.0 mg/l. July through September is a period of depressed bottom DO with ten-year monthly means of about 4.5 mg/l.

FIGURE 5-2:
1973-2002 Surface and Bottom Summer DO Means and +/- 2 Standard Errors with 30 Year Regression for Upper East River - WLIS



2002 Results

2002 summer mean surface and bottom DO concentrations were 5.7 and 4.6 mg/l, marking the first time since 1991 that mean bottom DO fell below 5.0 mg/l. Summer mean bottom DO concentrations exceeded 5.0 mg/l at three stations out of nine sampled (Figure 5-4). Of the 115 surface and bottom samples taken in 2002, 63% fell below 5.0 mg/l.

Bottom DO levels were particularly problematic in the region from July and August when mean monthly DO levels fell to 4.2 and 3.1 mg/l, recovering to just under 5.0 in September (Figure 5-3). Hart Island (station E10), located in WLIS, recorded the lowest bottom DO value of 1.1 mg/l on August 5th (Table 5-2). Bottom DO remained hypoxic throughout August, staying at or below 2.1 mg/l during all four sampling times in the month. It recovered to above 5.0 mg/l in September. The waters at Hart Island are considerably deeper than other parts of the region and New York Harbor and may be one reason for the particularly low bottom DO; bottom samples are taken at depths greater than 80 ft. Stations E9 and E8, both in WLIS, had minimum DO values below 1.5 mg/l occurring on August 5th (Table 5-2).

TABLE 5-2: Upper East River-WLIS 2002 DO and Fecal Coliform Means, Minimums and Maximums

Station Code	Location	Dissolved Oxygen				Fecal Coliform	
		Mean		Minimum		Summer Geometric Mean	Maximum
		Surface	Bottom	Surface	Bottom		
H3	East 155th Street	5.3	5.3	3.3	3.1	101	878
E4	Hell Gate	4.5	4.3	3.3	2.9	113	1,138
E6	Flushing Bay	5.1	4.7	2.9	3.0	79	1,920
E7	Whitestone	5.1	4.6	2.9	2.8	48	1,830
E8	Throgs Neck	6.0	4.4	3.1	1.5	37	730
E14	Bronx River	5.6	5.5	3.8	4.3	102	1,940
E9	Stepping Stones	7.0	4.3	4.8	1.5	–	–
E10	Hart Island	7.4	4.0	3.6	1.1	9	48

FIGURE 5-3:
2002 Surface and Bottom Monthly DO Means and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Upper East River – WLIS

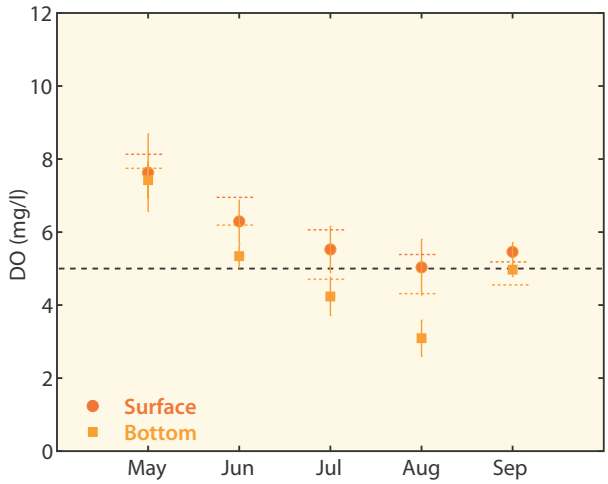


FIGURE 5-5:
1973-2002 Fecal Coliform Summer Geometric Means and +/- 2 Standard Errors with 30 Year Regression for Upper East River - WLIS

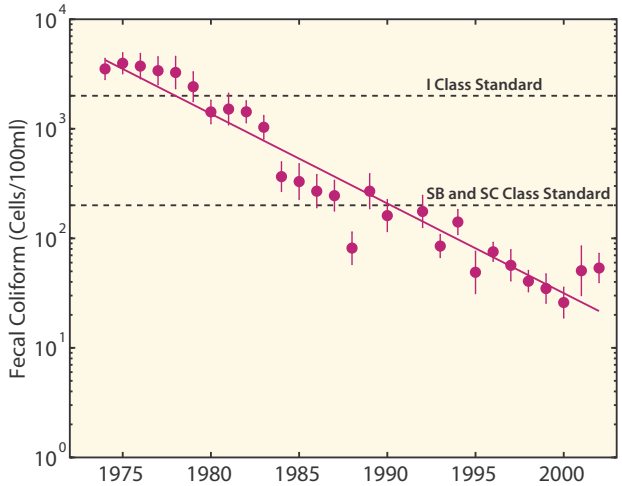
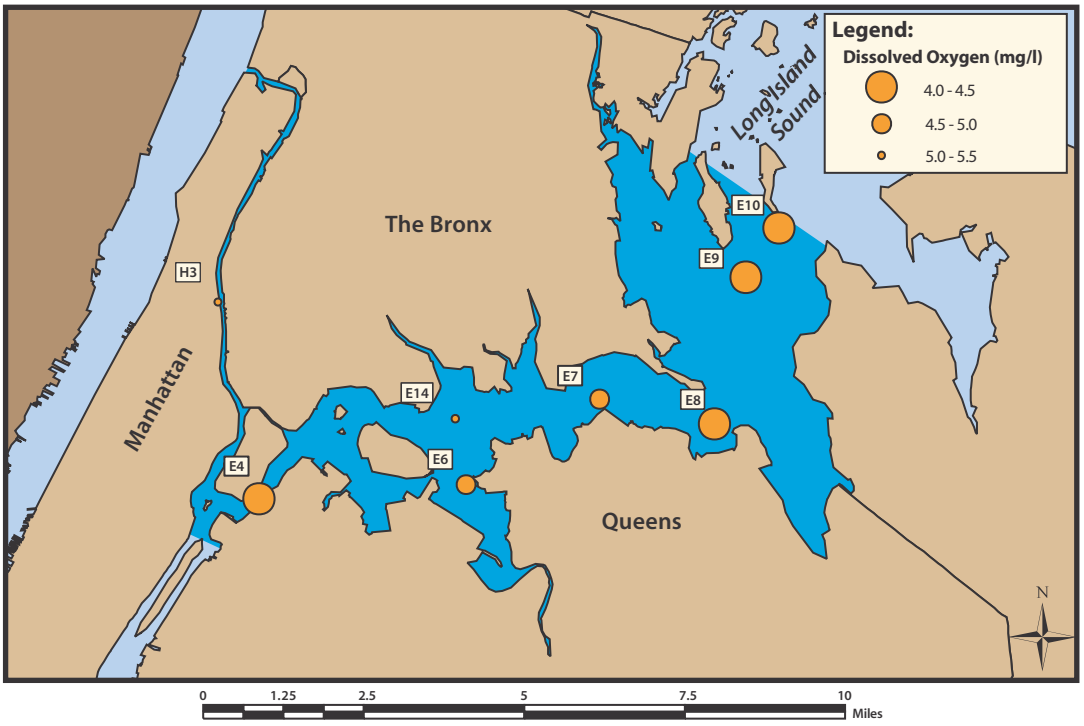


FIGURE 5-4: Map of 2002 DO Values for Upper East River – WLIS



Fecal Coliform

Long-term Trends

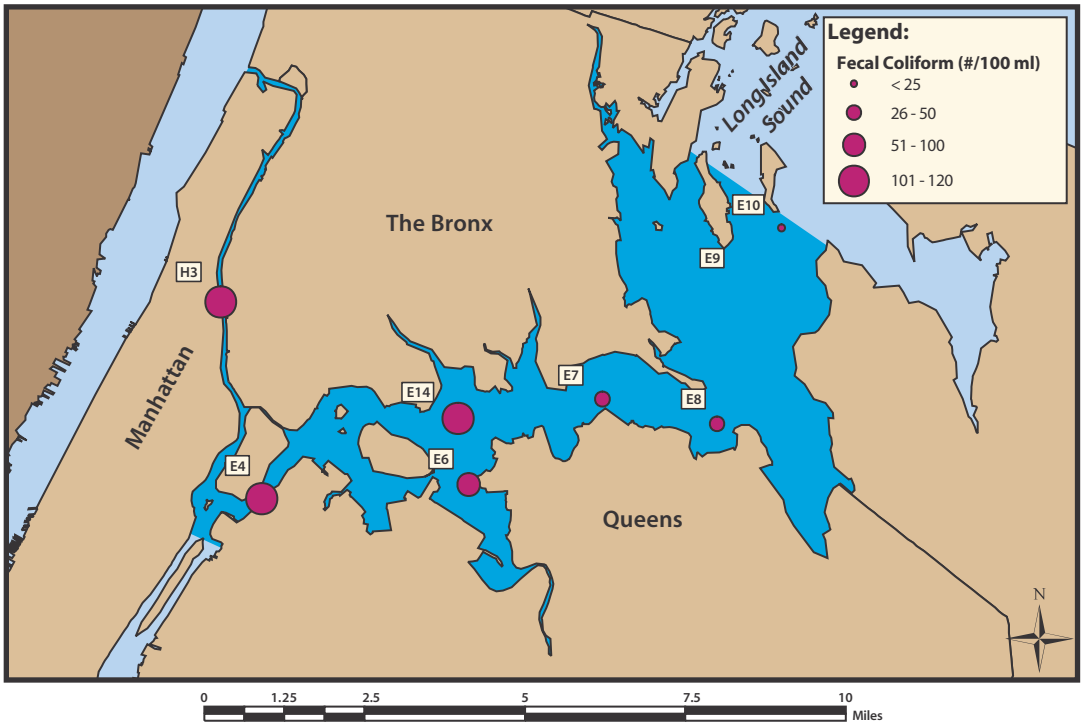
The reduction of FC in the Upper East River – WLIS has been one of the great successes in New York Harbor – with dramatic declines over the last three decades. FC levels begin to rapidly descend in the early 1980s – shortly after the secondary upgrades at the Upper East River treatment plants in the late 1970s means well over 2,000 cells/100ml persisted throughout the 1970s – declining to around 50 cells/100ml in recent years (Figure 5-4). For the past ten years, FC levels appear to have stabilized at these levels.

2002 Results

For 2002, the summer geometric mean for the region was 54 cells/100ml, a level well within the range of the previous ten years. Summer monthly means for the region were in line with ten year monthly geometric means which all are below 100 cells/100ml (Figure 5-7).

Several locations had summer geometric means slightly above 100 cells/100ml including Bronx River (E14), Hell Gate (E4) and Harlem River (H3) (Figure 5-6). Several stations had single measurement maximums that approached but did not exceed 2,000 cells/100ml.

FIGURE 5-6: Map of 2002 FC Summer Geometric Means for Upper East River – WLIS

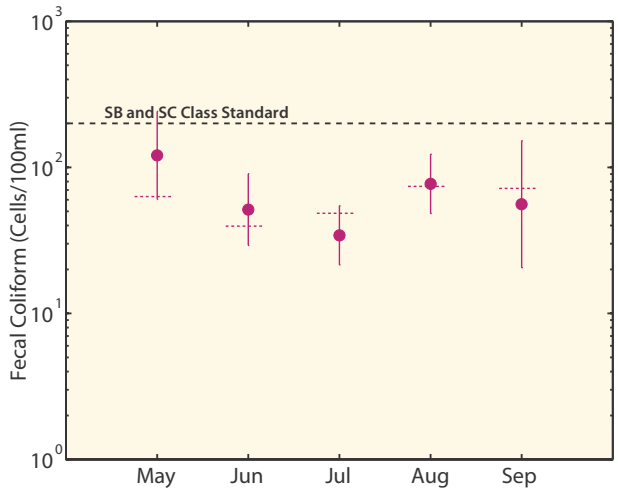


Chlorophyll a

Long-term Trends

Chlorophyll a summer means in the Upper East River – WLIS have over the past six years been in the 10 –15 µg/l range. Values, however, vary significantly throughout the region, increasing from west to east. The Harlem River has typically had values below 10 µg/l similar to levels found in the Lower East River.

FIGURE 5-7:
2002 monthly FC Geometric Mean and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Upper East River – WLIS



The Upper East River has typically had elevated levels similar to those found in the Lower Bay. Both the Upper East River and WLIS experienced extremely elevated chlorophyll a levels in the early to mid 1990s. Since that time, levels have been returning back towards values seen in the late 1980s (Figure 5-8). Although significant variability occurs from year to year, the overall 30 year trend is not strong.

2002 Results

2002 chlorophyll a values for the region fell below prior year levels with monthly means well below the ten-year monthly means throughout the summer (Figure 5-9). The June ten-year mean is 20 µg/l while in 2002 the mean was 7 µg/l. Similarly depressed levels are apparent in July 2002. In August, chlorophyll a levels were consistent with historic means, however variability was significant indicating dispersed bloom activity throughout the region. Bronx River (E14) had the highest chlorophyll a summer mean (Figure 5-10) and individual maximum for the region, 25 and 129 µg/l on August 19th, respectively.

FIGURE 5-8:
1986-2002 Chlorophyll a Summer Means and +/- 2 Standard Errors with 17 Year Regression for Upper East River - WLIS

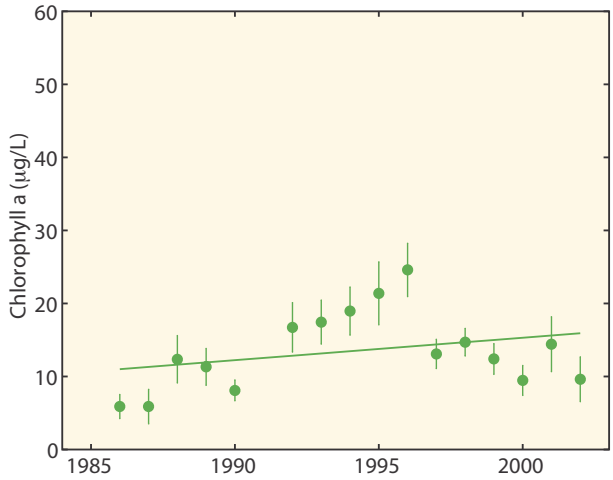


FIGURE 5-9:
2002 Chlorophyll a Monthly Means and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Upper East River – WLIS

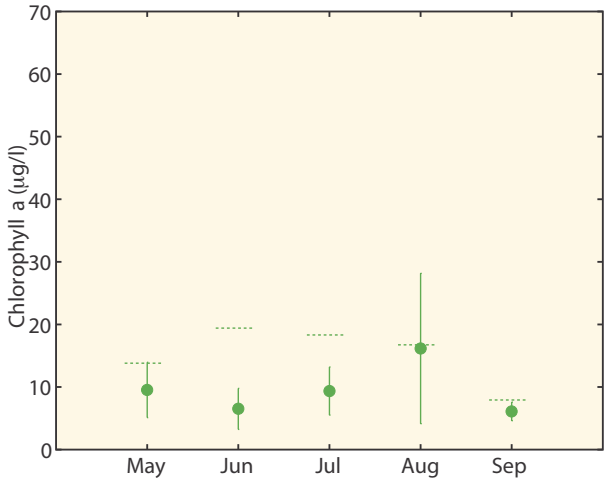
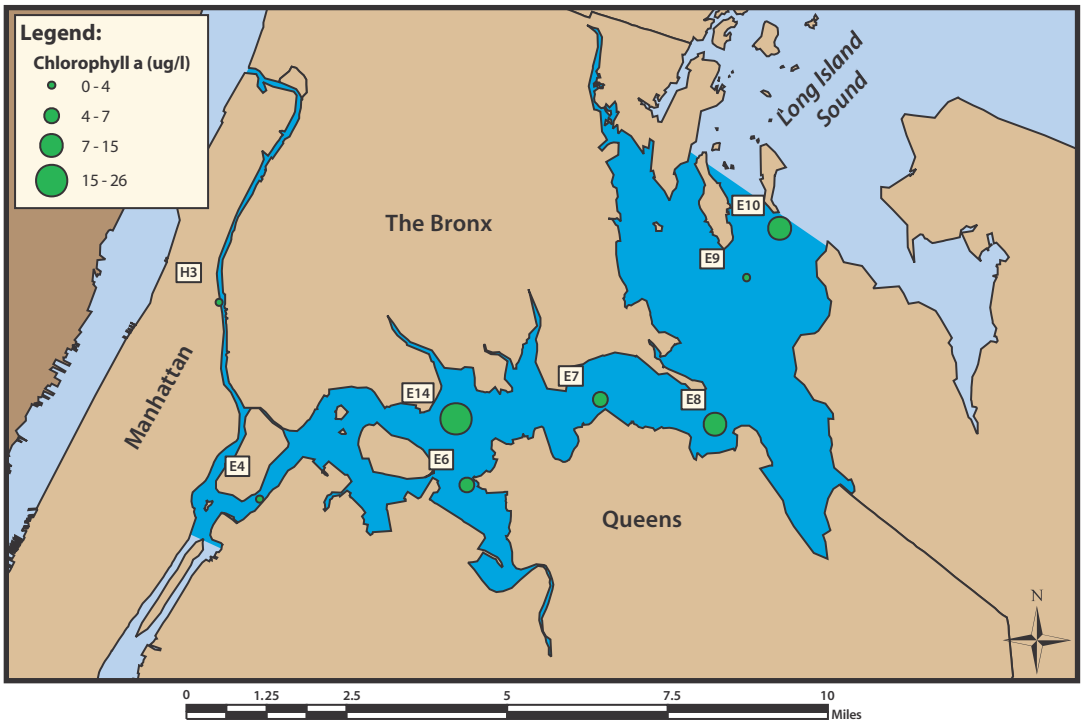


FIGURE 5-10: Map of 2002 Chlorophyll a Values for Upper East River – WLIS



Turbidity

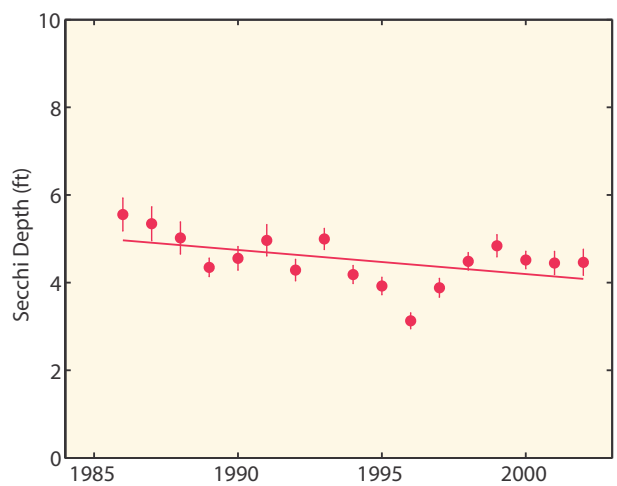
Long-term Trends

Turbidity in the Upper East River –WLIS appears to be slightly increasing over the past 17 years (Figure 5-11). Due to the diverse currents into this region from the Hudson, the Lower East River, and Long Island Sound, water clarity varies in each of the subregions. Generally in the 4-5 ft range, secchi depth in the Upper East River-WLIS is comparable to Jamaica Bay. The Harlem River, receiving flows from the Hudson River, has the lowest water clarity in the region, ranging from 3-4 ft. The Upper East River and WLIS have better water clarity ranging from 4-6 ft.

2002 Results

Harlem River station (H3) had the most turbid waters in the region with a summer mean secchi depth of 3.1 ft, ranging from 1.5 to 6.5 ft. Hell Gate (E4) had a mean of 4.9 ft. However, it had a broad range including a minimum of 2.5 ft on June 24th and a maximum of 9.5 ft on September 30th. Bronx River (E14) had a summer mean of 3.6 ft with a range of 2.0 to 7.0 ft. Hart Island (E10) had a summer mean of 4.8 ft with a range of 3.0 to 8.0 ft.

FIGURE 5-11:
1986-2002 Secchi Depth Summer Means and +/- 2 Standard Errors with 17 Year Regression for Upper East River - WLIS



Lower Bay

Conditions vary throughout the Lower Bay. The sites towards the eastern end (N9 and N16) of the Lower Bay are more influenced by saline waters as well as mixing with tidal outflow from Jamaica Bay. The sites towards the western end (K5A and K6) are more heavily affected by flows from the Raritan River as well as tidal currents coming from the Kills (Figure 6-1).

NYS has classified most of the Lower Bay as suitable for primary and secondary contact such as boating, fishing and swimming as well as fish propagation and survival. In addition, a region along the southeastern tip of Staten Island is classified as SA, appropriate for commercial shellfishing.

FIGURE 6-1: Map of Lower Bay Including 2002 Sampling Sites and WPCP Locations

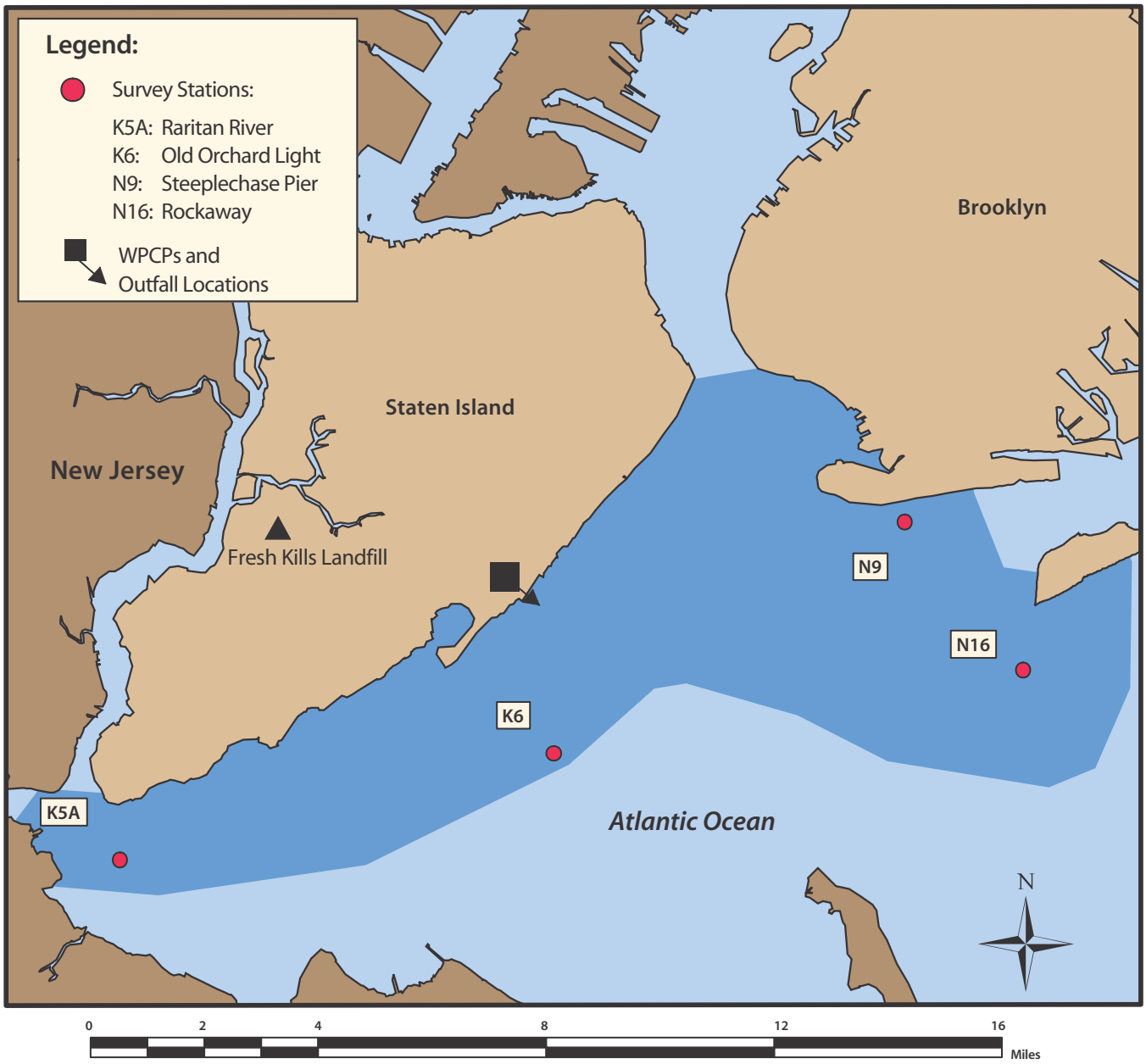
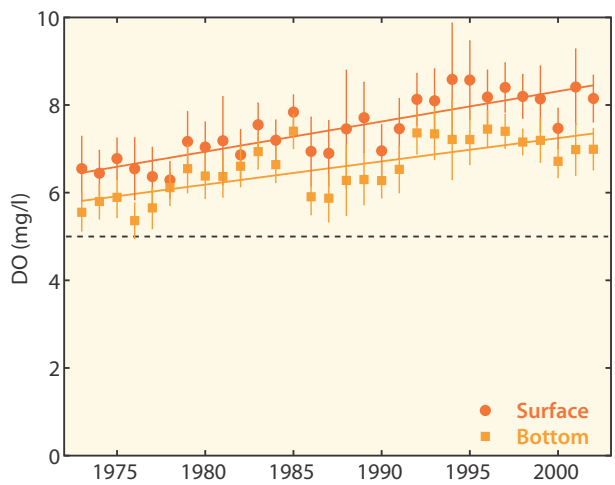


TABLE 6-1: Lower Bay WPCPs Capacities, Construction Dates and 2002 Flows

Plant	Capacity (MGD)	Initially Built	Upgrade to Secondary	Mean Dry Weather Flow (MGD)	Mean Total Flow (MGD)
Owls Head	120	1952	1995	95	101

FIGURE 6-2:
1973-2002 Surface and Bottom Summer DO Means and +/- 2 Standard Errors with 30 Year Regression for Lower Bay



General Factors Affecting Water Quality

Water quality in the Lower Bay is affected by a number of factors. Fresh water flows from the Raritan River and Hudson River plume mix with ocean water in this, the harbor's gateway to the Atlantic Ocean. In the western end of the Lower Bay, water quality is impacted by flows from the Raritan River and the Kills, a highly industrialized corridor.

Water Quality in the Lower Bay

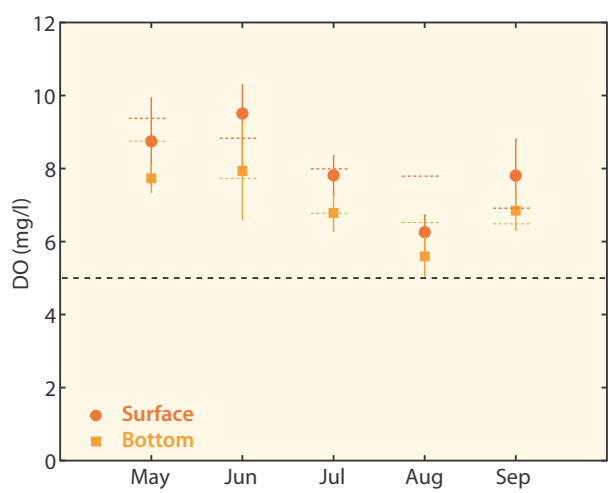
Dissolved Oxygen

Long-term Trends

DO in the Lower Bay has been very supportive of aquatic life over the past thirty years in both surface and bottom waters, improving over time (Figure 6-2). Since the early 1970s, mean summer bottom DO for the region has not fallen below 5.0 mg/l in a single year.

Although a fair degree of interannual variability occurs, the general trend has been upwards. In the mid-to-late 1970s, top and bottom annual summer DO means were approximately 6.5 and 5.5 mg/l – during which time, 25%-37% of Lower Bay DO samples fell below 5.0 mg/l. Mean surface DO for the past ten years exceeds 8.0 mg/l and bottom DO mean exceeds 7.0 mg/l.

FIGURE 6-3:
2002 Surface and Bottom Monthly DO Means and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Lower Bay



2002 Results

With the exception of a significant dip in August, summer monthly DO means were roughly in-line with ten-year monthly means for bottom and surface waters in the Lower Bay (Figure 6-3). The summer mean surface DO was 8.2 mg/l and bottom DO was 7.0 mg/l for the region.

Bottom DO values fell below state standards on only a few occasions. Of 56 total measurements taken in 2002, 3 samples, or 5.4% fell below 5.0 mg/l. Each of these samples were taken at the Raritan River station (K5A), where the low bottom DO recorded was 4.0 mg/l (Table 6-2). However, for the summer, Raritan River had a bottom DO mean of 6.2 mg/l (Figure 6-4). Over the past ten years, annually between 3.1% and 13.5% of samples have fallen below the state standard.

FIGURE 6-4: Map of 2002 DO Means for Lower Bay

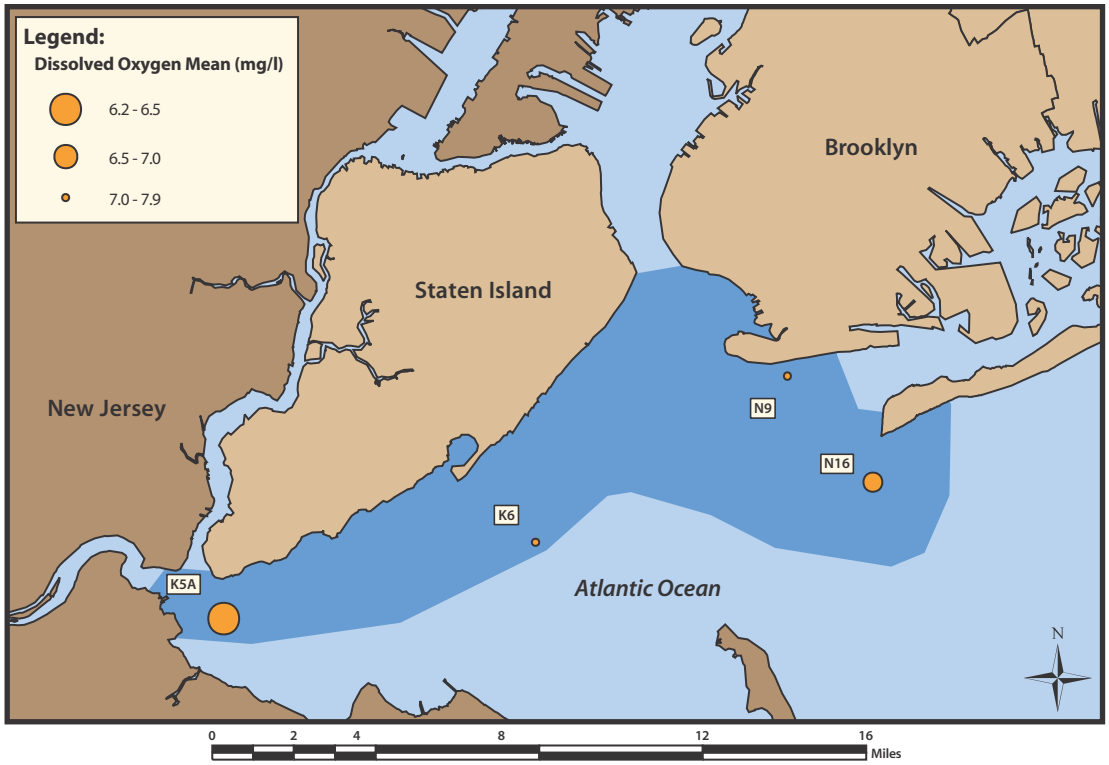


TABLE 6-2: Lower Bay DO and Fecal Coliform 2002 Means, Minimums, and Maximums

Station Code	Location	Dissolved Oxygen				Fecal Coliform	
		Mean		Minimum		Summer Geometric Mean	Maximum
		Surface	Bottom	Surface	Bottom		
K5A	Raritan River	7.9	6.2	4.8	4.0	13	50
K6	Old Orchard Light	10.1	7.9	7.1	5.5	2	10
N9	Steeplechase Pier	7.2	7.0	5.6	5.2	7	107
N16	Rockaway	7.6	6.8	6.4	5.4	4	932

Fecal Coliform

Long-term Trends

Fecal Coliform summer geometric means in the Lower Bay have been decreasing over the past 30 years from the 100-200 cell/100ml range in the 1970s to typically below 10 cells/100ml per year (Figure 6-5). As with other regions in New York Harbor, the biggest declines in FC occurred from the 1970s to the early 1990s. Since then, FC levels have remained essentially the same.

2002 Results

2002 monthly FC geometric means were statistically consistent with ten-year monthly means (Figure 6-6). The highest recorded FC concentration of 932 cells/100ml was observed at the Rockaway station (N16) on September 10th. This occurred over a week after a significant rainfall event that also saw elevated FC levels in Jamaica Bay. Despite this temporary spike in FC, Rockaway had a summer mean of 4 cells/100ml.

FIGURE 6-5:
1973-2002 Fecal Coliform Summer Geometric Means and +/- 2 Standard Errors with 30 Year Regression for Lower Bay

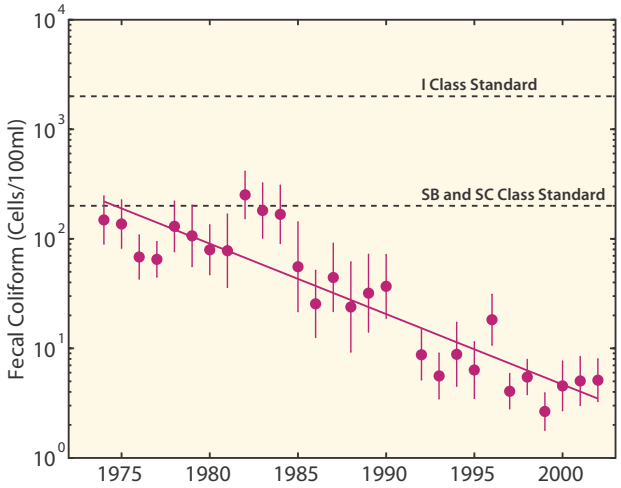


FIGURE 6-6:
2002 Monthly FC Geometric Mean and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Lower Bay

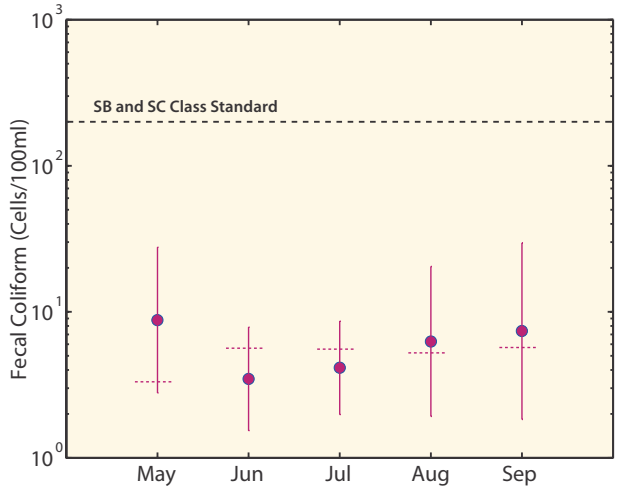


FIGURE 6-7:
1986-2002 Chlorophyll a Summer Means and +/- 2 Standard Errors with 17 Year Regression for Lower Bay

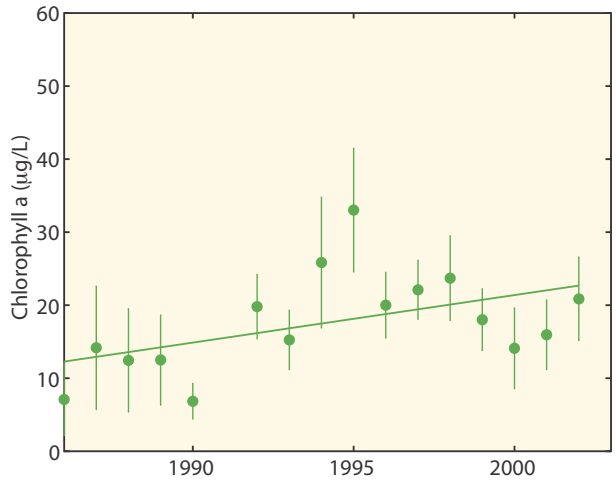
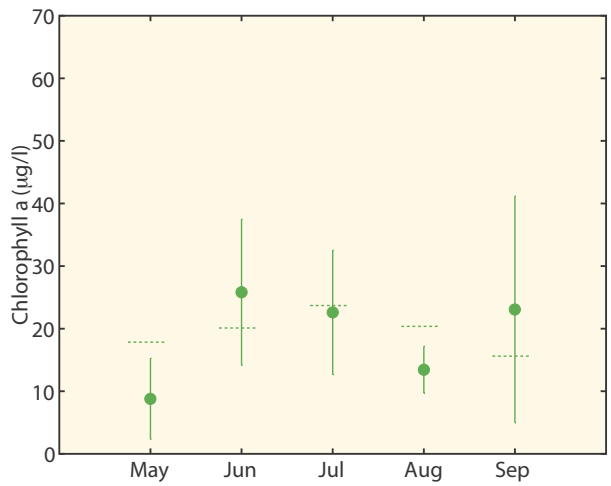


FIGURE 6-8:
2002 Chlorophyll a Monthly Means and +/- 2 Standard Errors with Comparison to 10 Year Monthly Means (short dashed lines) for Lower Bay



Chlorophyll a

Long-term Trends

Behind Jamaica Bay, the Lower Bay is the second most productive region for biomass growth. Chlorophyll a values have been increasing 1986 (Figure 6-7). Since 1992, annual summer means have been in the range of 15-33 µg/l, in contrast to a range of 7-14 from 1986 to 1991. The higher residence time in the Lower Bay as well as the high water clarity compared to other regions, probably accounts for much of the elevated chlorophyll a concentrations. There is high spatial variability between the east and west side of the Lower Bay. Due in part to the fact that only four sampling stations are found in the Lower Bay, the high chlorophyll a values of the western stations close to the Raritan River elevate the regional mean significantly.

2002 Results

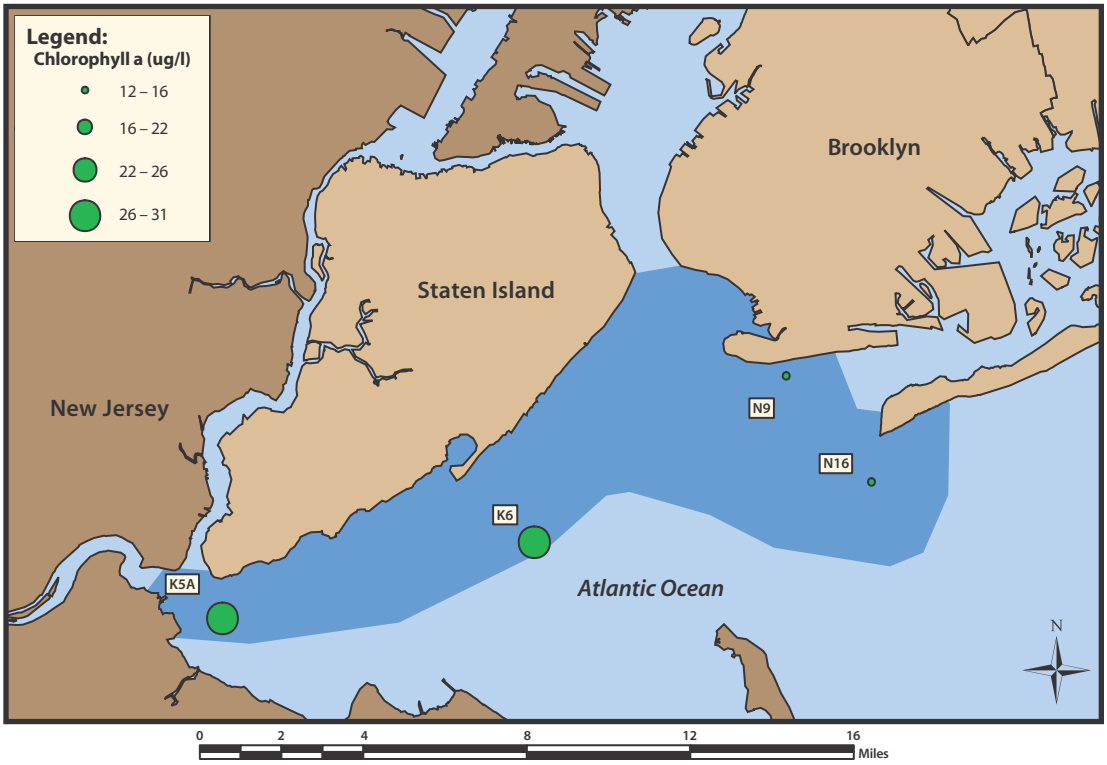
With the exception of low chlorophyll a in August, summer monthly means were statistically consistent with ten year means (Figure 6-8). Raritan River (K5A) had a summer mean of 31±28 µg/l and a regional high of 114 µg/l on September 18th. Old Orchestra Light (K6) likewise had an elevated mean of 28±21 µg/l. The Rockaway station (N16) observed a summer chlorophyll a mean of 14±22 µg/l and a high of 93 µg/l on June 9th.

Turbidity

Long-term Trends

The Lower Bay has traditionally had the least turbid waters in the New York Harbor, however the long-term trendline indicates a slow increase in turbidity (Figure 6-10). The sites to the east, including Rockaway (N16) and Steeplechase Pier (N9) generally have the clearest waters in the Harbor. Sites to the west have turbidity more similar to stations in the Upper East River and the Kills. This is likely due to sediments from the Raritan River.

FIGURE 6-9: Map of 2002 Chlorophyll a Values for Lower Bay

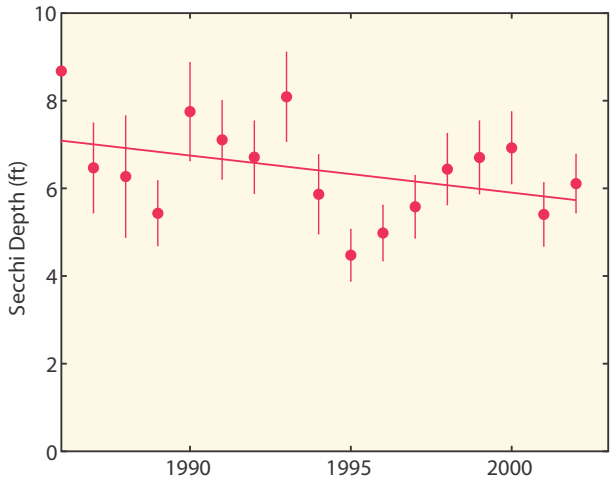


2002 Results

Summer mean secchi depth for the region was 6.1 ft, with monthly means ranging from 4.6 ft in June to 7.1 ft in September.

The eastern portion of Lower Bay had the clearest water in the Harbor through the summer months. Rockaway station (N16) and Steeplechase Pier (N9) had summer secchi depths means of 8.1±2.7 and 7.1±2.0. N16 observed the clearest water in the Harbor with a secchi depth of 14 ft recorded on July 30th. Much more turbid water was observed in the western portion of the Lower Bay where stations Raritan River (K5A) and Old Orchestra Light (K6) had summer means of 4.0± and 4.8±1.7, respectively. These findings are in agreement with results from previous years.

FIGURE 6-10:
1986-2002 Secchi Depth Summer Means and +/-2 Standard Errors with 17 Year Regression for Lower Bay



Enhancing Spatial Analysis of Harbor Survey Data Through Correlation of Ground and Satellite Observations

It is believed that satellite imagery could be a useful complement to the traditional methodology in which NYCDEP gathers water quality data in New York Harbor. In the Hudson River and areas affected by its sediments (New York Bay, Harlem River) the Secchi Depth correlates with Landsat™ red reflectance. In the East River and Long Island Sound chlorophyll a concentration correlates with the ratio of green to red reflectance. Therefore, Landsat™ images can be used to estimate these parameters. With the high spatial resolution of Landsat™ it is possible to resolve sub-kilometer scale variability in water quality. This is not possible using the present set of ground sampling stations of the Harbor Survey program, and Landsat™ could therefore be a valuable addition to that program. MODIS estimated chlorophyll a concentrations do not correlate with ground measurements. Those estimates are therefore not directly useable in New York Harbor (Hellweger, 2002).

NYCDEP is considering the possibility of moving or expanding the number of stations away from non-water features. In order to further test the usefulness of remote sensing data, the sampling times may be adjusted to coincide with satellite overpass.

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