## INTRODUCTION

The New York City Department of Environmental Protection (NYC DEP) performed its 88th Annual Water Quality Survey of New York Harbor from June through September of 1997. Additional winter, spring and fall sampling throughout the Harbor were also performed. The purpose of the Harbor Survey Program is to document the impact of NYC's various water pollution control programs on water quality in the Harbor. In addition, to support modeling and clean-up activities associated with the Long Island Sound Study, and at the bequest of USEPA and NYSDEC, the Harbor Survey Program has been expanded since 1989 to include more intensive sampling of the East River-Long Island Sound transect. The Harbor Survey Program is funded primarily by NYC DEP and performed by the NYC DEP Marine Sciences Section.

***The purpose of the Survey is to document the impact of water pollution control programs...***

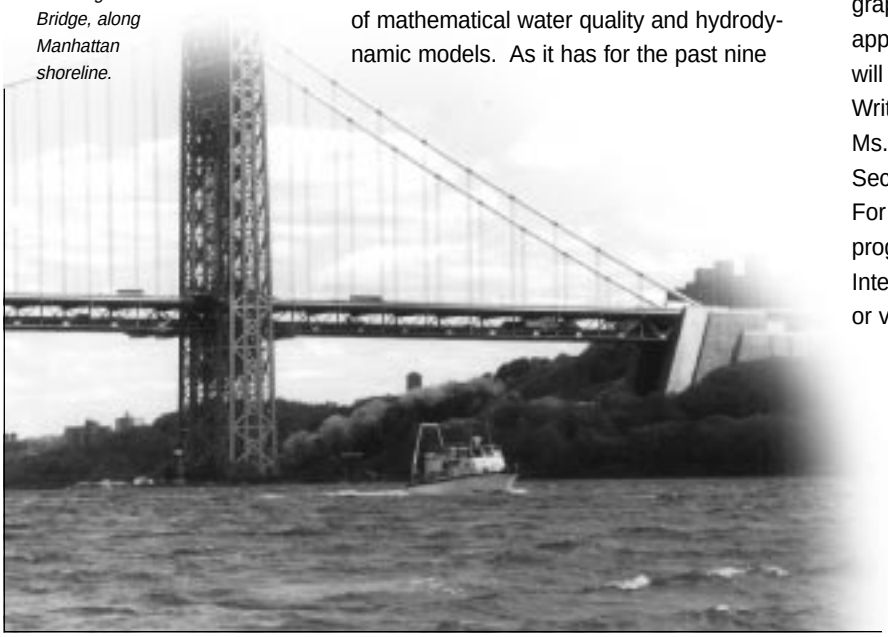
This report describes recent patterns of ambient summer water quality in the Harbor, makes comparisons with New York State Department of Environmental Conservation (NYS DEC) water quality standards (where possible), documents long-term trends and provides data for calibration and verification of mathematical water quality and hydrodynamic models. As it has for the past nine years, the Harbor Survey Program continued in 1997 to support the Long Island Sound Study, for which it performed hypoxia and nutrient monitoring, receiving partial funding through a USEPA grant. Harbor Survey involvement in additional DEP programs includes participation in the *Shoreline Survey Sentinel Monitoring Program* and a new *Enhanced Beach Protection Program*.

Temporal and spatial variability in water quality in the Harbor is often very high, and the number of samples collected for any one parameter may or may not be sufficient to account for this variability. As a result, no one set of data in this report is fully representative of true conditions. For example, plankton blooms can form and dissipate within a few days, and therefore their existence may sometimes go undetected. Also, sampling after precipitation events has been linked to higher coliform concentrations and lower dissolved oxygen (DO) levels in some Harbor areas, and possibly affects the concentration of other parameters, as well.

Unlike past years, in which descriptive statistics and associated data tables, graphs, and figures were provided as appendices, data and additional materials will now be made available upon request. Written requests can be directed to Ms. Naji Yao, Deputy Chief, Marine Sciences Section, Wards Island, New York 10035. For information on this and other NYC DEP programs, contact the Bureau of Public and Intergovernmental Affairs at 718-595-6600 or visit our Web site:

www.ci.nyc.ny.us/dep

*HSV Osprey heading south of George Washington Bridge, along Manhattan shoreline.*



# Factors Affecting Water Quality in New York Harbor

## Regional Hydrodynamics

The Hudson-Raritan system **(Figure 1)** is a varied and complex coastal plain estuary dominated by a drowned river valley (the Hudson). New York City's 578 miles of waterfront include a network of tidal straits (Arthur Kill, Kill Van Kull, and the Harlem and East Rivers), open and enclosed bays (Raritan, Jamaica and NY Bays), tidal mud flats, and beaches. The estuary communicates with the Atlantic Ocean through the Race at the eastern end of Long Island Sound, and through the mouth of lower NY Bay at Sandy Hook (Swanson et al., 1982). The tidal pulse is semi-diurnal throughout. The progressive tidal wave of the Harbor and the standing tidal wave in the Sound meet in the Harlem and East Rivers.

Upstate New York, and portions of New Jersey, Massachusetts and Vermont together comprise the Harbor Estuary's total watershed of approximately 16,300 $mi^2$ (42,217 $km^2$). Freshwater input into the estuary, is dominated by the Hudson River, draining 13,400 $mi^2$ (34,600 $km^2$), with the Raritan, Passaic, and Hackensack Rivers in New Jersey (NJ) draining most of the remaining area.

With an average flow at the Battery of 21,000 $ft^3/s$ (594 $m^3/s$), the Hudson River constitutes approximately 87% of the total riverine flow into the system (Mueller et al., 1982). Still, the volume of water introduced from the tributaries is small compared to the amount introduced by tidal action (by about 220 times on a volumetric, annual basis), and tides dominate the density-driven estuarine circulation (NOAA, 1985).

Water residence times vary spatially and temporally. For example, residence times vary from 1.25 days in the East River, to 35 days in Jamaica Bay. Residence times for the Hudson River vary from 15 days during spring high river flows, to 45-60 days during summer low-flow conditions (Clark *et al.*, 1982).

This network of varying freshwater inflows, tides, and tidal flows produces vertical density stratification in some areas (Hudson River and upper NY Bay), with seasonal and tidal variations in stratification. Other areas are vertically homogeneous, e.g., the East River and Arthur Kill. Because the difference between surface and bottom salinities in the estuary is generally less than 10 ppt, the estuary is classified as moderately stratified and partially mixed (NOAA, 1985; Clark *et al.*, 1992). The complex circulation and mixing patterns produce high spatial and temporal variability in water quality, and make the net transport of waste materials difficult to quantify (O'Connor and Mueller, 1984). In addition, tidal current speeds are variable, with maximum speeds of five knots reached at Hells Gate in the East River.

## Regional Population Growth Since The 1800s

Historic increases in regional population are directly responsible for degradation of the local aquatic resources through destruction of habitat, dredging and filling, changes in land use, over-harvesting of fisheries, inappropriate solid waste disposal, and especially the discharge of untreated municipal and industrial effluents (Suszkowski, 1990). In 1810, New York emerged as the largest city in the new nation, surpassing Boston and

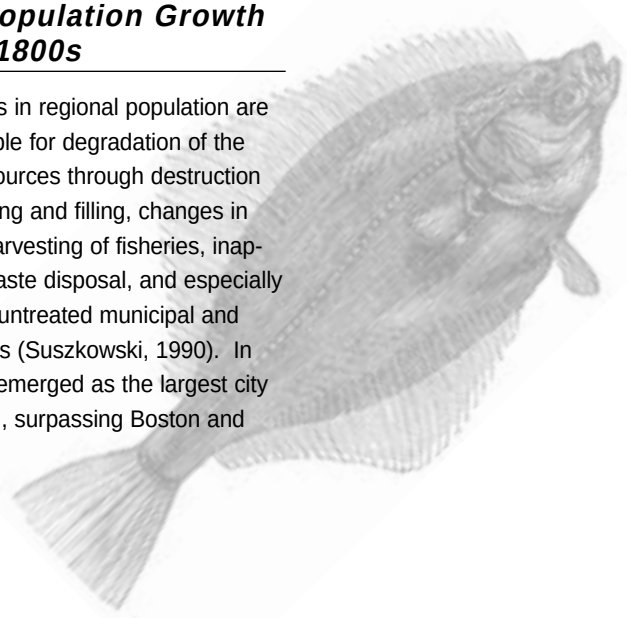
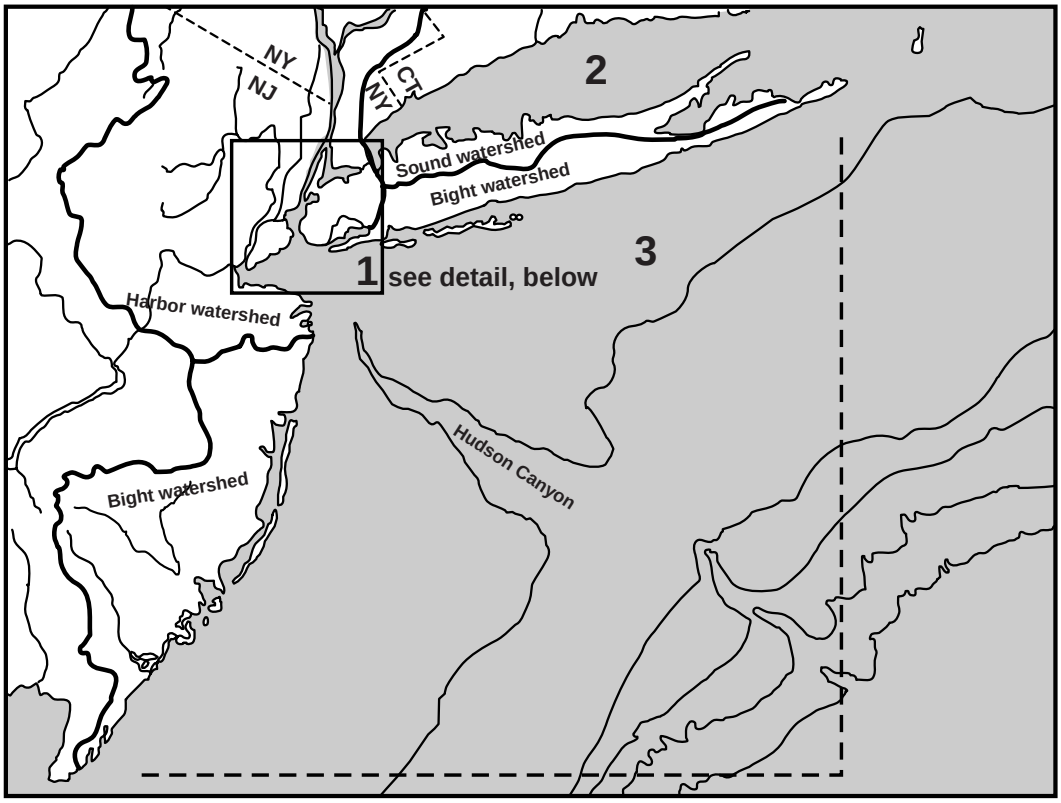


**FIGURE 1** **THE HUDSON-RARITAN SYSTEM**



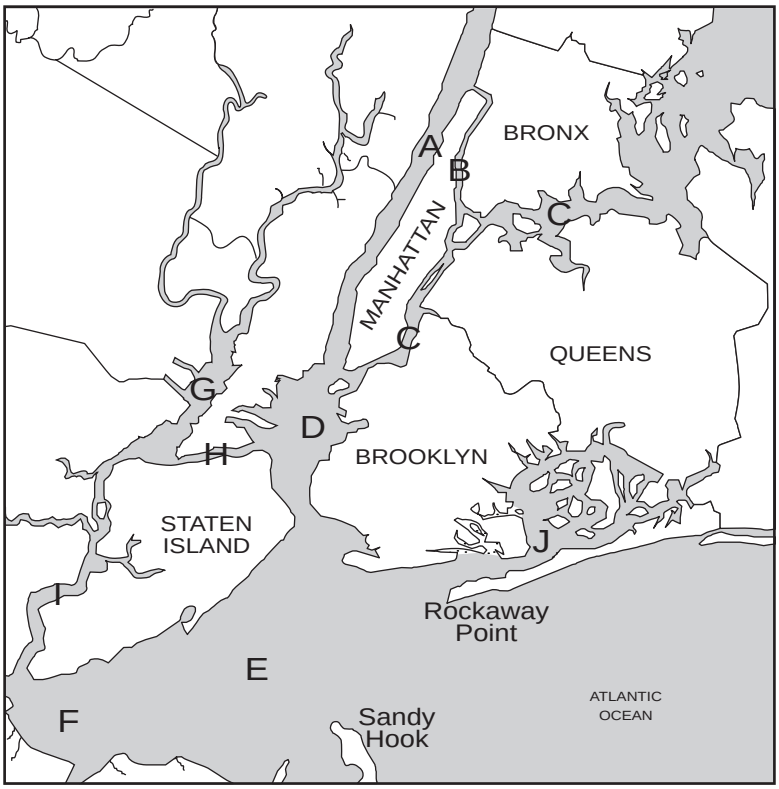

### THE HARBOR-SOUND-BIGHT ESTUARY

***1. New York Harbor***

- A. Hudson River
- B. Harlem River
- C. East River
- D. Upper NY Bay
- E. Lower NY Bay
- F. Raritan Bay
- G. Newark Bay
- H. Kill Van Kull
- I. Arthur Kill
- J. Jamaica Bay

***2. Long Island Sound***

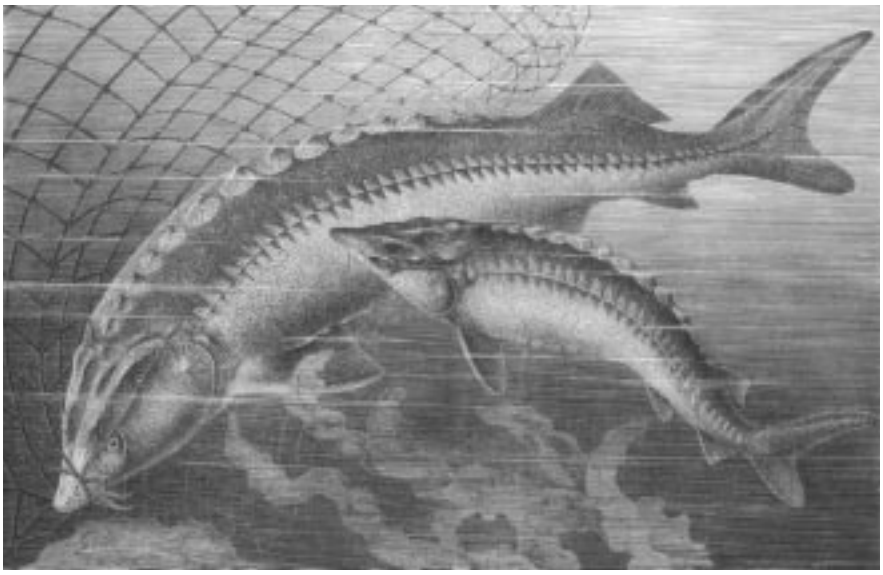
***3. New York Bight***



Philadelphia (US EPA, 1998). With most of the industrial activity of New York and New Jersey centered around the Harbor, and the proximity of shipping and other transportation routes, the Harbor Estuary became a major link in the region's industrial economy. Since the turn of the century, progressive suburban development transformed a once agricultural region into a densely populated metropolis. Population in the Harbor drainage area increased from about four million in 1880 to ~17 million in 1980. By the late 1980s, 88% of residents lived within 13% of the drainage area, including NYC's 7.5 million inhabitants (Suszkowski,1990).

Major degradations in water quality from 1890 to 1920 are attributable to increases in population and the rate of development in the late 1800s (Pearce, 1987; Studholme, 1987). In the early 1900s, the Metropolitan Sewerage Commission of NY reported evidence of gross sewage pollution within 15 miles of Manhattan (Caspe, 1990). In 1906, "seas of floating garbage" were described, exacerbated by the ocean disposal of garbage which was not banned until 1936. In addition, discharges of raw sewage and industrial effluents were associated with the decline of a major oyster fishery around Staten Island prior to 1900 (Pearce, 1987). By 1910, ~600 mgd (26 $m^3/s$) of untreated sewage was being discharged from NYC alone (Caspe, 1990). Typhoid outbreaks in 1904 in Jamaica Bay, and 1918 in Raritan Bay, closed the oyster industry by 1925 (Studholme, 1987). Over-fishing, loss of habitat and spawning areas from dredge/fill operations, and associated changes in salinity, currents, and siltation are blamed for the decline of several other important commercial fisheries by the 1930s. These fisheries include hard and soft clams, shad, sturgeon, menhaden, and smelt (Pearce, 1987; Studholme, 1988; Studholme, 1987).

***Over-fishing, loss of habitat...are blamed for the decline of important commercial fisheries...***



## Physical Changes

Over the decades, significant physical changes have occurred throughout the Harbor including dredging of channels, blasting of reefs, filling of wetlands and streams, and bulkheading of shorelines. The net effect of these changes has been to reduce the ability of the estuary to both flush out contaminants and to absorb the effects of pollution. A number of significant changes include the following:

- Between 1609 and 1978, ~1348 acres (5.5 $km^2$) of Manhattan were land filled (Squires, 1990);
- By 1970, ~2200 acres of Newark Bay marsh were destroyed for the construction of Newark Airport. Newark Bay is presently 33% smaller than in 1886, and its mean depth has increased from 2 m to 3.1 m (Suszkowski, 1990);
- Between 1949 and 1979, ~4930 acres of Jamaica Bay were filled for the construction of JFK Airport (Squires 1990). By 1971, ~70.9 million $m^3$ had been dredged from Jamaica Bay, including 37 million $m^3$ taken from Grassy Bay to provide fill for the Airport (West-Valle et al., 1992); Jamaica Bay's mean depth has changed from 3 to 16 ft (Thatcher and Mendoza, 1990) and the bay's residence time has increased from 11 to 35 days (West-Valle et al., 1992);
- From 1680 to 1850, East River wetlands, stream mouths and coves were altered, filled and/or bulkheaded. This destroyed littoral zones and created rigid and even shorelines (NYC DEP, 1983). Blasting of reefs and rocks from 1850 to 1920 increased depths to 30-40 feet below mean low water, and reduced currents at Hells Gate (the confluence of the East and Harlem Rivers) from more than 10 knots to about 5 knots (Neyer, 1994);
- Between 1895 and 1938, Rikers Island grew from 60 acres to more than 400 acres from the dumping of coal, refuse and ashes;
- Prior to 1959, wetlands had been destroyed on a massive scale, with the rate of destruction peaking in the tri-state area from 1954-1964. Whereas the NYC portion of the Harbor supported ~27,600 acres of wetlands in the year 1900, by 1969, only 3,800 acres remained (Squires, 1990).

*Spuyten Duyvil Railroad Bridge at Junction of Hudson and Harlem Rivers*

## Pollutant Sources

The Hudson-Raritan Estuary is currently subjected to loadings from numerous municipal and industrial wastewater sources, as well as, non-point runoff from its drainage area. Of the average fresh water inflow to the Harbor of ~27,000 $ft^3/s$ (765 $m^3/s$), approximately 80.7% is from tributaries, 14.9% is attributed to municipal point sources, 3.7% is from more than 1,000 storm water outfalls, 1.3% is from ~650 combined sewer overflows (CSOs), and 0.3% is from ~400 direct industrial discharges (HydroQual, Inc., 1991). The non-tributary sources represent an estimated flow of 5,300 $ft^3/s$ (150 $m^3/s$).

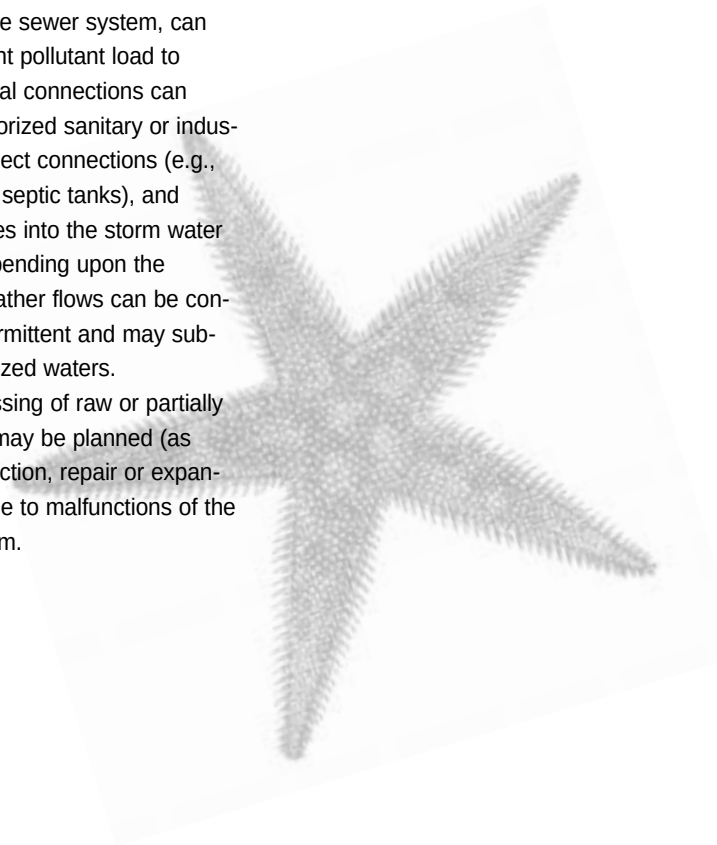
Note that 'Harbor' boundaries for this flow component analysis extend to Poughkeepsie on the Hudson River, to Throgs Neck on the East River, to the head-of-tide on the NJ tributaries, and to the Sandy Hook-Rockaway transect. In contrast, for most of this report, the 'Harbor' is defined by its NYC limits **(Figure 2)**. These are the Westchester-Bronx border on the Hudson and in Western Long Island Sound; the Kill Van Kull and Arthur Kill around Staten Island; and the Sandy Hook-Rockaway transect. Figure 2 depicts this latter description of *the Harbor*, showing an approximation of municipal and CSO outfall locations.

### Water Pollution Control Plants

Approximately 2.5 billion gallons per day (bgd) or 108 cubic meters per second ($m^3/s$ of processed sewage were discharged in 1997 from 79 water pollution control plants (WPCPs) located in NYC, six coastal NJ counties, two coastal CT counties, and Westchester and Rockland Counties in NY (Interstate Sanitation Commission, 1997). Most of these WPCPs provide full secondary treatment, defined as 85% removal of biochemical oxygen demand (BOD) and total suspended solids (TSS), and/or effluent limits of 30 mg/l BOD and 30 mg/l TSS, as defined by the Federal Water Pollution Control Act. It is important to note that secondary treatment does not remove nitrogen from effluent. Of the 2.5 bgd total, NYC's 14 WPCPs discharged 1.44 bgd in 1997. The infrastructure associated with the NYC WPCPs includes: 6,344 miles of collection system piping; 130,000 catch basins; and 5,000 seepage basins. Further details on NYC's WPCPs are provided below.

### Illegal Connections and Bypasses

Illegal connections to the sewer system which circumvent the WPCPs, and bypassing of sewage from the sewer system, can contribute an important pollutant load to receiving waters. Illegal connections can originate from unauthorized sanitary or industrial connections, indirect connections (e.g., infiltration from failing septic tanks), and unpermitted discharges into the storm water drainage system. Depending upon the source, illegal dry-weather flows can be continuous, or highly intermittent and may substantially impact localized waters. Concerning the bypassing of raw or partially treated sewage, this may be planned (as during WPCP construction, repair or expansion) or may occur due to malfunctions of the sewer regulator system.



## Figure 2 New York Harbor / Location of WPCPs & CSOs

### Storm Water Runoff

Storm water runoff from urban and suburban impervious surfaces (streets, sidewalks, rooftops etc.) may contain large quantities of a variety of pollutants. Estimates from NYC's 208 Model indicate that 48% of the storm water flow to the Harbor comes from NJ, 18% from Westchester, 11% from NYC, and the remainder from upstream counties. Data on storm water pollutant concentrations are currently being collected as part of the *Storm Water Permit Program* (NYC DEP, 1994).

***Combined sewer overflows...are the greatest single source of pathogenic and floatable pollutants.***

### Combined Sewer Overflows (CSOs)

Between 70-80% of NYC's ~6,300 miles of sewers are classified as combined sewers, i.e., they accommodate household and industrial waste during dry weather, as well as, rainwater and surface water runoff, during rain events (Gaffoglio, 1990). When runoff flows exceed the hydraulic capacity of the WPCPs the combined sewage (runoff plus untreated domestic sewage) is discharged to the Harbor, causing episodic deteriorations in water quality. For some regulators, this can occur with as little as 0.04 in/hr of rainfall.

Combined sewer overflows from NYC, NJ, and Westchester County effect water quality in the Harbor, and are the greatest single source of pathogenic and floatable pollutants (HEP, 1996; Wagner, 1992; Interstate Sanitation Commission, 1988). Virtually the entire Harbor is bordered by ~730 CSOs (see figure 2 for an approximation), including: 460 from NYC, 248 from NJ, and 22 from Westchester County (HEP, 1996). A comparison between discharges shows CSO fecal coliform loadings to exceed that from chlorinated WPCP effluents by more than 10,000 times, during an average storm event (Wagner, 1992). Together with storm water runoff, CSOs contribute 85% of the Harbor's floatable debris (Leo et al., 1992; HydroQual, Inc., 1992), which reduces aesthetics, may close bathing beaches, and can adversely impact biota.

### Industrial Dischargers

Greater than 90 % of NYC's waste water is comprised of residential and commercial domestic sewage, with less than 1 % of the flow from industrial sources (NYC DEP, 1998). In New York City, 721 industrial facilities are currently under regulation (see *Industrial Pretreatment*, page 17). These include such industrial categories as electroplating, metals molding, casting, and finishing, pharmaceutical manufacturing and organic chemical manufacturing. Flow contributions from these industries to NYC WPCPs are relatively small, and are no longer a significant source of priority pollutants to the Harbor.

*A marine vessel and crew move out from Staten Island pier*

### Nonpoint Source Pollution, Upstream Sources and Atmospheric Deposition

According to the United States Environmental Protection Agency (US EPA), due to its diffuse nature, nonpoint source pollution is the largest single factor preventing attainment of water quality standards nationwide. This is deemed especially true for those waters impaired by nutrients and siltation (US EPA, 1991). By their very nature, estuaries tend to concentrate particulate pollutants discharged into their watersheds. Sustained development of suburban and rural lands within the Hudson-Raritan's 16,300 $mi^2$ watershed and in the Long Island Sound drainage basin, have accelerated nonpoint runoff. This, in turn, has increased the loading of a variety of pollutants to surrounding waters. These pollutants continue to concentrate and affect water and sediment quality in the lower estuary and Long Island Sound (Rohmann and Lilienthal, 1985). Wet and dry atmospheric deposition to the estuary's 16,300 $mi^2$ drainage area represents a further nonpoint source of importance (van Jaarsveid, 1993). Atmospheric deposition can contribute a number of pollutants to the Harbor, including: nutrients, PCBs, PAHs and metals (Valigura, et al. 1998; HEP, 1996; Bidleman and McConnell, 1995; Giusti et al., 1993; Kelly et al. 1991). Again due to its diffuse and ambiguous nature, the importance of atmospheric loadings are often minimized and go unrecognized.

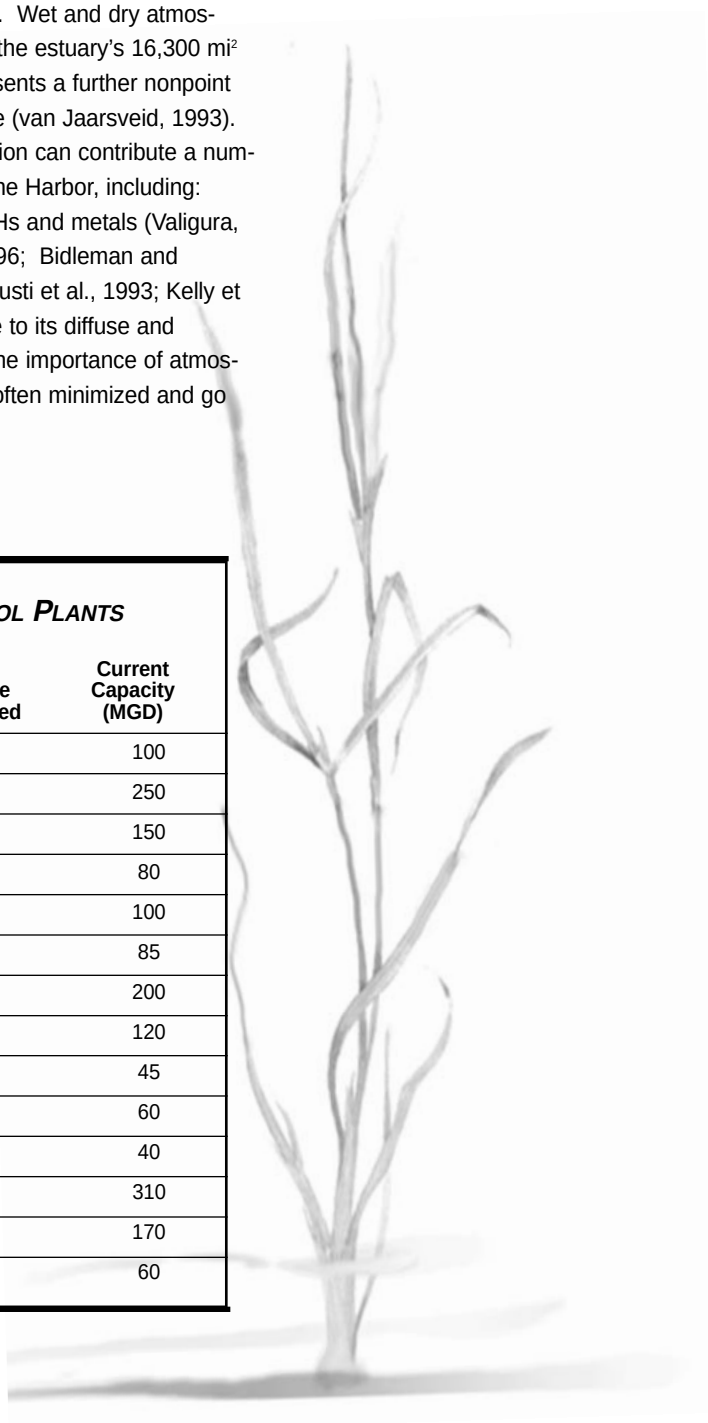


**TABLE 1**

**Chronology of NYC Water Pollution Control Plants**

| Wastewater Pollution Control Plant | Primary Treatment Attained | Secondary Treatment First Attained | Last Upgrade Completed | Current Capacity (MGD) |
|---|---|---|---|---|
| Coney Island | 1936 | 1963 | 1994 | 100 |
| Wards Island | 1937 | 1937 | 1997 | 250 |
| Bowery Bay | 1939 | 1942 | 1973 | 150 |
| Tallman Island | 1939 | 1939 | 1976 | 80 |
| Jamaica | 1943 | 1943 | 1971 | 100 |
| 26th Ward | 1944 | 1951 | 1990 | 85 |
| Hunts Point | 1952 | 1952 | 1979 | 200 |
| Owls Head | 1952 | 1952 | 1995 | 120 |
| Rockaway | 1952 | 1962 | 1971 | 45 |
| Port Richmond | 1953 | 1978 | 1979 | 60 |
| Oakwood Beach | 1956 | 1956 | 1978 | 40 |
| Newtown Creek | 1967 | 1967* | 1969* | 310 |
| North River | 1986 | 1991 | 1991 | 170 |
| Red Hook | 1987 | 1989 | 1990 | 60 |

*Currently operated as modified aeration, with planning for upgrade to full secondary ongoing.

## POLLUTANT ABATEMENT AND WATER QUALITY IN NEW YORK HARBOR

### Historical Changes to Sewage Treatment

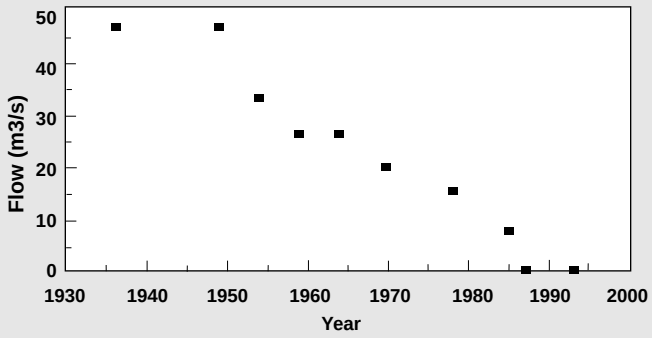
Water quality conditions necessary to attract and support aquatic life have significantly improved in most areas of the Harbor in the past 20 years, as most recently evidenced by increased numbers of waterfowl and improvements to certain local fish stocks and benthic communities. This is primarily attributable to enhanced control of sewage and industrial discharges, and product bans (e.g., DDT, PCBs, lead etc.). Wastewater collection and sewer construction in NYC began in 1696 (O'Connor, 1990), with much of lower and central Manhattan's sewers constructed between 1830 and 1870. Today there are ~6,300 miles (10,000 km) of sewers in NYC's five boroughs.

***Water quality conditions necessary to support aquatic life have improved...***

Construction of WPCPs throughout the region during much of the twentieth century has reduced discharges of untreated wastewater into the Harbor from approximately 1,070 mgd (46.9 $m^3/s$) in 1936 to less than one mgd (0.04 $m^3/s$) by 1993 **(Figure 3)** (Interstate Sanitation Commission, 1970; 1978; 1985; and 1993). The first wastewater treatment plant in the region, built in 1886 to protect bathing beaches on Coney Island, consisted of a crude facility designed to capture floatable materials. Construction of modern facilities in NYC began in 1935 with the Coney Island WPCP, and culminated with the completion of the North River WPCP in 1991. **Table 1** lists the 14 NYC WPCPs along with associated startup and treatment modification dates.

**FIGURE 3**

**Untreated Sewage Discharges Into New York Harbor 1936-1993**




### More Recent Changes to Sewage Treatment

Improvements to the sewage treatment system, innovative pollution prevention or abatement programs, and improved operational procedures since 1986 have resulted in the abatement of illegal connections, reduced raw sewage bypassing, and increased capture of combined sewage during rain events. Reductions to pollutant loadings from NYC facilities since 1986 are attributed to the following programs:

#### Water Pollution Control Plant Construction

New York City's 14 WPCPs currently process 1.44 bgd (63.5 $m^3/s$), which is roughly equivalent to 10% of the Hudson River flow. As noted in Table 1 the last two NYC WPCPs to be constructed, North River and Red Hook, went on line in 1986 and 1987, respectively. Of NYC's 14 WPCPs, thirteen are now operating at secondary treatment. Treatment plants that were most recently upgraded to full secondary include: Red Hook (1989), North River (1991), Coney Island (1994), and Owls Head (1995). Planning and evaluation of the upgrade for the 310 mgd Newtown Creek plant is ongoing.

### Shoreline Survey and Sentinel Monitoring

As noted above, illegal connections to the sewer system which circumvent the WPCPs can contribute a significant pollutant load to receiving waters. The NYC DEP is currently engaged in identifying and remediating these illegal connections through the Shoreline Survey Program (NYC DEP, 1993b) and the Sentinel Monitoring Program, as described below.

***Shoreline Survey Program*** This program, tasked with identifying illegal connections to the sewer system and abating dry weather discharges, completed two full shoreline inspections of the NYC drainage area by 1993. In all, the program identified 3,901 outfalls along the City's 425 miles of shoreline. Of the total, 451 outfalls were observed to have discharges, with 60% of these confirmed to contain sewage contamination; representing a relative flow of greater than 3 million gallons a day (mgd). Since 1989, the Shoreline Survey Program has abated over 2 mgd from these sources. In addition, following identification through the Shoreline Survey, the NYS DEC has acted to abate another 150,000 gallons per day. Together, NYC DEP and NYSDEC have reduced over 71% of estimated dry weather sanitary discharge and abated 176 outfalls, harbor-wide.

***Sentinel Monitoring Program*** This program was established to supplement the Shoreline Survey Program. To continue to monitor the Harbor for illegal connections the Sentinel Monitoring Program has established a total of 99 monitoring stations **(Figure 4)**, which include 53 Harbor Survey stations and an additional 46 open water sites. Quarterly fecal coliform sampling at these stations will be compared to an established baseline; the exceedance of which will trigger intensive surveillance of the adjacent shoreline.

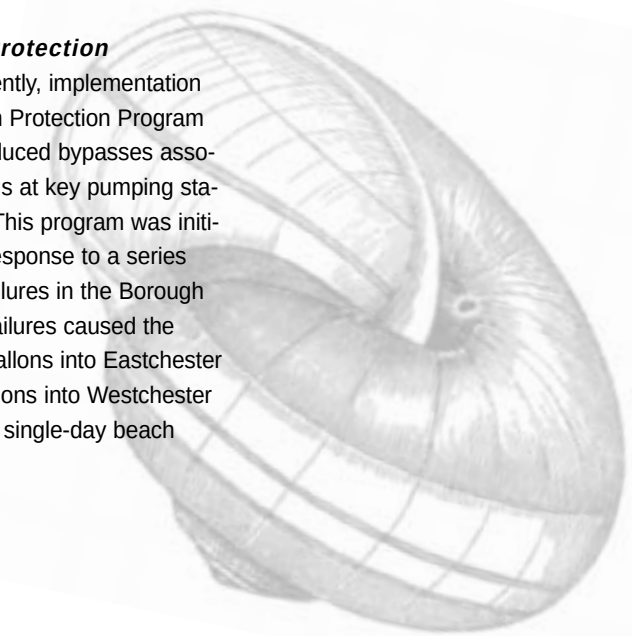
### Reduced Raw Sewage Bypassing

Increased surveillance and maintenance of regulators and pumping stations, and improved WPCP operations have reduced bypassing from these sources by 93%, from 1,845 mg (equivalent to 5.1 mgd) in fiscal year 1989 to 84 mg (0.2 mgd) in FY97. In addition to reducing coliform concentrations, discharge abatement has also reduced loadings of TSS, BOD, and total Kjeldahl nitrogen (TKN) by an estimated 3,000, 2,900, and 300 lbs/day, respectively (O'Shea and Brosnan, 1997). Though not as easily quantified, metals, organic priority pollutants, floatables and other pollutant loadings from these sources have also declined. In addition, the connecting of an area of Tottenville, Staten Island, to the Oakwood Beach WPCP in 1993, resulted in the capture of 0.7 mgd of previously uncaptured raw sewage.

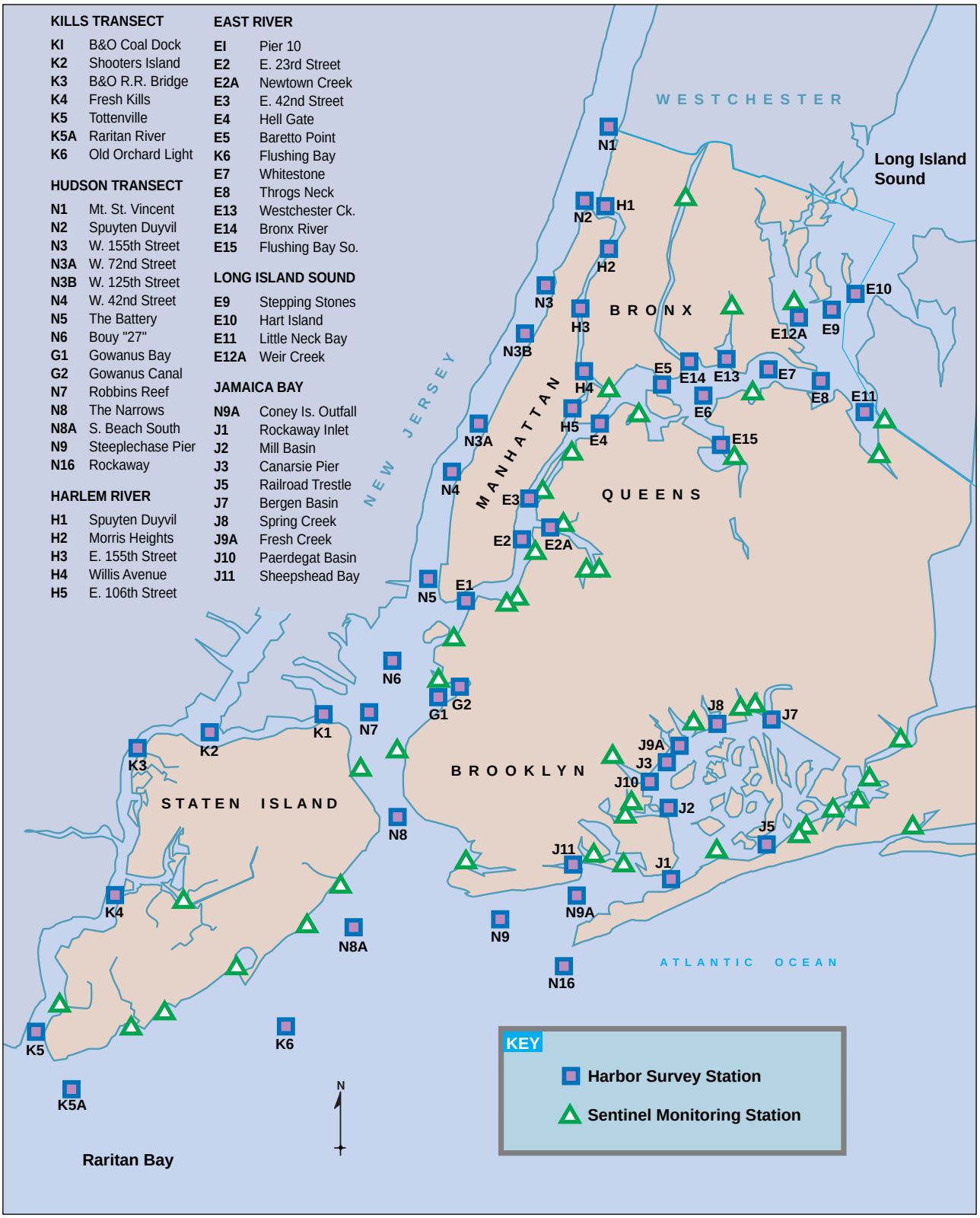
***Increased surveillance, maintenance, and improved operations have reduced bypassing...***

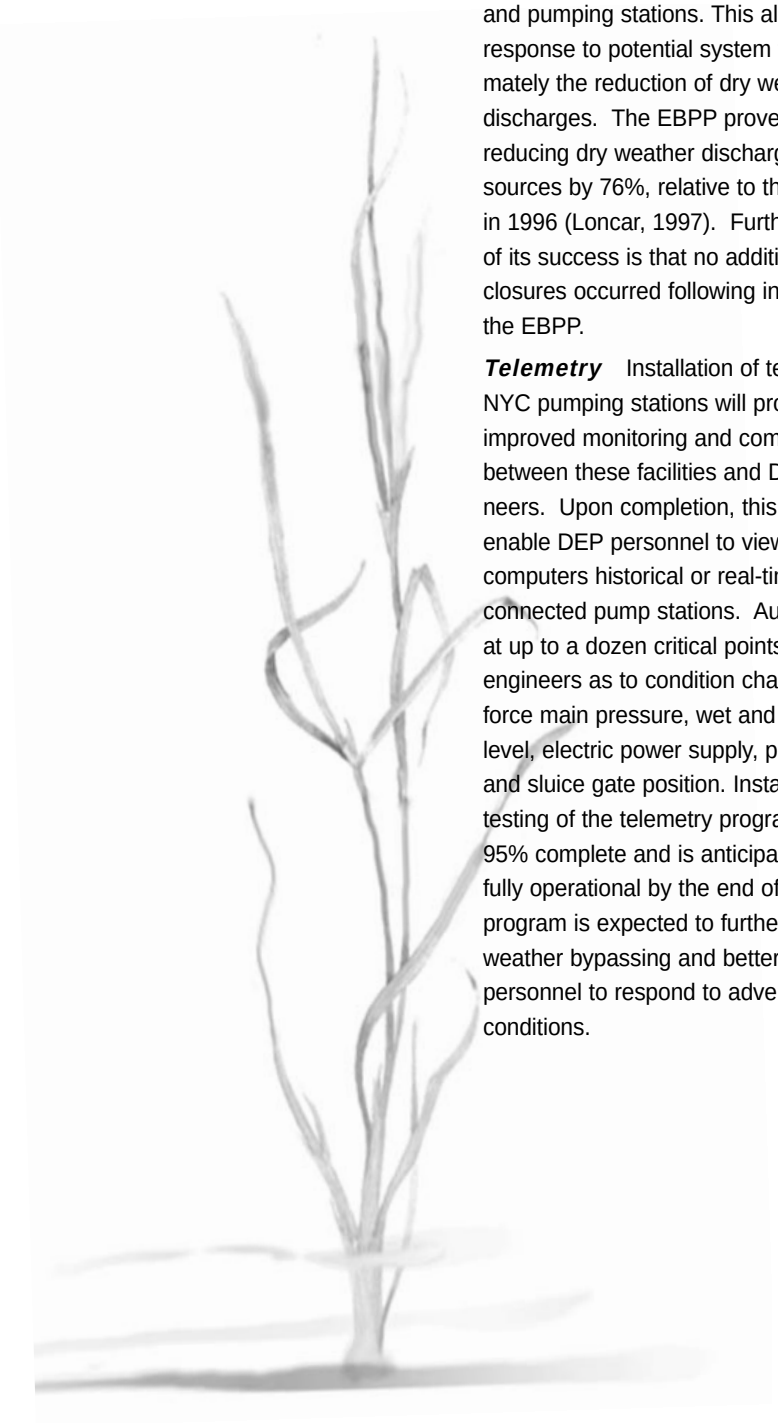
Recent operational improvements that will continue to reduce sewage bypassing are described below:

***Enhanced Beach Protection Program*** Most recently, implementation of an Enhanced Beach Protection Program (EBPP) has further reduced bypasses associated with malfunctions at key pumping stations and regulators. This program was initiated in July 1997, in response to a series of collection system failures in the Borough of the Bronx. These failures caused the release of <1 million gallons into Eastchester Bay and ~5 million gallons into Westchester Creek, resulting in two single-day beach



## Figure 4 Sampling Locations for Harbor Survey / Sentinel Monitoring





closures at Orchard Beach. Under the EBPP, increased surveillance and preventative maintenance was conducted for the remainder of the summer at key sewer regulators and pumping stations. This allowed for rapid response to potential system failures and ultimately the reduction of dry weather sewer discharges. The EBPP proved successful, reducing dry weather discharge from these sources by 76%, relative to the same period in 1996 (Loncar, 1997). Further evidence of its success is that no additional beach closures occurred following initiation of the EBPP.

***Telemetry*** Installation of telemetry at 89 NYC pumping stations will provide for improved monitoring and communications between these facilities and DEP plant engineers. Upon completion, this system will enable DEP personnel to view from personal computers historical or real-time data for all connected pump stations. Automatic alarms at up to a dozen critical points will notify shift engineers as to condition changes, including: force main pressure, wet and dry well liquid level, electric power supply, pump operation, and sluice gate position. Installation and testing of the telemetry program is currently 95% complete and is anticipated to be fully operational by the end of 1998. This program is expected to further reduce dry weather bypassing and better enable DEP personnel to respond to adverse weather conditions.

### *Storm Water Program*

Presently, NYC DEP is completing a characterization of storm water runoff from five different land use locations, including: highways, commercial areas, heavy industrial zones, and high and low density residential areas. As part of this effort an inventory of industrial and waste handling facilities that discharge to the separate storm system is being compiled, and pollutant loads estimated. Other planned initiatives under the *Storm Water Program* include: control of construction and contaminated site runoff, a spill response program, stenciling of catch basins, and enforcement against improper disposal of spent vehicle fluids (Burns, 1997).

### *Abatement of Combined Sewer Overflows*

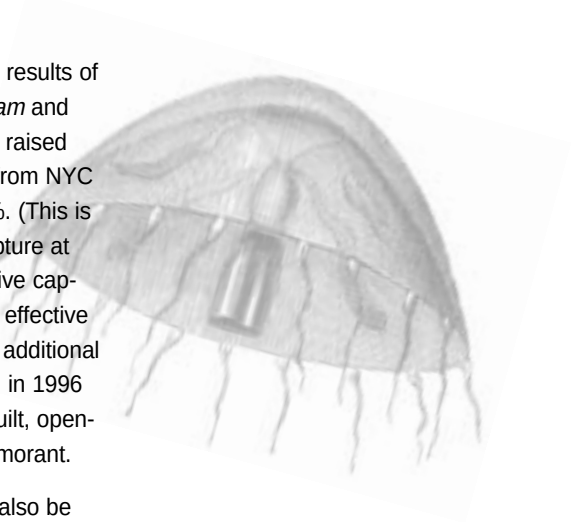
As part of a multi-year, Citywide CSO Abatement Program, NYC has committed $1.5 billion for construction of CSO abatement facilities over the next 10 years. Water quality studies have been used to determine where and to what extent capture and treatment of CSOs is necessary to meet NYS DEC water quality standards. Facility planning is proceeding and includes: sewer system improvements, in-line storage, and underground, off-line storage tanks, ranging from 7-30 million gallons (Moutal, 1992; Smith, 1992). A prototype CSO facility was constructed as early as 1972 at the head of Spring Creek in Jamaica Bay. The Spring Creek facility provides for ~10 mg of CSO storage, with another 20 mg of available in-line storage and further allows for overflow disinfection, and floatables and suspended solids removal. After a storm, the captured overflow is fed back to the 26th Ward WPCP for secondary treatment.

More immediate steps to reduce CSO impacts have also been achieved through full implementation of the USEPA's recommended *Nine Minimum Controls* (NMCs). Some elements of the NMCs implemented over the past 9 years are decribed below:

***Increased Wet Weather Capture*** From 1989 to 1997, NYC DEP instituted operational changes at many of its plants and made improvements to the functioning of its regulators. These changes have resulted in an increase in the capture of rainfall that enters the combined sewer system from an estimated 18% in 1989 to 41% in 1997. Tide gate infiltration also has been reduced by 40 mgd (151,400 $m^3$/d) since 1985. Water conservation (see *Other Pollution Reduction Programs*, p. 18) has also increased capacity for CSO capture at the plants.

***Floatables Control*** Floatables consist primarily of manmade debris that floats on or below the water surface. They contribute to several problems in the region including beach closings, interference with navigation, entanglement of wildlife, and aesthetic impairments. Excluding pier debris, approximately 95% of floatables in the Harbor originate from combined sewers and storm sewers conveying street litter.

To better control and capture floatables, NYC DEP began a *Boom and Skim Program* in 1993. This program currently consists of 18 containment booms and 5 netting systems placed at key tributary locations, and four skimmer vessels. For calendar years 1996 and 1997 combined, this program collected over 3,200 $yrds^3$ of floatable trash (Head & Associates, Ltd., 1998). Combined results of NYC DEP's *Boom and Skim Program* and increased wet-weather capture has raised the quantity of floatables captured from NYC CSOs since 1989 from 18% to 68%. (This is based on the above noted 41% capture at the plants, plus an estimated effective capture of 75% at the booms and 95% effective capture of the netting systems.) An additional *77 tons* of floatables were collected in 1996 and 1997 by NYC DEP's custom-built, open-water skimmer vessel, the S/V Cormorant.



Several intervention programs can also be credited with limiting the discharge of floatables into the Harbor. These include: the use of floating curtains around marine transfer stations and the use of nets to cover barges transporting garbage between these stations; public awareness and public education programs aimed at reducing littering; an increase in street sweeping within some watersheds; and city-wide catch basin cleaning and covering. New York City also participates with community groups, and is an annual co-sponsor of *Beach Cleanup Day.* In addition, collaborative efforts by the United States Army Core of Engineers, USEPA, and NJDEP, to collect large floatable debris and skim litter from open waters and shorelines, has further reduced floatables. These efforts and interim measures continue to provide temporary control of floatable discharges until other, long-term elements of the *CSO Abatement Plan* can be implemented.

***...approximately 95% of floatables in the Harbor originate from street litter.***

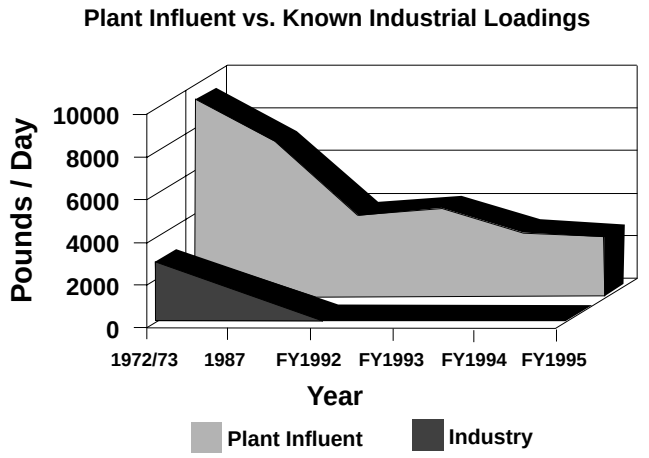
### *Industrial Pretreatment*

New York City's *Industrial Pretreatment Program (IPP)* regulates the types and quantities of chemicals which industry may discharge into municipal sewers. Since becoming a control authority in 1987, the NYC DEP has strengthened the *IPP*, previously overseen by USEPA, by performing intensive screening of industrial discharges and developing monitoring and enforcement programs. Active amendment of sewer use regulations have also been aggressively pursued to maintain sewage collection and treatment facilities, and improve effluent and sludge quality.

As of January 1996, 721 facilities were regulated under the *IPP*. Of these facilities, 402 are listed as Significant Industrial Users. Total metals contributions from industry have decreased due to this program from 3,000 pounds/day in 1974, to less than 155 pounds/day by the end of fiscal year 1995 (**Figure 5**). While most of this decrease in mass is attributable to zinc, loadings of seven other heavy metals to the treatment plants have been shown to have declined by 50-93% from 1985-1993 (Brosnan et al., 1994; Stubin and Brosnan, 1994). These declines are attributed to the combined efforts of the *IPP* and *Corrosion Control Program* (see below), as well as, the institution of "clean techniques" for metals monitoring.

The *IPP* is now implementing strategies to both determine and reduce previously unquantified metal loadings to the sewer system. A 1993 headworks analysis indicated that one-fifth of the total load of nine toxic metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc) entering the plants could not be accounted for (NYC DEP, 1993a). Potential sources, other than industry, include residential and commercial waste, and street runoff. A second headworks analysis is now being conducted to improve the accuracy of metal loadings data. As part of a track-down effort, oxidation-reduction potential meters have been employed at key locations within the sewage system to determine if metals are being improperly disposed. Enforcement actions have been brought against several firms believed to be disposing of metals in exceedance of regulations.

**FIGURE 5** **TOXIC METAL LOADINGS**



## Other Pollution Reduction Programs

Additional DEP programs that have contributed (secondarily) to reductions in pollutant loadings to NYC facilities and the Harbor include the following:

***Corrosion Control*** Initiated in 1992, this program has reduced leaching of copper, lead, and zinc into NYC drinking water. Consequential to source water reductions, metal loadings to WPCPs would likely decline, further improving effluent and biosolids quality.

***Water Conservation*** Since 1986, NYC has promoted efforts to preserve drinking water supplies. To date, this effort has reduced demand by about 200 mgd. Lower flows result in enhanced pollutant removals at the WPCPs, and allow for greater capture and treatment of CSOs.

***Landfill Remediation*** As of February 1991, NYC DEP took responsibility for remediating four landfills that have been declared Inactive Hazardous Waste Sites by the NYS DEC. Leachate capture and treatment, and reduction of contaminated seepage will reduce these nonpoint source contributions to the Harbor.

***Biosolids Program*** As mandated by the Ocean Dumping Ban Act of 1988, June 30, 1992 marked the last day of ocean dumping of sewage sludge biosolids at the 106-mile dump site in the Atlantic Ocean. As an alternative to open water disposal, NYC's *Beneficial Reuse Program* is transforming biosolids into pelletized fertilizer for croplands and planning direct application for restoration of grasslands for grazing and wildlife use (Maracic, 1996).

***Nutrient Removal*** To off-set the impacts of increased nitrogen loads due to biosolids de-watering operations, NYC DEP is implementing full biological nutrient removal at seven WPCPs (Tallman Island, Hunts Point, Bowery Bay, Wards Island, Red Hook, Oakwood Beach, and 26th Ward). In addition, pilot tests for biological and physical-chemical nutrient reduction are being conducted at Tallman Island, 26th Ward, and Newtown Creek to achieve the 58.8% nitrogen reduction called for as part of the Long Island Sound Study agreement (LISS, 1997). This agreement calls for cost-effective reduction actions to be revisited every five years, pursuant to improved technologies and ecological conditions.

*Herring Gulls*