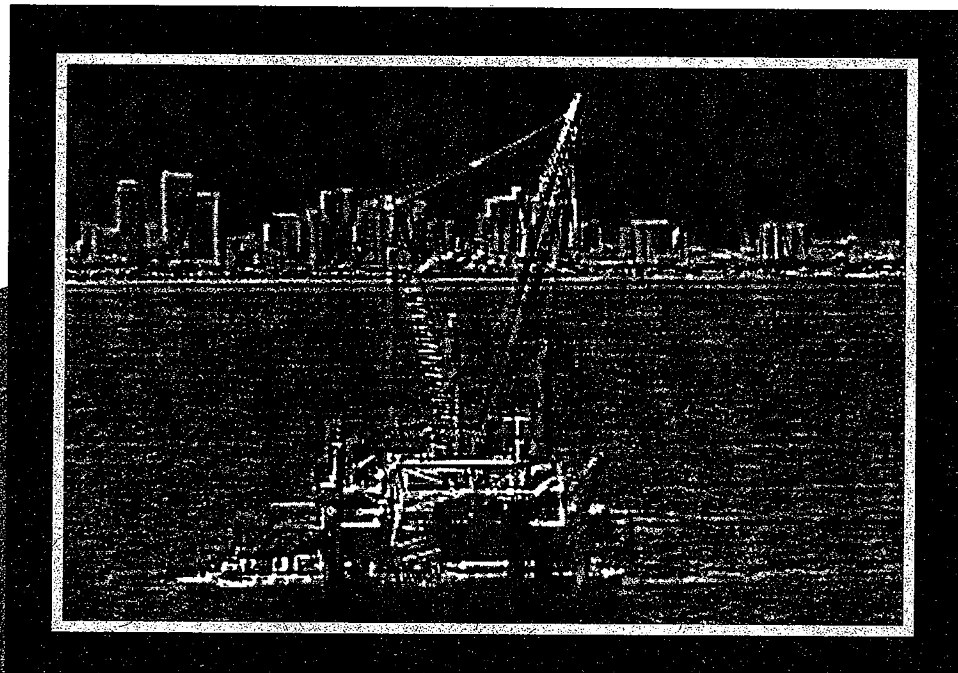

THE STATE OF BOSTON HARBOR 1992

The Massachusetts Water Resources Authority

Boston Harbor:
A Resource Worth Protecting

It is difficult to underestimate Boston Harbor's contribution to the quality of life for area residents. With 180 miles of shoreline, 50 square miles of water, and 30 islands, the Harbor is a major recreational resource. Whether walking along a local beach, fishing from a city dock, sailing across a bay, bicycling along the shore, or simply looking out from a crowded highway to the wide expanse of water, area residents all benefit from the Harbor.

The Harbor is also of prime significance for the commercial life of the region. Boston is the largest seaport in New England, connecting the region to markets throughout the world. The port's cargo facilities handle more than 21 million tons of cargo worth close to $8 billion each year. In addition, the Harbor generates jobs and money for the region in fields such as commercial fishing and real estate. It also serves as a dramatic setting for events like the arrival of the Tall Ships, which attract tourists to the area and underline Boston's status as a world-class city.

Boston Harbor is, however, a problem as well as a resource. Water quality in the Harbor is inextricably linked to the region's management of its sewerage system. The Harbor and its tributaries, such as the Charles and Mystic rivers, have long been used as disposal sites for the region's sewage. Moreover, until the second half of this century, the sewage was largely untreated.

Today, the Massachusetts Water Resources Authority is reducing the impact of the sewerage system on Boston Harbor by (a) comprehensively rehabilitating the current sewerage system, (b) controlling discharges of potentially hazardous substances into that system, and (c) constructing modern treatment facilities. These improvements will go a long way toward protecting the Harbor, ensuring that future generations do not see it as a problem but rather as a valuable resource.

Cover photo: *Installation of diffusers toward the end of the MWRA's new effluent outfall tunnel.*

THE STATE OF BOSTON HARBOR 1992

Massachusetts Water Resources Authority
Douglas B. MacDonald
Executive Director

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Environmental Quality Department

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EXECUTIVE SUMMARY

Each year, the MWRA produces a State of Boston Harbor Report that describes the environmental health of Boston Harbor. As we are now nearing the half-way point in the multi-billion dollar Boston Harbor Project to upgrade the region's sewerage system, this year's report examines the Harbor's health in the context of that project. The 1992 State of Boston Harbor Report therefore covers four main areas:

1) the relationships between the region's sewerage system and the pollution problems in Boston Harbor and its tributaries;

2) recent improvements in the existing sewerage system;

3) the effects of those improvements on Harbor water quality; and

4) the progress made on new treatment facilities and what can be expected in the way of further improvements in environmental quality as the Boston Harbor Project continues.

Three themes emerge from the data discussed in the report:

First, the sewerage collection system now has more capacity and is more efficient.

Pipes are being systematically inspected.

- Over the last four years, 116 miles of the MWRA's 230 miles of interceptor pipes have been internally inspected with closed-circuit TV.

Pumping facilities have been upgraded or replaced.

- The new $35.7 million Charlestown Pump Station is the most visible example of necessary reinvestment in pumping system infrastructure.

Headworks have been overhauled.

- A $25.2 million overhaul has led to an increase in the amount of grit and screenings taken out of the sewage flow from 104,000 cubic feet in 1987 to 165,000 cubic feet in 1992.

The Deer Island Power and Pump Station has been upgraded.

- A $33.2 million upgrade has led to an average of 7 pumps being operational at any one time in 1992, versus 5 in 1988.

Increased capacity has resulted in improved system performance.

Headworks now need to hold back (or "choke") less flow, i.e. the collection system is better able to transport, store, and regulate the flow.

- Choking time decreased from 5,395 hours in 1987 to 584 in 1992.

Combined sewer overflows (CSOs), which occur when the system's capacity is exceeded, have decreased.

- There were no dry weather overflows in 1992.
- Wet weather CSO flow in 1992 was approximately 45% less than that measured in 1990.

Second, the treatment system is also much improved, with measurable effects on environmental quality.

The sewage flow now contains less of the substances that are particularly difficult to treat. This is in large part the result of an aggressive toxic reduction program, which helps industries and homes minimize the amount of toxic contaminants in their discharges into the sewerage system.

- Zinc and copper loadings to the treatment plants have decreased by at least 75% since the early 1980s, which is reflected in decreased concentrations measured in the Harbor.
- Discharges of EPA-designated "priority pollutants" have decreased by about 33% since 1990.
- Pesticides measured in mussels at Deer Island in 1992 were only 25% to 50% of what they were in 1987.
- Instances of liver diseases in winter flounder caught off Deer Island have decreased dramatically since the early 1980s.

While still severely undersized, the treatment plants themselves are more effective following more than $100 million of improvements affecting every part of the treatment process.

The most dramatic advances involve the way in which the plants deal with scum and sludge.

New scum removal systems now skim grease and floatable trash off the top of the sedimentation tanks. This material used to be discharged into the Harbor and float back onto area beaches.

The new way in which the MWRA deals with sludge, the solid material that settles out from the liquid effluent, represents a major environmental advance. Until December 1991, sludge was discharged into the Harbor. Since that time, sludge has been shipped to the MWRA's new sludge-to-fertilizer plant.

- Dry-weather fecal coliform counts at the Nut Island sludge dumping site decreased from 2,364 per 100 ml in 1990 while sludge was still being discharged, to 4 in 1992.

Treatment plant performance has consequently improved.

- The number of Deer Island NPDES violations in Fiscal Year 1992 was 7, as compared to 35 in Fiscal Year 1987. The number at Nut Island was 0 in 1992, 1 in 1987.

More CSO flow is now treated.

Improved CSO treatment has also improved the quality of the flow that still gets diverted away from the treatment plants due to temporary system overload. Since 1987, MWRA has built three new CSO treatment facilities at a combined cost of approximately $13 million. About half of the total CSO flow is now chlorinated and screened.

- Fecal coliform counts in the waters close to new CSO treatment facilities at Fox Point have decreased from 749 per 100 ml to 79, and at Commercial Point from 175 to 49. (State swimming standard is 200 per 100 ml.)
- Water samples at Malibu and Tenean beaches, close to new CSO facilities, always met swimming standards in 1992. In contrast, these beaches did not meet standards 15% and 17% of the time in 1987.

Third, there is nevertheless a limit to how much more environmental improvement can be made before completion of new court-ordered secondary treatment facilities and the associated effluent outfall tunnel.

The requirements of the Clean Water Act are not going to be met, however, by massaging the current treatment system. Primary treatment does not remove enough solids (TSS) and organic material (BOD), and the Harbor is too small a body of water to absorb the amount of oxygen-consuming material that is currently being discharged into it.

- In 1992, 22% of dissolved oxygen measurements taken in bottom waters at dawn were below water quality standards.

Consequently, MWRA is engaged in a multi-billion dollar construction project. New facilities will come on-line in stages. More sophisticated primary treatment will begin operation in 1994, and partial secondary in 1996.

- By the end of the century, when the secondary facilities will be fully operational, BOD and TSS loading are predicted to decrease by 90% from 1990 levels.

The 1992 State of Boston Harbor Report therefore conveys a dual message. On the one hand, rehabilitation of the sewerage system has already made a measurable difference to the state of the Harbor. On the other hand, the limited nature of the environmental benefit that can be gained from this rehabilitation underlines the need to press on with new secondary facilities and a new effluent outfall tunnel into Massachusetts Bay.

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BOSTON HARBOR AND THE REGION'S WASTEWATER

1

A. Understanding the Problem

Most of us take for granted the availability of water entering our homes and businesses. Flushing a toilet, taking a shower, using a washing machine, hosing down a dirty factory floor—for all these activities we demand, and are used to getting an instant stream of clean, fresh water. We also tend to take for granted that we do not have to worry about the subsequent stream of wastewater leaving our homes and businesses. We assume that the combination of water, industrial cleaner, and dirt from the factory floor, the soapy water from the shower or washing machine, and whatever is flushed down the toilet will all be transported far away and somehow "dealt with."

Wastewater is generated by every home and industry in the Boston region.

However, the safe management of our domestic and industrial wastewater (sewage) cannot be taken for granted; it is one of the key issues facing the region. Specifically, our wastewater must be treated and then disposed of in a way that does not harm human health or marine life.

Management of the metropolitan region's wastewater is the responsibility of the MWRA. Homes and businesses in 43 Boston-area communities generate and discharge wastewater into an intricate network of local pipes. These pipes lead to the Authority's much larger "interceptor" pipes, which carry the flow through a variety of pump stations and other facilities until it reaches one of two treatment plants on the edge of Boston Harbor (see centerfold). This means that wastewater from locations as close to the Harbor as Rowes Wharf, and from as far away as Ashland some 30 miles west of Boston, is channeled into these plants. The plants treat the flow to remove as many contaminants as possible, and the resultant "effluent," or cleaned wastewater, is discharged into the Harbor.

The MWRA now manages the collection, treatment, and disposal of the region's wastewater.

This system is best understood in the context of the history of the region's attempts to deal with its sewage.

Historically, the region's sewage has been channeled into Boston Harbor.

Boston Harbor has long been the location of choice for the disposal of the region's sewage. Attracted by the ability of the water and the tides to dilute sewage and move it offshore, early residents built pipes to transport waste using the shortest line to the water. Later they combined these pipes with the storm drains that they had built to carry storm run-off into the Harbor, but the sewage remained untreated.

The human health risks associated with this convenient method of sewage disposal soon became evident. Outbreaks of disease were attributed to poor sanitary conditions. Periodic modifications to improve the system, however, were aimed only at pushing sewage further offshore into slightly deeper waters. In the 1870s, for instance, a brick sewer line was constructed under Dorchester Bay to Moon Island, where sewage was held in vast storage tanks before being released on the outgoing tide. The Harbor still had to absorb untreated sewage.

It was not until 1952 that a primary treatment plant was built on Nut Island to treat at least a portion of the sewage that had previously been discharged untreated into the Harbor. And it was not until 16 years later that a much larger primary treatment plant was built on Deer Island to treat most of the rest of the region's sewage. These plants marked the end of the wholesale dumping of untreated sewage into the Harbor.

The system's primary treatment plants came on line in 1952 and 1968.

The most important advance provided by the two primary treatment plants was that sewage was disinfected to kill most of the disease-causing pathogens, or germs. The effluent discharged from the plants therefore posed much less risk to human health.

Even treated effluent from primary plants can have a major environmental impact.

However, small amounts of untreated or partially treated sewage were still discharged either into the Harbor or into tributary rivers through some of the relief outlets associated with the old pipes that combined sewage with storm water.

Unfortunately, although primary treatment deals well with pathogens, it is less effective with other materials contained in sewage. Some of these, such as solids and oxygen-consuming organic matter, would be relatively harmless in the Harbor at low concentrations. By the late 1960s, however, they had become a genuine problem: while the Harbor's small size remained constant, the amount of sewage (and therefore the amount of solids and organics) flowing through the system had increased dramatically as a consequence of population growth.

Types of Pollutants in Boston Harbor

1. Pathogens

High levels of pathogens, or disease-causing organisms, are a risk to human health. Since most pathogens are difficult to measure directly, the presence of fecal coliform bacteria, a group of bacteria typically found in human waste, is used as an indication of the potential presence of disease-causing organisms. When fecal coliform levels in the water exceed state standards, beaches and shellfish beds are closed. Chlorination during the sewage treatment process serves to kill most bacteria; a major source of pathogens to Boston Harbor is therefore untreated sewage that discharges during heavy rains when stormwater overloads combined sewer systems.

2. Toxic materials

The toxic materials of most concern are metals and organic compounds. In addition to harming marine life directly, many of these materials can accumulate in living tissue; they can therefore harm organisms further up the food chain.

Metals—All metals occur naturally in seawater in trace amounts, but higher concentrations can be harmful. Metals of concern include arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, silver, and zinc.

Organic compounds—These include chemicals such as acetone, benzene, naphthalene, petroleum hydrocarbons, pesticides (e.g. DDT), and polychlorinated biphenyls (PCBs).

Toxic contaminants enter Boston Harbor from industrial, commercial and residential discharges to the MWRA sewerage system. Non-sewage sources of toxic materials include stormwater, rivers, and groundwater. The contribution of sewage effluent to the overall load of toxic materials to the Harbor varies. For example, effluent accounts for approximately 70% of the copper and 16% of the lead finding its way into the Harbor.

3. Suspended solids

An important reason for concern about suspended solids (particles suspended in the water) is that toxic materials in the effluent stream tend to be concentrated on them. In addition, water containing suspended solids is murky, which is not only unattractive but also reduces the amount of light available for photosynthesis by marine plants.

Sludge and sewage effluent both contributed solids to Boston Harbor in the 1980s. The cessation of sludge discharges decreased this amount, but effluent is still a major contributor of suspended solids.

4. Oxygen-consuming organic matter

As organic material in the water decomposes, oxygen dissolved in the water is consumed. In an area that contains a great deal of decomposing organic matter, the water can therefore be depleted of the oxygen necessary to support most marine life. The amount of oxygen-consuming material is measured as BOD (biochemical oxygen demand). Effluent is the leading source of BOD in Boston Harbor.

5. Nutrients

Nitrogen is an important nutrient for algae, the marine plants at the base of the food chain. In excessive amounts, however, nitrogen can stimulate growth until excessive quantities of algae accumulate. Oxygen is consumed when these algae die and decompose, and oxygen levels can become depleted. Sewage effluent accounts for more than 90% of the nitrogen entering Boston Harbor.

Moreover, the flow of sewage now contained many toxic contaminants such as pesticides and metals. These contaminants tend to adhere to the solids in the flow. Although some of the solids are separated out during primary treatment, the potential environmental benefit to be gained was negated by the practice at the Deer Island and Nut Island treatment plants of discharging removed solids into Harbor waters as "sludge."

B. Crafting a Solution

Growing awareness of the threat to the environment caused by disposing of inadequately treated sewage effluent led to the enactment by Congress of the Clean Water Act in 1972. The Act, passed only four years after the Deer Island primary treatment plant opened, mandated secondary treatment for publicly owned treatment plants. Secondary treatment is more sophisticated than primary and greatly increases the amount of solids and other materials removed from sewage before treated effluent is discharged.

The 1972 Clean Water Act mandated changes in sewage treatment.

MWRA's program to renovate the sewerage system is subject to a court schedule.

Over the next decade, the Metropolitan District Commission (the agency then responsible for the sewerage system) made several failed attempts to obtain a waiver from the secondary treatment requirement. Meanwhile, conditions worsened in the Harbor. By the early 1980s, beaches were often closed to swimmers and shellfishing was prohibited. Pollution was also taking its toll on marine life: flounder exposed to high concentrations of contaminants developed liver tumors and fin rot; areas of the Harbor became inhospitable to sensitive bottom-dwelling organisms.

Eventually, a series of lawsuits in the early 1980s led to the creation of the MWRA and the establishment by a federal court of a mandatory schedule for meeting the secondary treatment standards of the Clean Water Act and hence improving the water quality of Boston Harbor.

This court schedule governs the MWRA's ongoing program to (i) upgrade existing treatment facilities, (ii) stop dumping sludge into the Harbor, (iii) build new primary and secondary treatment facilities on Deer Island and a new outfall tunnel to carry the treated effluent out into the deeper waters of Massachusetts Bay, and (iv) control overflows from those sections of the system where sewers are combined with storm drains (combined sewer overflows).

There are several dates in the schedule that are of particular importance in terms of the quality of the material released from the treatment plants. As Table 1-1 shows, the MWRA has already stopped discharging both scum and sludge. Scum, the grease and trash skimmed off from wastewater, used to form noticeable slicks in the Harbor; sludge added solids, toxic contaminants, and pathogens to the Harbor.

Key environmental dates in court schedule.

Date	Environmental Milestone
2/89	Scum no longer discharged into Harbor.
12/91	Sludge no longer discharged into Harbor.
7/95	Full operation of new primary treatment plant, with discharge through effluent outfall tunnel.
10/96	Operation of first battery of secondary treatment.
12/99	Full operation of new secondary treatment plant.

Table1-1

New treatment facilities are at the heart of the MWRA program.

At the heart of the program lie the new treatment facilities, without which compliance with the Clean Water Act would clearly be impossible. With the addition of the new effluent outfall tunnel, these facilities account for approximately $3.5 billion of the $4.3 billion that the Authority expects to have spent by the end of Fiscal Year 1999 on court-ordered projects mandated by the Clean Water Act. This figure represents over 65% of the funds allocated to overhauling the entire wastewater system between 1986 and the end of the century.

The MWRA is undertaking the court-ordered program in the context of an overhaul of the entire system.

Improving the region's entire sewerage infrastructure is an integral component of the Boston Harbor environmental protection program. Since the various parts of the system are interconnected, a failure in one area usually has consequences in another. A new plant, however sophisticated, cannot function independently of the community pipes, MWRA interceptors, and pumps that deliver the region's sewage for treatment. Moreover, the existing treatment plants must be made to operate as efficiently as possible until the new facilities come on line. The Authority is therefore engaged in an ambitious system-wide overhaul. Although the cost of this overhaul, approximately $500 million, is only a fraction of the cost of the new facilities, it still represents a major and long overdue investment in the region's infrastructure.

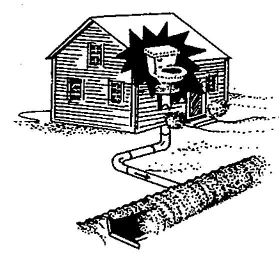
OVERHAULING THE EXISTING SYSTEM

2

A. Introduction

Each of the 43 communities in the MWRA service area owns and maintains its own sewage pipes. There are some 5,400 miles of these local pipes, which are typically between 8 inches and 2 feet in diameter. In most communities, sewage and stormwater runoff are carried in separate pipes. However, several communities in the MWRA service area have combined systems, where sewage and stormwater runoff are carried in the same pipe.

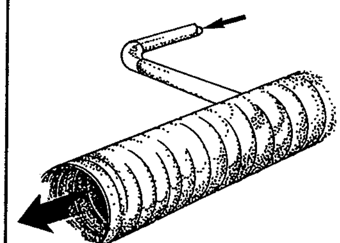
The sewage collection system is made up of pipes and pumps.



The communities' pipes feed into the Authority's 230 miles of "interceptor" sewers, which at some places may be 12 feet but are more typically about 5 feet in diameter. The sewage is transported through these interceptors until it eventually reaches the treatment plants on Deer Island or Nut Island. It moves through the system in large part by force of gravity; the system was designed so that the pipes follow the contours of the land and run parallel to stream and river beds. However, at some places the sewage has to be pumped uphill, at one of the Authority's pumping stations.

By the early 1980s, many sections of pipe were too small to handle the amount of flow generated by a population much larger than they were designed to serve. Some sections were over 100 years old. Other sections needed to be cleaned or repaired or had deteriorated so much that they needed to be replaced. The pumping system also contained archaic elements: the Smithsonian was interested in acquiring one steam pump which was still in use in the 1980s at the East Boston pump station. Understaffed and underfunded, the MDC Sewerage Division was forced to be reactive, making repairs as accidents occurred but unable to do much more than apply the engineering equivalents of Band-Aids to the larger needs of the system.

By the early 1980s, the collection system was in decline.



The capacity of the collection system was often exceeded. A problem at one of the treatment plants would create a domino effect back through the system, with bottlenecks and backups exacerbated by lack of pumping power and inadequate storage capacity within the pipes. This was most common during heavy rain, when the volume of flow was much increased. In some cases, untreated sewage would overflow into private dwellings, backyards, and streets, and into local streams and rivers.

Today, the MWRA is working both to rebuild the collection system at its weakest points and to maintain it by cleaning pipes and managing sewage flows with modern metering technology and communications systems. New computer programs will soon allow MWRA not only to generate detailed maps of any given section of pipe but to simulate any number of operational scenarios affecting that pipe and hence promote proactive flow management.

B. Pipes

Major new pipe construction projects are targeted to those areas where backups and overflows cause the most severe customer service and environmental problems. Currently, most of these areas are located in the southern part of the MWRA's region (see Fig. 2-1 and Table 2-1).

New pipes with adequate capacity are now being built.

The new interceptors will not only improve the delivery of sewage to the treatment plant, they will also protect environmentally sensitive rivers, wetlands, and drinking water supplies by dramatically reducing backups and overflows.

These projects typically take many years to complete because of the complexities of the planning and permitting process. Moreover, they often involve several communities, requiring MWRA to ensure that local concerns are addressed both before and during construction.

MWRA Interceptors

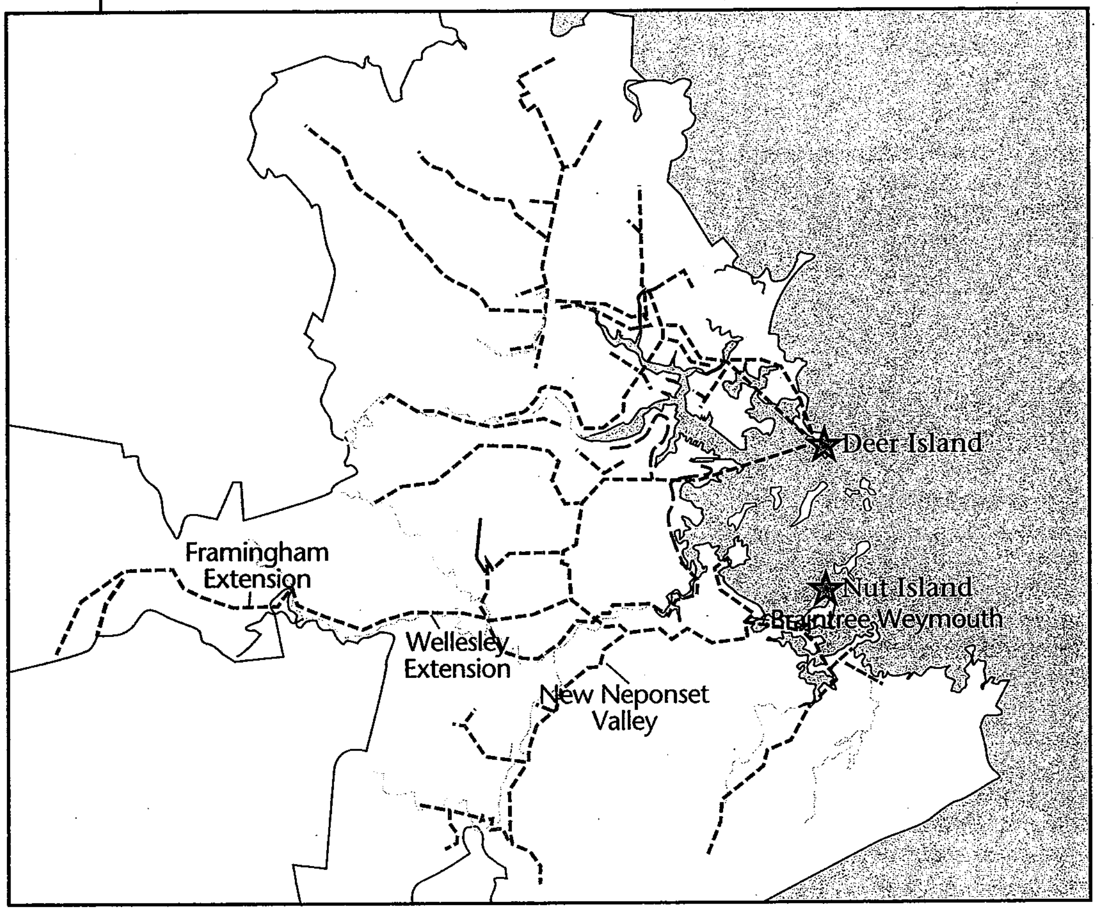


Fig. 2-1

Components, anticipated cost and completion dates of major interceptor projects

Project	New Pipe (miles)	Repaired Pipe (miles)	Other Components	Cost (millions)	Year
Wellesley Extension	7.1	7.0	–	$72	1995
New Neponset Valley Relief	8.7	–	New 46-million-gallons-per-day (mgd) pump station	$40	1995
Framingham Extension	6.8	4.3	New 22-mgd pump station	$46	1997
Braintree Weymouth Relief	1.3	2.2	New 60-mgd pump station New 13-mgd pump station 2.9-mile deep-rock tunnel	$136	2000

Table 2-1

The MWRA is also engaged in aggressive upkeep of existing sewer pipes. Regular inspections (See Table 2-2) ensure that the pipes do not fall back into disrepair once they have been upgraded. Pipeline repair and rehabilitation was allocated $2.2 million in Fiscal Year 1993.

Existing pipes are now being systematically maintained.

Miles of MWRA pipe internally inspected with closed-circuit TV.

Fiscal Year	Miles inspected
89	15
90	23
91	35
92	43

Table 2-2

Closed-circuit TV cameras are attached to small "boats," which are pulled through the pipes by electric winches.

Maintenance work is helping control infiltration/inflow.

The Authority's maintenance work helps identify the cracks in pipes and pipe joints that lead to *infiltration* of groundwater, and the illegally connected sump pumps, improperly connected catch basins and defective tidegates that lead to *inflow* of stormwater runoff and surface water.

Infiltration/Inflow (I/I) unnecessarily increases the amount of flow in the system, which results in the treatment plants treating a greater volume of flow than should be necessary. Approximately 60% of the average daily flow reaching the plants is actually I/I. This is a difficult problem for MWRA to solve because so much I/I originates in local systems' pipes. The MWRA has therefore recently established a $25 million I/I Local Financial Assistance Program to assist communities in the funding of I/I reduction and sewer system rehabilitation projects. This program will provide 25% grants and 75% interest-free loans as an incentive for communities to reduce extraneous flow.

It is already possible to see reductions in the amount of inflow. Inflow accounts for only 10% of the flow overall, but it has a dramatic time-specific impact, particularly during storms. It creates sudden peaks of flow that can overwhelm system capacity.

MWRA's newly installed wastewater meters record flow at 170 points in the system and are useful in the identification and quantification of inflow. As Fig. 2-2 shows, flow meter data from a site in Everett near the Mystic River identified a twice-daily influx of water coincident with the time of high tide. Subsequent investigations by MWRA and the City of Everett led to the discovery and repair of an old overflow pipe that was allowing water from the Mystic River to enter the sewer system at a peak rate of 4 million gallons per day (mgd). The meter record shows that the inflow was eliminated once the end of the pipe was sealed shut.

Tidal inflow was reduced following repair of an old overflow pipe.

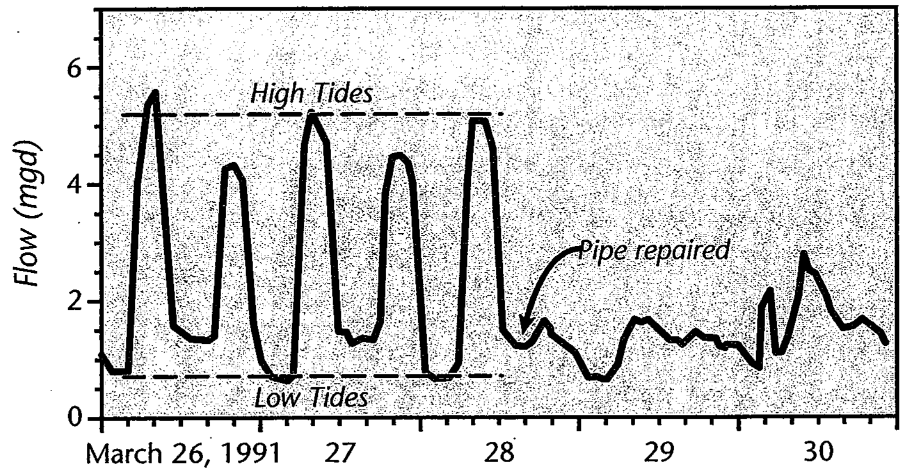


Fig. 2-2

Readings from meter EV-3C in Everett for the period March 26 to 30, 1991.

C. Pumping Facilities

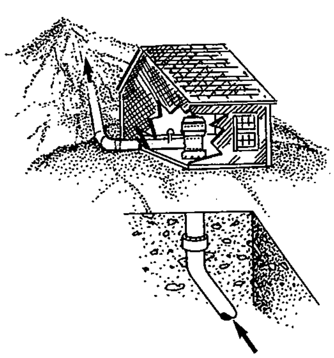
Pumping in the sewage collection system is handled by 9 major pumping stations (see Fig. 2-3). Two CSO treatment facilities, Prison Point and Cottage Farm, can also function as pump stations.

Before the creation of the MWRA, unreliable old or obsolete equipment often forced the pumping system into crisis mode. Today the MWRA is able to repair equipment when it breaks down and to practice cost-effective preventive maintenance. In Fiscal Year 1993, pump maintenance was allocated $500,000 in operating funds.

Outdated pumping facilities are being replaced.

Spending on new pumping facilities and equipment has been focused on the system's most vulnerable points, such as the antiquated Charlestown Pump Station or the underpowered Hingham Pump Station. Some of the large southern system interceptor pipe projects also include construction of new pumping stations (see Table 2-1).

The Charlestown Pump Station receives flow from Charlestown, parts of Cambridge, Somerville, and Medford, via a tunnel under the Mystic River. Flow is lifted and pumped to an interceptor leading to the Chelsea Headworks and ultimately the Deer Island treatment plant. Originally built in 1895, the station was converted to diesel power in 1950. By the early 1980s, its pumps had become inefficient and often broke down. Maintenance was expensive because replacement parts for the outmoded engines had to be custom-made. Limitations of space made rehabilitation of the station impractical and total replacement the only sensible option.



The new 93-mgd Charlestown facility, which will soon come on-line at a cost of $35.7 million, features electric rather than diesel power to operate new screens and pumps. It also includes flow meters, a stand-by generator, and a wet well to hold incoming flow and facilitate automatic regulation of the volume going to the pumps. The environmental benefit gained from the construction of a new pump station is the reduction of the risk of catastrophic breakdown, with all the attendant backups and overflows.

Rehabilitation rather than replacement was possible at the Hingham Pump Station, where the Authority has spent approximately $3.1 million over the last few years with dramatic environmental effect. The station used to overflow periodically into the Weymouth Back River because its pumps' capacity was only 3 mgd, whereas incoming flow from the town could reach 5 mgd. These overflows were of particular significance because the river is a state-designated Area of Critical Environmental Concern.

The installation of larger, more powerful, variable-speed pumps have given the station a capacity of 7 mgd. Two new "comminutors" grind up solids and protect the pumps from excessive wear and tear, and an emergency stand-by generator gives the station operational independence in the event of power failures. These improvements have allowed the Authority to permanently close off the bypass pipe that used to discharge the station's excess flow out to the river, thereby eliminating pollution from this source.

Pump Stations

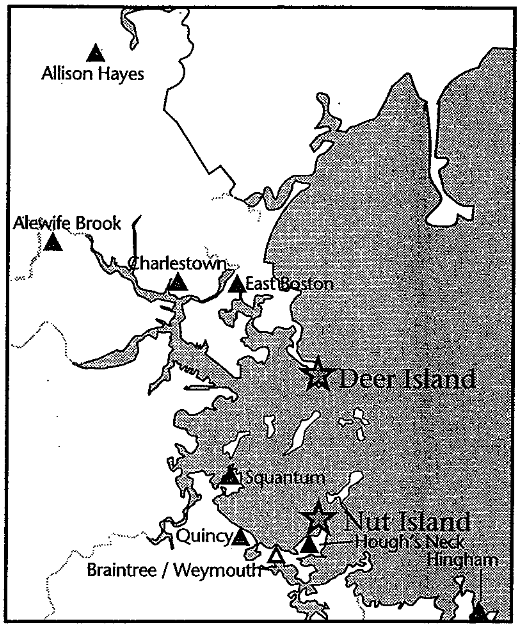


Fig. 2-3

Headworks

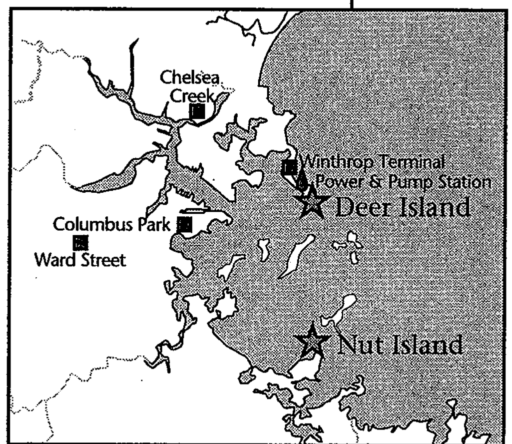


Fig. 2-4

Headworks screen the wastewater flow before it enters the treatment facilities.

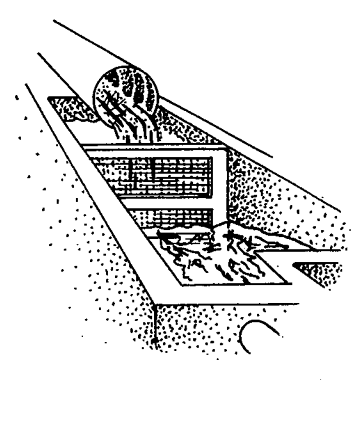
D. Headworks and Deer Island Power and Pump Station

Rags, grit, and large objects are screened out of sewage flows at the system's headworks facilities, shortly before the sewage enters the MWRA's treatment plants. This represents the first stage of primary treatment, and is sometimes referred to as "preliminary treatment." As Fig. 2-4 shows, three of the headworks serving the Deer Island plant are actually located off-island. These are called the "remote" headworks.

Headworks have been upgraded.

By the early 1980s, obsolete and inefficient equipment at the remote headworks was causing problems further back in the collection system and at the treatment plant itself. When intake channels had to be closed off for equipment repair, flow backed up to pumping stations and made it impossible for the stations to pump any more flow. Moreover, inefficient grit removal at the headworks increased the wear and tear on equipment at the treatment plant.

Completed in 1990, the $25.4 million upgrade to the three remote headworks included replacement or rehabilitation of sluice gates, grit collectors, and screening equipment. The upgrade increased the amount of grit and screenings collected from 104,000 cubic feet in 1987 to 165,000 cubic feet in 1992. Moreover, in 1992 all four intake channels at each of these headworks were available 98% of the time.



There was no more dramatic example of the sewerage system's vulnerability in the early 1980s than the "Mother's Day '83" disaster at the Deer Island Power and Pump station. For 48 straight hours, heroic MDC divers felt their way around in the pitch darkness of a three-story building flooded with raw sewage, trying to locate and close a malfunctioning valve. The incident brought a good portion of the region's sewerage system to a standstill: the

The Power and Pump Station has been overhauled.

Deer Island plant closed down, upstream pump stations had to stop operating, and the entire northern part of the system backed up.

A $33.3 million upgrade, completed in 1990, included replacement of five pumps, new electric pump motors, and back-up diesel generators. As Table 2-3 shows, pumping capacity and reliability is consequently much improved.

Pumping capacity has increased at Deer Island Power and Pump.

Fiscal Year	# Pumps Operated	High Peak Flow (mgd)
88	4.9	480
89	5.9	600
90	6.7	623
91	8.3	677
92	7.2	746

Table 2-3

Choking time has decreased dramatically.

Regulating the amount of flow going through the headworks and on to the Deer Island plant will always be necessary, particularly during heavy storms. However, the Deer Island Power and Pump upgrade and improvements at the headworks and throughout the collections system have led to a decrease in the amount of time that the headworks have to regulate or "choke back" flow (see Fig. 2-5). This is an excellent indicator of overall system improvement.

Choking time at Deer Island headworks has decreased.

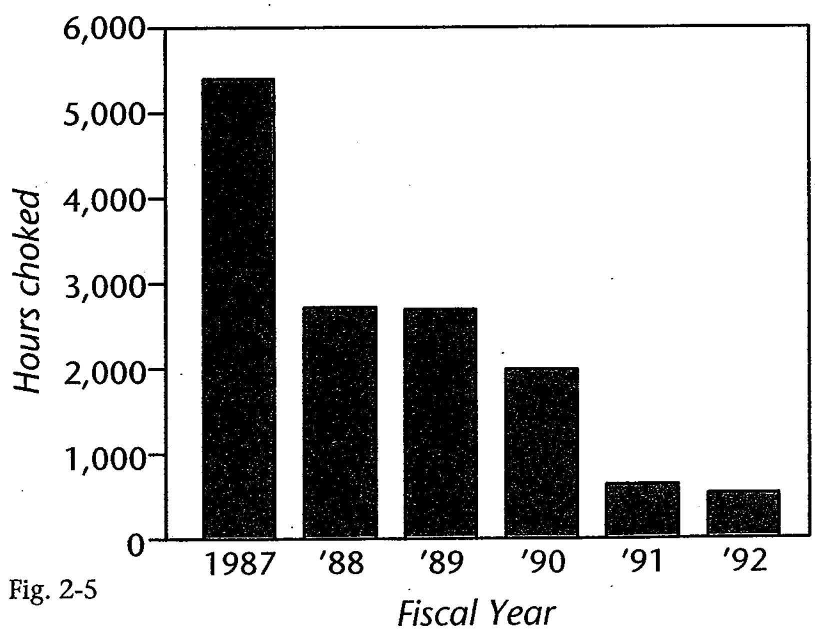


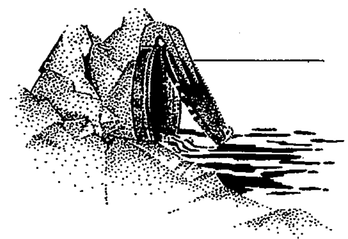
Fig. 2-5

The total number of hours the headworks at Ward Street, Chelsea Creek and Columbus Park choked back flow between 1987 and 1992.

E. Combined Sewer Overflows

Parts of six communities—Boston, Cambridge, Somerville, Chelsea, Brookline, and Everett—have combined systems, with pipes that carry both sewage and rainwater. These systems, which are still common in many urban areas across America, date from the late 1800s when combined sewers were accepted practice. Of the six MWRA communities with combined sewers, all but Brookline and Everett have combined sewer overflow structures (CSOs) that divert excess flow into Boston Harbor or its tributaries during heavy rains. There are more than 80 CSO outfalls that can discharge combined rainwater and sewage (see Fig. 2-6).

Combined storm drains and sanitary sewers can overflow.



Under normal circumstances, all the flow in combined systems is carried to a treatment plant. However, CSO activations can occur when pipe capacity in the combined systems is exceeded. This happens most often during storms. Not only does stormwater enter the combined systems directly, it also enters indirectly, through inflow into the pipes of adjacent communities. This inflow uses up pipe capacity that would otherwise be available for combined sewage.

CSOs were largely untreated.

Until recent years, the problem of combined sewer overflows was exacerbated by mechanical breakdowns that limited the collection system's capacity to transport, store, and regulate the flow. This used to lead to overflows even during dry weather. Moreover, only a small proportion of the combined sewer overflows received any sort of screening or disinfection. Beaches near the overflow points were closed regularly because of violations of bacterial water quality standards.

Work done on pumping stations and headworks over the last few years has increased overall system capacity, which means that more of the flow can get to the treatment plants. Even routine maintenance work has reduced CSO activations: regular cleaning of the interceptor pipes creates more space to store wastewater in the event that the treatment plants are temporarily overloaded.

Combined sewer overflow outlets and treatment facilities

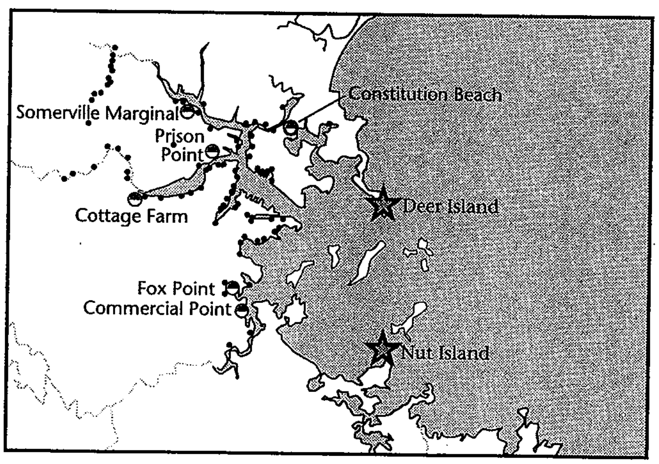


Fig. 2-6

Maintenance work on CSO structures has had a similar impact. Tidegates, which permit the discharge of wastewater but prevent river or Harbor water from flowing into the sewer system, can wear out or get locked in place. Regulators, the devices that direct most flow in a combined sewer to the treatment facility and divert excess flow to an outfall, can get blocked or otherwise malfunction, as can the outfalls themselves. Regular maintenance of these structures reduces inflow and increases the amount of sewage that reaches the treatment plants.

Improved maintenance provides more capacity to transport combined sewer flow.

In the winter of 1989-90, a malfunctioning regulator in the CSO pipe at the head of the Fort Point Channel was unnecessarily diverting flow to a nearby CSO outfall rather than to the treatment plants. As Fig. 2-7 shows, after the discovery and repair of this faulty equipment, wet weather fecal coliform counts in the Channel decreased by approximately half.

Fecal coliform counts in Fort Point Channel decreased once a malfunctioning CSO regulator was repaired.

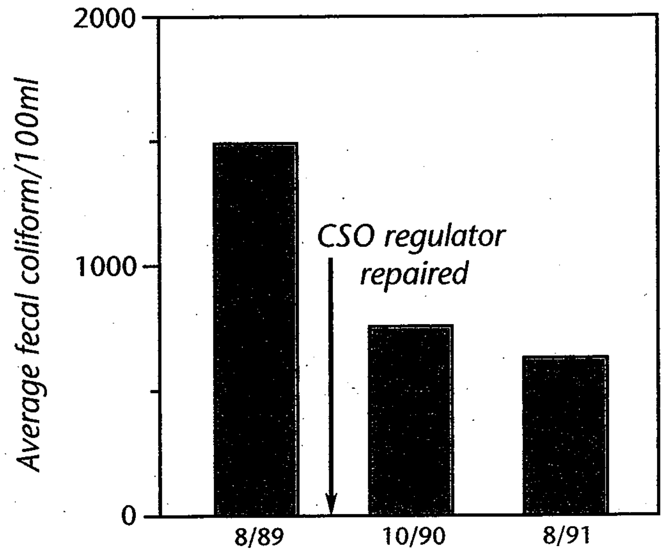


Fig. 2-7

Each bar represents the average (geometric mean) fecal coliform count of approximately 20 samples. There was about a quarter-inch of rain during each sampling period.

Today, dry weather CSO activity has been eliminated, and wet weather activity is far less common than even a few years ago (see Table 2-4 and Fig. 2-8).

The number of dry weather combined sewer overflows.

Fiscal Year	Cottage Farm	Prison Point	Somer-ville Marginal
87	10	1	n.a.
88	12	n.a.	0
89	3	0	0
90	3	0	0
91	1	0	0
92	0	0	0

Table 2-4

n.a. - not available
Overflows were designated "dry weather" if there was no rain during the previous 24 hours.

Wet weather flow through CSOs has decreased.

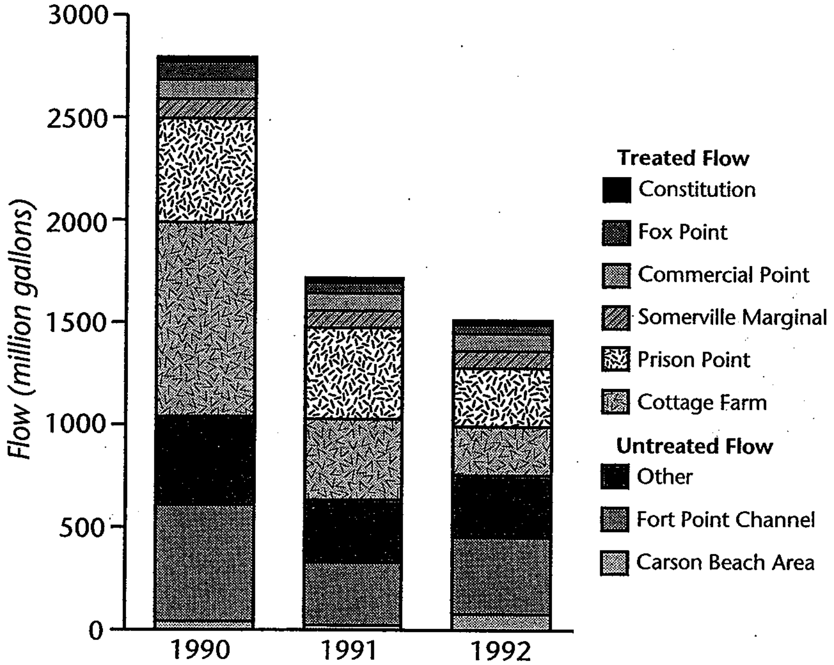


Fig. 2-8

MWRA meter records were used to determine flow through the six CSO treatment facilities. Flow through Commercial Point in 1990 was untreated.
Boston Water and Sewer Commission model data were used to estimate untreated flow. Although BWSC's model does not include discharges of untreated CSO flow into the Charles or other discharges by Cambridge, Chelsea, and Somerville, it nevertheless indicates the downward trend in wet weather CSO activity.

Some of this decrease in wet weather CSO flow is due to the increased capability of the Deer Island Power and Pump station to pump more flow through the plant. This permits flow that used to back up and discharge through CSO outlets to be treated at Deer Island. It is then discharged through the relief outfall close to the mouth of the Harbor, where there is better flushing than at CSO discharge sites such as the Inner Harbor and the Charles River.

MWRA has spent millions of dollars to build or upgrade the six CSO treatment facilities (see Table 2-5). These screen and chlorinate CSO flow before it is discharged. Approximately 50% of the total CSO volume is now treated in this manner.

More of the CSO flow now receives preliminary treatment.

The six CSO treatment facilities

Facility	Improvements	Date Completed	Cost
Prison Point	Built in 1981 under the MDC		
Cottage Farm	Upgrade	1987	$ 452,000
Constitution	New Construction	1987	$1,264,746
Somerville Marginal	Upgrade	1989	$1,696,931
Fox Point	New Construction	1989	$4,164,000
Commercial Point	New Construction	1991	$7,140,000

Table 2-5 n.a.- not available

CSO facilities measurably improved environmental quality.

Screening and chlorination at the MWRA's six CSO treatment facilities make CSOs in these areas far less likely to degrade bacterial water quality and cause beach closings. The improvements in water quality can be seen by comparing fecal coliform counts measured near the CSO outlet before and after the construction of treatment facilities (see Fig. 2-9).

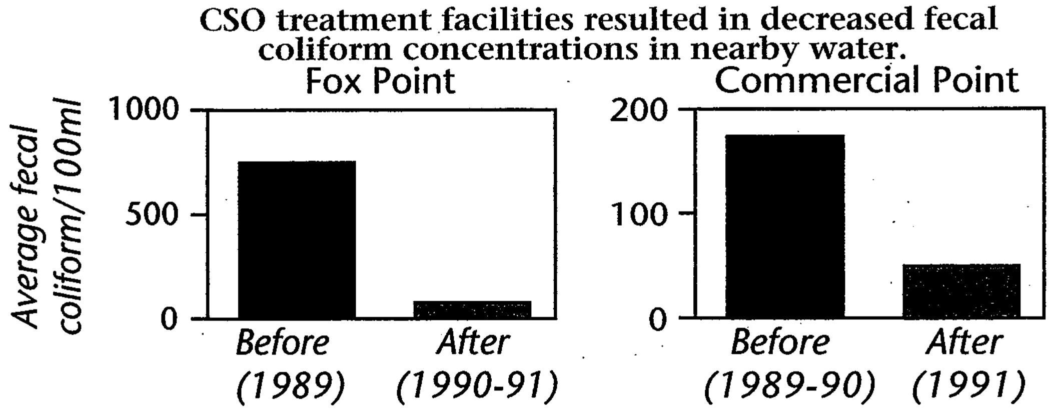


Fig. 2-9

Average (geometric mean) fecal coliform counts measured at CSO facilities.

As Fig. 2-10 demonstrates, water quality at beaches also shows improvement near new CSO facilities

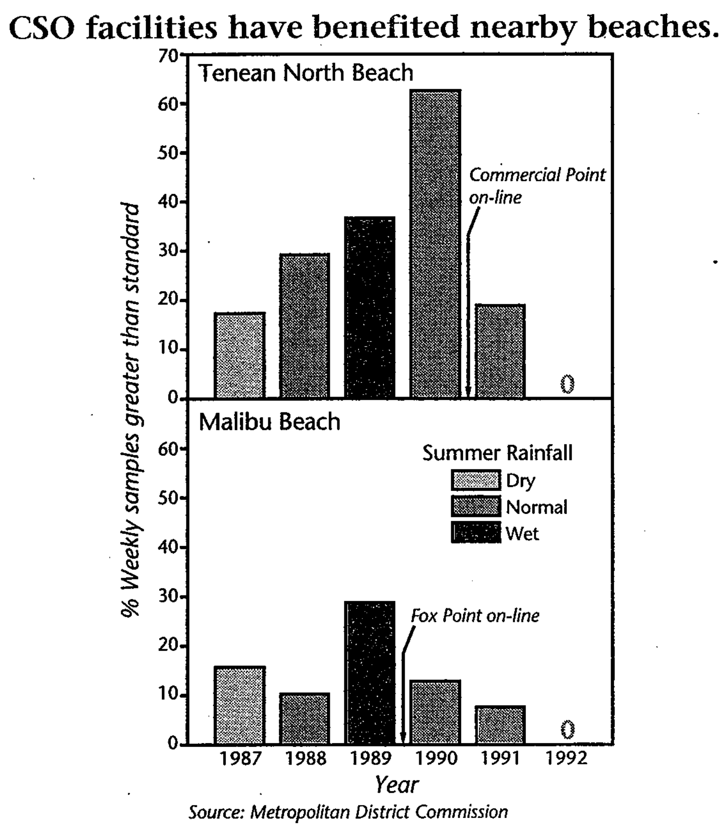


Fig. 2-10

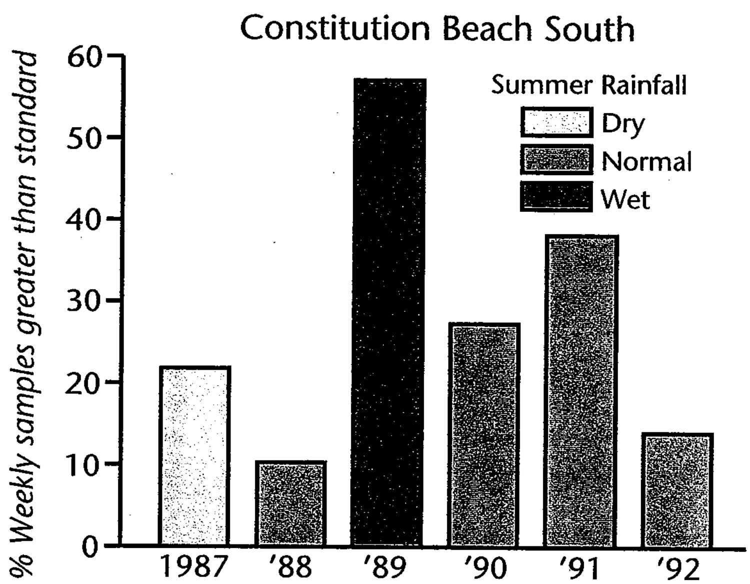
The percentage of routine bacterial samples that exceeded the state water quality standard for swimming (geometric mean of no more than 200 fecal coliform per 100 ml of water) over the past four years. Total rainfall for the months of June, July, and August was 6.4" in 1987 (dry), 13.8" in 1989 (wet), and ranged from 10.0" to 11.3" in the remaining years (normal).

Constitution Beach: More than a CSO Problem

Before a CSO screening and disinfection facility began operation in March 1987, untreated sewage that discharged near Constitution Beach during rainstorms caused high bacteria counts in the water and consequent beach closures. However, even after the CSO treatment facility began operating in 1987, problems with beach contamination remained (see Fig. 2-11, left).

Sampling in 1987 indicated that a large storm drain emptying at the beach was a significant source of bacteria. The Boston Water and Sewer Commission found that the sanitary sewers from many neighborhood residences were connected to the storm drain rather than to the sewer system. In 1990, 26 of these improper connections were repaired, and the counts of coliform in the immediate vicinity of the storm drain decreased (see Fig. 2-11, right). Although water quality at the beach remains a problem, the average fecal coliform count decreased from 60 in 1990 to 17 in 1992. Continued inspection of the storm drains has revealed more illegal sewer connections; water quality at the beach should steadily improve as these are repaired.

Constitution Beach is slowly improving.



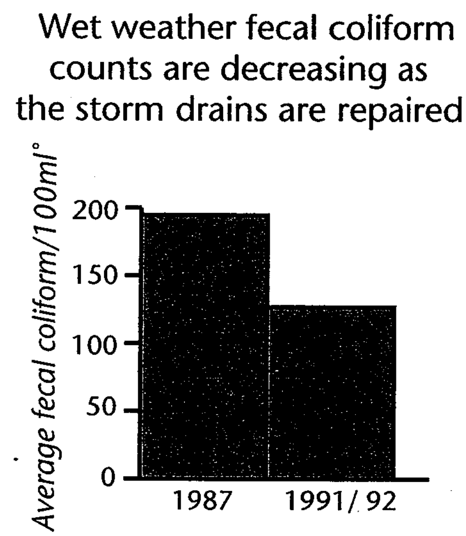


Fig. 2-11

Left: The percentage of routine bacterial samples that exceeded the state water quality standard for swimming (geometric mean of no more than 200 fecal coliform per 100 ml of water) over the past four years. Source: Metropolitan District Commission. Rainfall as for Fig. 2-10.
Right: Average (geometric mean) fecal coliform counts from samples taken during wet weather.

However, CSO discharges still present problems.

Approximately half of the CSO volume now passes through one of the six CSO treatment facilities, where it is screened to remove trash and chlorinated to kill bacteria. Although solids and organic materials are not removed, chlorination decreases the likelihood of adverse impacts on human health. However, the remaining half of the flow is discharged untreated through other CSO outfalls, particularly in the Inner Harbor and along the Charles River.

CSO discharges exacerbate pollution of the Charles River.

As Fig. 2-12 demonstrates, water quality in the Charles River is already severely degraded at a station near the Newton Yacht Club, which is upstream of any CSOs. CSOs, therefore, are not the only source of sewage pollution in the Charles but do contribute significantly to wet-weather water quality problems. Fecal coliform counts along most of the lower Charles are particularly high close to CSO outlets (see Fig. 2-12). In addition, dissolved oxygen levels in the river are exceedingly low and often violate standards, at least in part because CSO discharges contain so much organic matter. Aesthetically, too, CSOs create problems, causing unattractive, oily slicks of debris to accumulate, particularly close to the Charles River Dam.

The dam itself is part of the reason for poor water quality in the Charles, for it limits the exchange of water with the Harbor. The Charles is therefore poorly flushed, and cannot absorb high loads of pollutants without environmental deterioration.

Fecal coliform counts along the Charles River are much higher than the State standard.

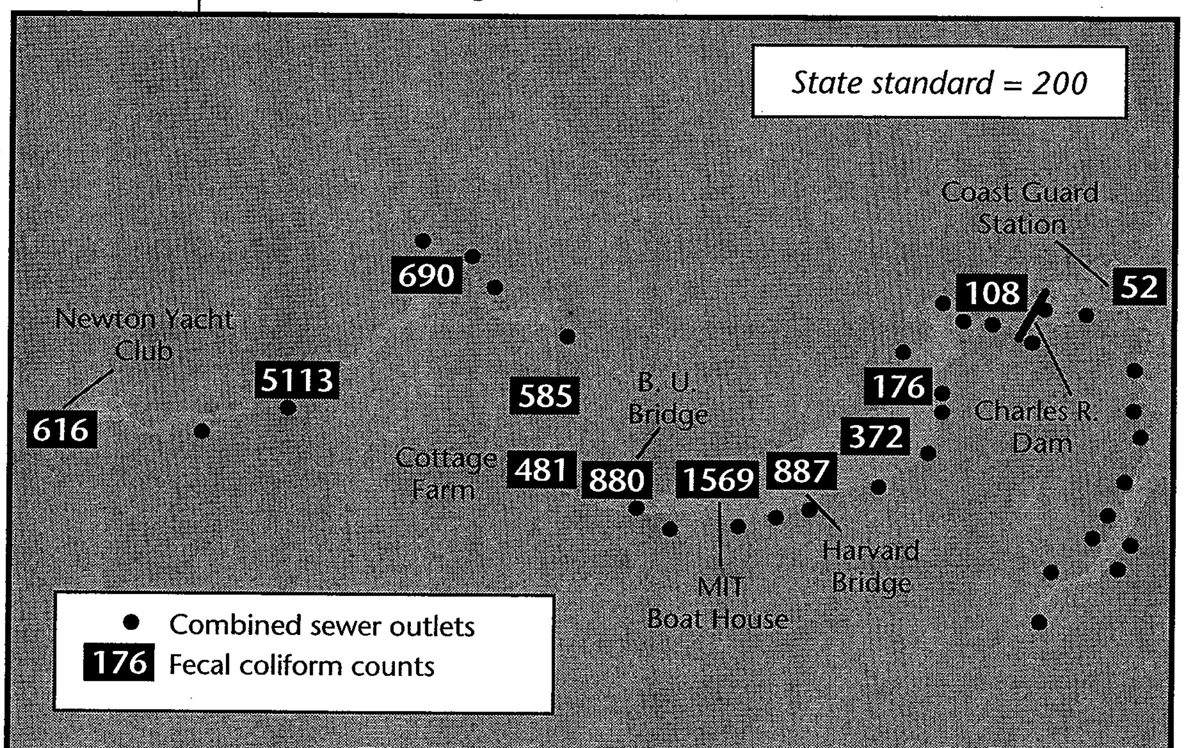


Fig. 2-12

Average (geometric mean) fecal coliform counts taken during the summer of 1991. Source: Rex 1993.

The CSO management planning process is ongoing.

Two major components of CSO control are ongoing. First, the Authority is working with the CSO communities to develop low-cost, easily implemented structural or operational modifications that maximize the storage, transport, and treatment capabilities of the existing system, thereby further reducing overflows. The second, longer-term project involves evaluating a set of CSO control strategies which include different combinations of new construction, optimization of interceptor capacity, reduction of infiltration and inflow, and a variety of treatment options. The goal is to develop a system-wide, integrated plan that ensures CSO control requirements are met in a cost-effective manner.

F. Improvements at Treatment Plants (Deer Island/Nut Island)

Fast-track upgrades have improved the treatment plants.

The Deer Island and Nut Island primary treatment plants were built in 1968 and 1952 respectively. Outdated almost as soon as they were built, by the early 1980s they were inefficient and occasionally subject to dramatic breakdowns.

The long-term solution for the region's sewage treatment involves the building of a new secondary plant on Deer Island and the decommissioning of the two old plants. However, in the interim, the old plants must be made to operate as effectively as possible.

Since it took over the operation of the plants, the MWRA has spent over $100 million on intermediate upgrades or "fast-track" improvements to virtually every stage of the primary treatment process (see Fig. 2-13). Some of these improvements, such as odor and noise control systems mitigate impacts on adjacent communities, but most increase the plants' reliability and efficiency.

Primary Wastewater Treatment

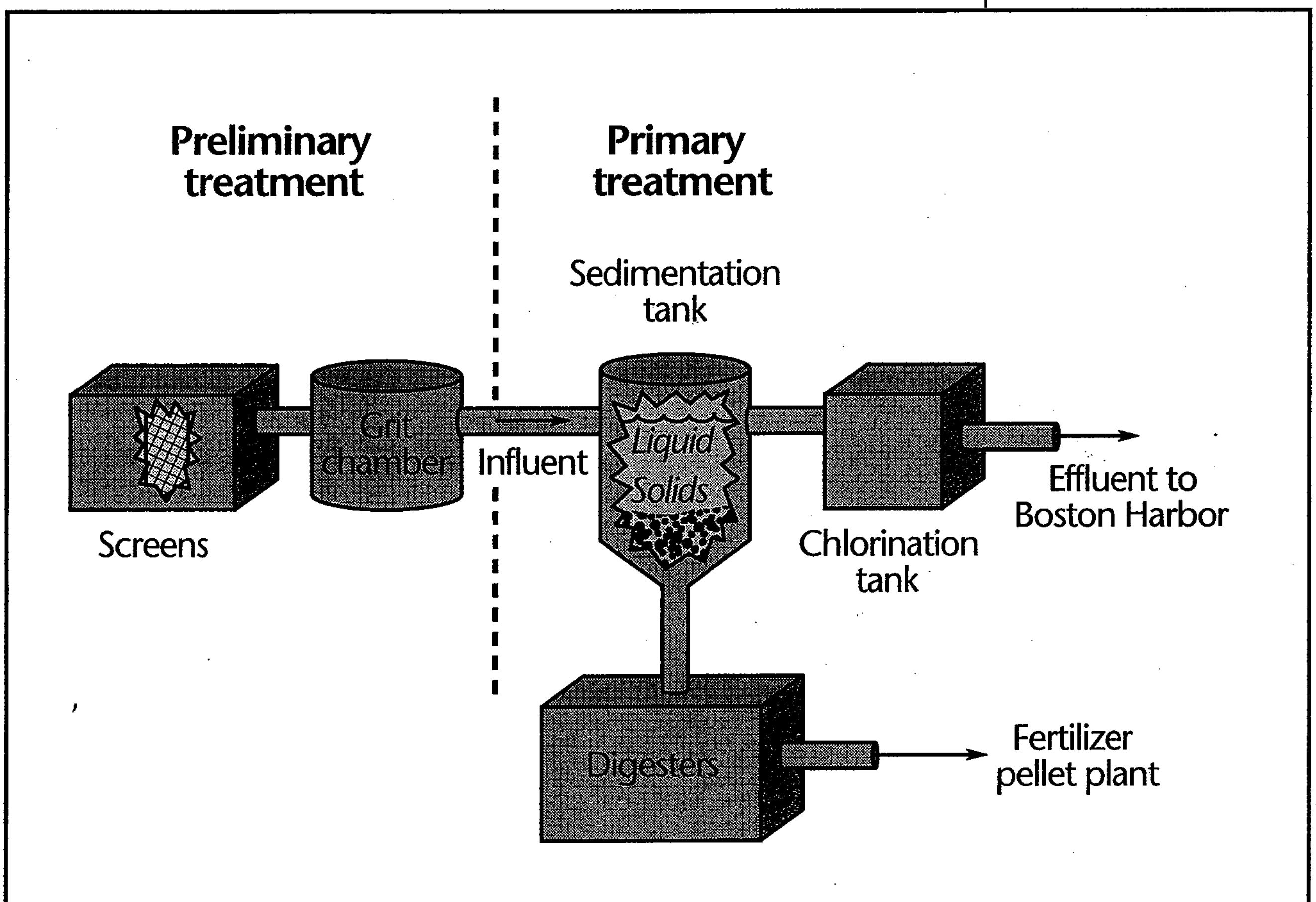
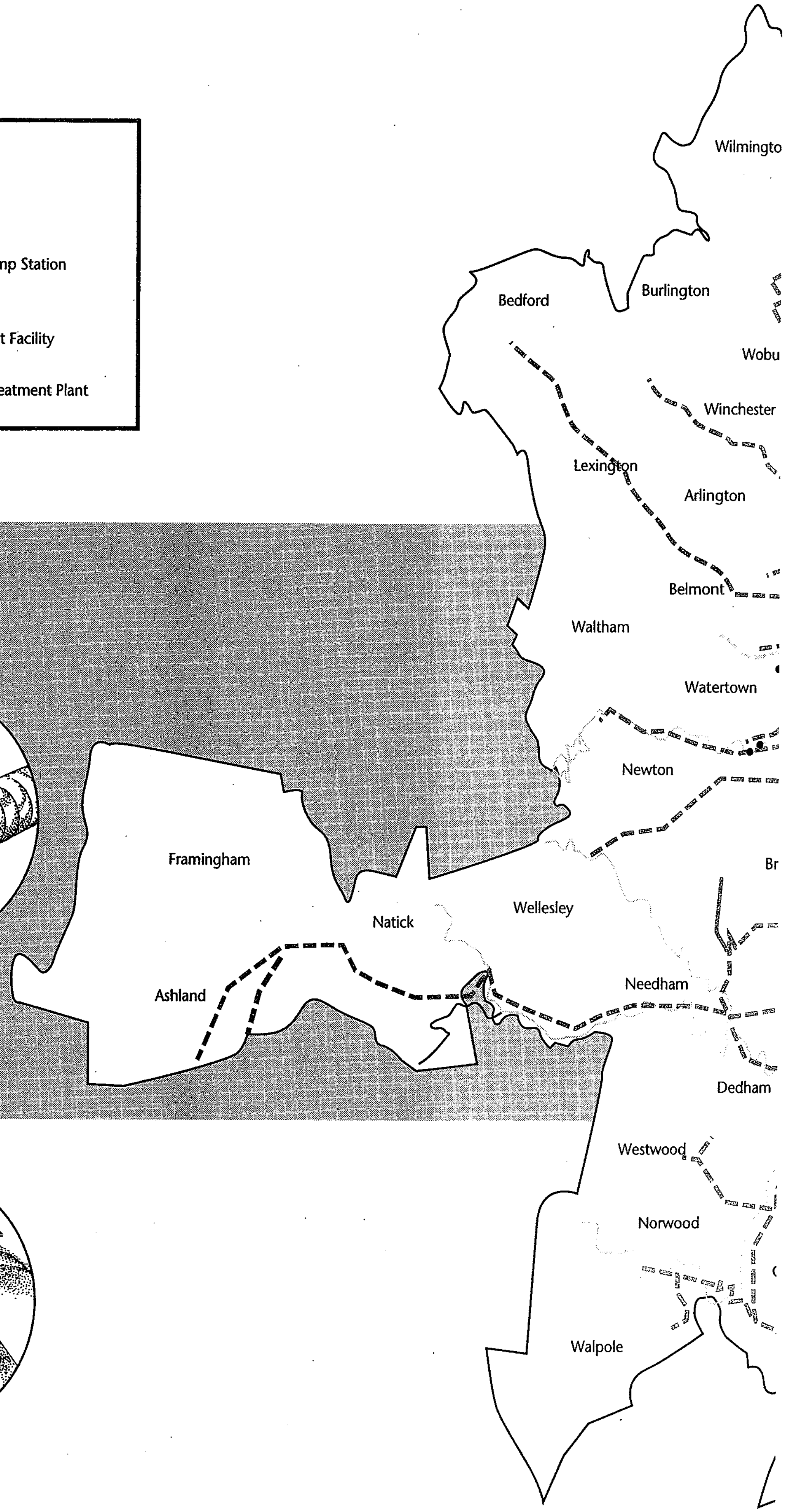


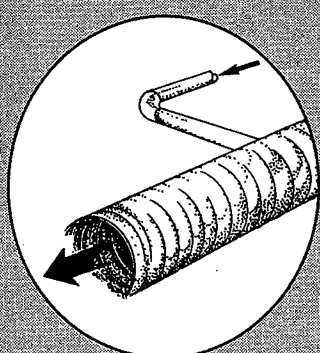
Fig. 2-13

More solids settle out in sedimentation tanks.

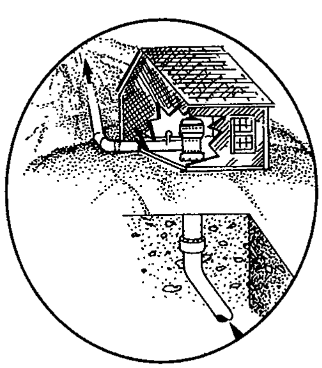
Primary treatment at the plants begins with the separation of the solid material from the liquid flow in sedimentation tanks. A rehabilitation project at Deer Island has increased the amount of time the wastewater remains in these tanks, so that more solids can settle to the bottom. This reduces the amount of solids and BOD in the effluent eventually discharged into the Harbor.

Scum removal systems at both plants have made a dramatic difference to



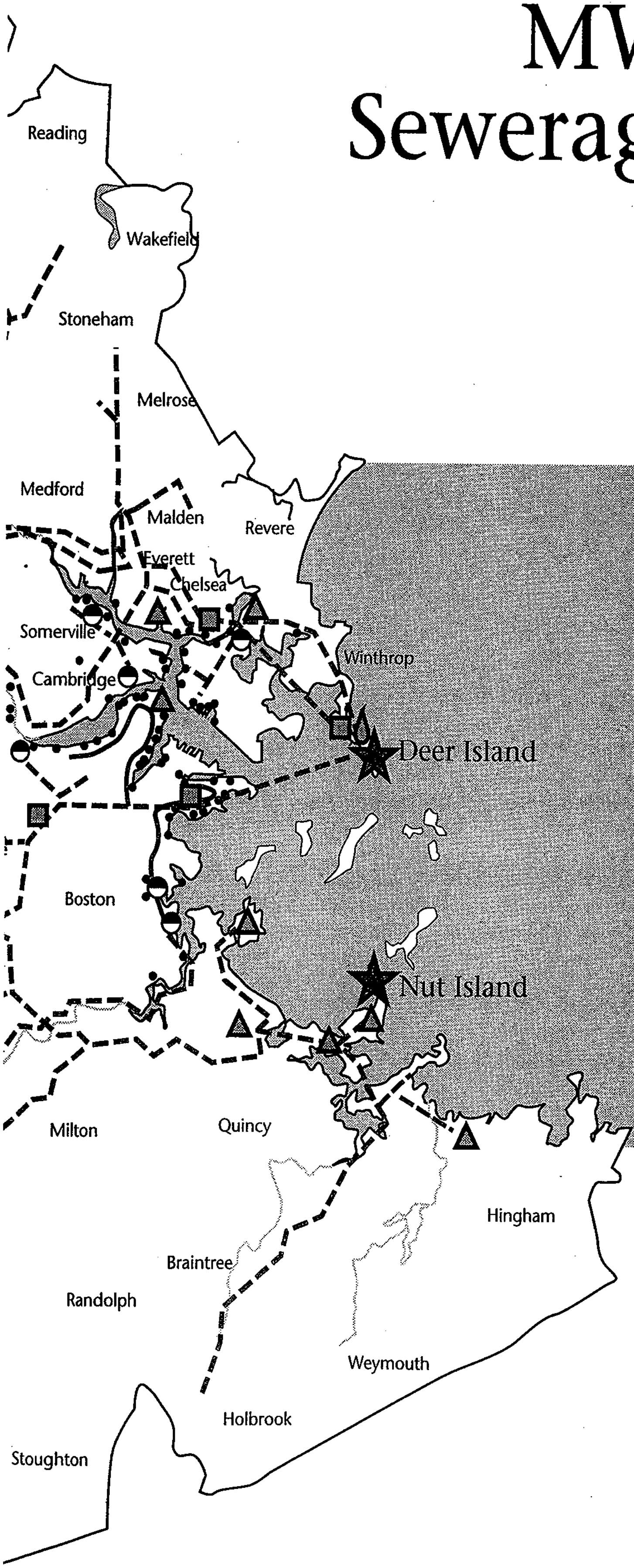


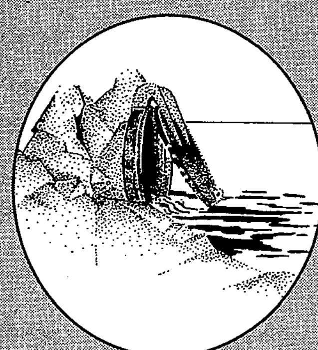
Interceptor



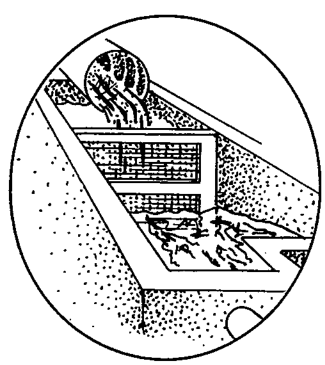
Pump Station

MWRA Sewerage System





CSO Outlet



Headworks

New scum removal systems have visible impact on the Harbor.

the aesthetics of the Harbor. Grease and floatable trash such as rags and plastics are now skimmed off the top of the sedimentation tanks. This scum is then crushed and bound with inert material that turns it into a soil-like substance that is transported to landfills. Previously the scum was discharged into the Harbor and eventually floated back onto area beaches.

There was a slight decrease in the number of plastic tampon applicators collected on Boston Harbor beaches in the 1991 annual beach cleanup conducted by Massachusetts Coastal Zone Management (see Table 2-6). Since tampon applicators are sewage-related wastes, the decrease indicates the effectiveness of the improvements in the sedimentation tanks and scum removal systems. Some sewage-related debris may still escape these processes to be discharged with the effluent, or it may enter the Harbor through CSO discharges.

Scum removal results in fewer "sewage indicators" per mile of beach on Boston Harbor.

Year	# tampon applicators per mile of beach
1989	208
1990	213
1991	170

Average number of plastic tampon applicators collected per mile of beach on Boston Harbor.
Source: Massachusetts Coastal Zone Management.

Table 2-6

Deer Island has a new chlorination system.

From the sedimentation tanks, the wastewater passes into the chlorination system where it is disinfected before being discharged into the Harbor. Liquid chlorine provided the disinfection at Deer Island until 1991, when the Authority completed a new disinfection facility that uses sodium hypochlorite. The new facility is much more reliable than its predecessor. The old gas diffusers, in particular, were subject to breakdown. Moreover, sodium hypochlorite is safer to store and handle than liquid chlorine.

Sludge is no longer discharged into Boston Harbor.

Solids that settle out in the sedimentation tanks are thickened and transferred to digesters. At this stage, the solids are called sludge. In the digesters, bacteria break down sludge, reducing its volume by about 50 percent.

Until 1991, approximately 40 dry tons of sludge from the digesters were discharged daily into the Harbor on the outgoing tide. About one-third of the sludge would return to the Harbor on the following incoming tide.

Sludge is now turned into fertilizer pellets.

In December 1991, MWRA opened its $90 million sludge pelletizing plant at the former Fore River Shipyard. Since that time, digested sludge has been barged from both treatment plants to the facility on the Quincy-Braintree border, where it is dewatered and heat-dried into fertilizer pellets. The cessation of sludge dumping represents the major environmental advance for the Harbor since the creation of the MWRA.

Sludge pellets cannot be sold in Massachusetts for use as fertilizer unless both federal and state standards are met. Fortunately, due to aggressive source reduction programs, the concentration of toxic chemicals and heavy metals in sludge from the MWRA's treatment plants is below the limits set by federal and Massachusetts regulations. The Authority has applied for a Massachusetts certification to classify its pellets as "Type I" fertilizer, which meets the strictest criteria for toxic metals and can be sold in-state with no restrictions. As Table 2-7 shows, metal concentrations in MWRA pellets compare favorably with the concentrations found in sludge pellets generated by other municipal treatment plants for agricultural land application.

Comparison of levels of contaminants measured in sludge with state and federal standards and with sludge produced by other plants.

Metal (ppm)	MWRA sludge pellets[a]	State limit[b]	Federal limit[c]	Renton/ Seattle[d]	Blue Plains/ Washington D.C.[d]	South Shore/ Milwaukee[d]
Arsenic	2.5	n.a.	41	n.a.	n.a.	n.a.
Boron	13.4	300	n.a.	n.a.	n.a.	n.a.
Cadmium	6.3	14	39	6.3	6.7	11
Chromium	64.0	1000	1200	83	180	3100
Copper	745.7	1000	1500	730	526	700
Lead	227.5	300	300	100	140	230
Mercury	5.7	10	17	0.7	1.8	0.7
Molybdenum	12.8	25[e]	18	11	60	32
Nickel	36.0	200	420	23	50	150
Selenium	2.5	n.a.	36	n.a.	n.a.	n.a.
Zinc	982.3	2500	2800	850	750	1900

Table 2-7

ppm - parts per million
n.a. - not available
[a]Average concentration measured in sludge pellets during calendar year 1992.
[b]Type I standards, Mass. Dept. of Environmental Protection Reg. 310 CMR 32.
[c]High quality sewage sludge designation, Clean Water Act Part 503.
[d]MWRA 1991 survey of plants/cities that produce sludge for land application.
[e]In Massachusetts, pellets with molybdenum concentrations greater than 10 ppm cannot be used on crops that are used to feed grazing animals, like cows. At these levels molybdenum is not of concern to humans, but it can interfere with a cow's ability to absorb copper, an essential nutrient for the cow.

As a result of cessation of sludge dumping, Harbor water quality immediately improved.

There has been a dramatic reduction in the concentration of sewage-associated bacteria in the vicinity of the sludge outfall as a result of sludge abatement (see Fig. 2-14).

Fecal coliform counts decreased dramatically once sludge discharge stopped.

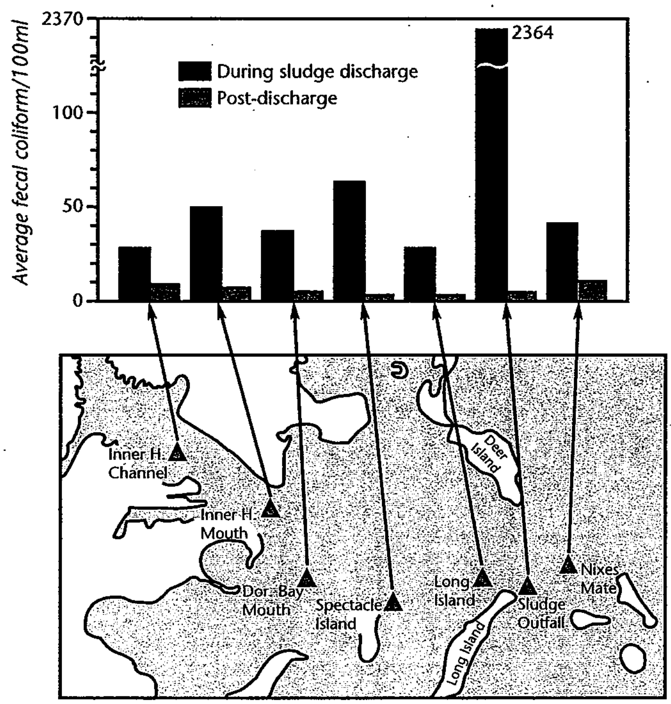


Fig. 2-14
The first series of samples was collected in October 1991; the second in November 1992. Samples were all collected during dry weather at low tide.

G. Pollutant Source Reduction

Discharge of toxic contaminants into the sewerage system must be controlled.

Three factors make it essential to control the amounts of toxic organic chemicals (such as 1,1,1-trichloroethane, a cleaner used by circuit board manufacturers) and toxic metals (such as the chromium used by metal finishers) that go into the sewerage system.

First, a considerable percentage of these pollutants does not get removed in the present primary treatment process but remains in the effluent discharged into Boston Harbor.

Second, some hazardous pollutants settle out in the sludge that is now turned into fertilizer. Contaminants therefore affect the marketability of the fertilizer made from the sludge: the fewer pollutants in the sludge, the more uses for the fertilizer.

Third, some of these pollutants could be hazardous to people exposed to sewerage system fumes, including MWRA's own maintenance and treatment plant personnel. They could also harm the sewerage infrastructure and treatment plant equipment.

The Authority's Toxic Reduction and Control Department (TRAC) has had considerable success in reducing the concentration of these pollutants in the flow that goes to the treatment plants. TRAC issues sewer use permits to industries, inspects their facilities, monitors their discharges, and enforces federal, state, and local discharge regulations. Enforcement can take several forms (see Table 2-8), from informal notices of violation, to financial penalties, to referrals for criminal prosecution. This table demonstrates TRAC's commitment to help companies achieve compliance before financial penalties must be imposed.

MWRA enforces discharge regulations.

TRAC enforcement actions 1990-92

Fiscal Year	Violation Notices[a]	Non-Compliance Notices[b]	Penalty Assessments[c]
90	0	23	2
91	16	99	15
92	127	171	11

Table 2-8

[a] Letter describing violation, asking user to identify reason for the violation and what steps will be taken to ensure it will not recur.
[b] Formal notice of violation specifying requirements the user has violated and a schedule by which user must return to compliance.
[c] Formal, written notice to user assessing civil monetary penalties.

Although TRAC permits and regulates over 1,300 local industrial sewer users, it pays particular attention to the nearly 250 that are designated Significant Industrial Users (SIUs). Defined by federal law, SIUs are companies that because of their size or the types of chemicals used to make their product are the most likely to violate local discharge limits or cause harm to the collection system or the treatment plants.

TRAC work over the last few years shows that households are also a source of toxic pollutants in the waste stream. Public outreach campaigns encourage people to use products that are environmentally safer and to take precautions when disposing of potentially hazardous materials such as pesticides and used motor oil. TRAC has also worked with communities to collect and dispose of household hazardous waste.

Toxic contaminant loadings in the waste stream have declined.

There is evidence that the amounts of the pollutants in the waste stream are declining. For example, total metal loadings in the influent have dropped considerably. Fig. 2-15 shows the decreased loadings of zinc and copper to the plants over the past decade.

Influent loadings of zinc and copper to the treatment plants have decreased.

Combined loading of zinc and copper based on average monthly concentrations (data missing for 11% of the months) and average monthly flows through both Deer Island and Nut Island.

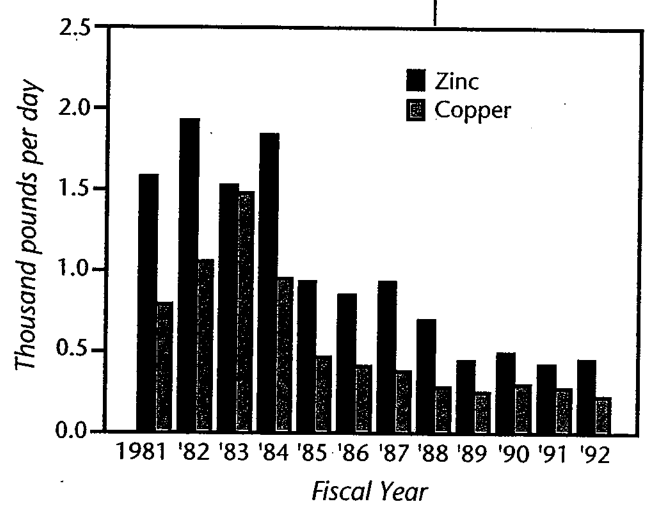


Fig. 2-15

Aside from the efforts of TRAC, several factors have contributed to the decline in the amount of toxic materials in the waste stream. First, the federal government has taken action on a national level. Manufacture of many of the most toxic pesticides and other hazardous materials has been banned. In addition, EPA continues to refine the standards for its pretreatment program, which regulates the amounts of toxic materials that industries can discharge into a sewerage system. Moreover, educational efforts such as Earth Day have increased public awareness of the problem.

Helping Business Achieve Compliance

Emtex Inc., located in Chelsea, dyes and laminates fabric for footwear.

Until recently, Emtex had recurring violations for pH, copper, zinc, mercury, and silver in its wastewater discharges. To comply with MWRA regulations, Emtex cooperated with the Toxic Reduction and Control Department to (i) review possible source reduction options, (ii) modify those processes that were contributing to its non-compliance, and (iii) focus particular attention on the dye house operation, which had a history of heavy metal discharges.

In October 1992, Emtex and MWRA signed a Consent Agreement whereby Emtex would undertake source reduction and pretreatment activities to assure compliance with MWRA regulations. Soon after this, the company stopped its industrial process discharges except those from its dye house. It also agreed to comply with a series of sampling and reporting deadlines, in an effort to isolate the problem.

The subsequent sampling and analysis identified that one of the company's imported fabrics contained zinc. The copper was traced to an additive in the dyes. Emtex has stopped processing the problem fabric and discontinued its use of the additive. Furthermore, it now tests all fabric shipments for zinc, copper, lead, and chromium before processing begins. The company has also installed a pH neutralization system at its final discharge point.

Since implementing the above recommendations, Emtex has been in compliance with MWRA regulations.

EFFECTS ON HARBOR WATER QUALITY TO DATE

3

MWRA monitors pollutants in Boston Harbor.

MWRA conducts scientific studies designed to characterize pollutants entering the Harbor, identify their consequent effects on environmental quality, and study their movement. These studies are often carried out in partnership with universities, private research laboratories, environmental agencies, and other government agencies.

The results of these studies are used to monitor compliance with discharge permits and to assess current environmental conditions in the Harbor. They are also used to track changes in conditions as improvements are made to the sewerage system.

Boston Harbor Monitoring Projects

1. **Pollutant characterization:**

-studies of sources of pollutants into the Harbor, including sources other than sewage

-monthly measurements of toxic contaminants in MWRA discharges to assess the effectiveness of pollution prevention and treatment programs

2. **Pollutant effects:**

-extensive monitoring of the concentrations of sewage-related bacteria, which are used to assess both water and sediment quality and potential health hazards

-studies of the distribution of sea floor animals as an indication of the extent and severity of pollution in the Harbor

-studies of the health of the winter flounder in Boston Harbor, because abnormalities in these fish can be strongly linked with a degraded environment

-studies of the amount of toxic contaminants accumulated in mussels near treatment plant discharges

-studies of the concentration of nutrients released from sediments as well as oxygen consumption by bottom-dwelling organisms

3. **Pollutant movement:**

-tracking of discharge plumes from sewage treatment plants and com bined sewer overflows

-studies on the fate of contaminated sediments in the Harbor

-modeling studies to predict water circulation and pollutant transport within the Harbor and near-shore waters

A. Effluent Quality

Discharge monitoring reveals that effluent quality is better.

Treatment plants are expected to meet discharge standards that limit the concentrations of pollutants that can be released in the effluent. In the case of MWRA discharges, interim standards were set with the understanding that the region's outdated system is in the process of being comprehensively upgraded. These interim limits are therefore not as stringent as those that will be required of the new plant.

Each month, the number of violations of the standards must be reported to the court. As Table 3-1 shows, the Deer and Nut Island plants violated standards on only a few occasions in Fiscal Year 1992.

Violations of interim discharge limits.

Deer Island

Fiscal Year	BOD	TSS	Coliform	pH
87	31	2	2	0
88	32	10	11	0
89	32	5	8	1
90	14	2	1	0
91	17	1	0	3
92	7	0	0	0

Nut Island

Fiscal Year	BOD	TSS	Coliform	pH
87	0	0	0	1
88	0	0	0	0
89	1	0	0	0
90	2	0	1	0
91	0	0	2	2
92	0	0	0	0

Table 3-1

Additional monthly monitoring of the effluent involves "priority pollutants," a group of 125 metals and organic pollutants designated of prime concern by EPA. As Fig. 3-1 shows, there has been a decrease in the amount of priority pollutants released from the plants.

There has been a decrease in the amount of priority pollutants released from the treatment plants.

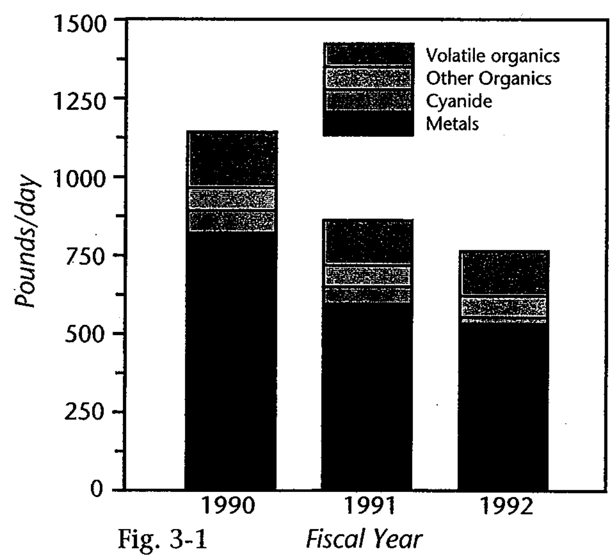


Fig. 3-1

The combined loadings of volatile organic compounds, other organic compounds, cyanide and metals were calculated from monthly concentrations and flows measured at the Deer Island and Nut Island plants.

The MWRA also runs monthly analyses of the toxicity of treatment plant effluent. These test the survival of several species of marine organisms exposed to varying concentrations of effluent. Very high mortality rates occurred in these tests during Fiscal Year 1992. Subsequent investigations by the EPA concluded that the mortality was probably caused by the presence of both surfactants (e.g. laundry detergents and soaps) and chlorine in the waste stream. The new treatment plant should greatly reduce these problems, since surfactants will be biodegraded by secondary treatment and chlorine will be removed from new plant effluent before it is discharged.

B. Harbor Water Quality

Harbor water quality is better.

People who spend time on and in the Harbor say that the water is cleaner than it used to be. This is probably based on the perception that floatable trash and grease slicks are no longer common eyesores: sludge abatement and the new scum removal system have had a major impact. Local swimmers participating in a September 1992 race at Carson Beach, sponsored by Save the Harbor/Save the Bay, spoke of the improved color and feel of the water. Regular boaters also comment on the improved visibility in the water.

Several lines of scientifically verifiable evidence also suggest that the decreased loading of toxic contaminants from the treatment plants is improving the environmental quality of the Harbor. The concentrations of several priority pollutants measured in water near the current Deer Island effluent discharges do not violate EPA water quality criteria (see Table 3-2).

Priority pollutant concentrations near Deer Island outfall.

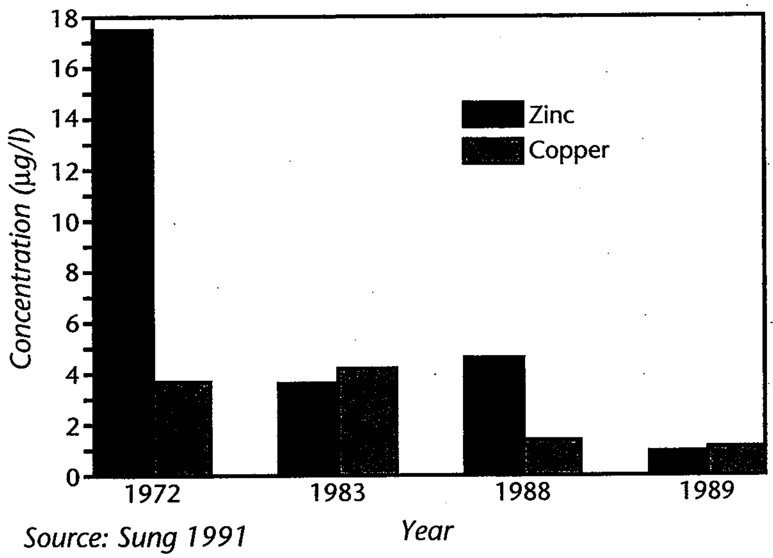
Contaminant	Observed concentration near D.I.[a] (ppt)	EPA marine acute criteria[b] (ppt)	EPA marine chronic criteria[b] (ppt)	Coastal water (ppt)
Arsenic	498	n.s.	n.s.	1500
Copper	1567	2900	n.s.	130
Mercury	5	2100	25	1
Heptachlor	0.089	53	3.6	0.01
Aldrin	0.05	1.3	n.s.	0.01
Dieldrin	0.62	710	1.9	0.01
DDT	0.064	130	1.0	0.01
PCBs	7	10000	30	1

Table 3-2

ppt - parts per trillion
n.s. - no standard
[a] Observed concentrations at two stations located near Deer Island.
Source: MWRA 1988, Secondary Treatment Facilities Plan, Appendix X.
[b] Source: EPA Quality Criteria for Water, EPA 1992.
[c] Data from typical coastal Atlantic waters. Source: Furness and Rainbow 1990.

The most complete water quality data sets for Harbor metal concentrations are measurements of zinc and copper (see Fig. 3-2). These show improvement in water quality since the early 1980s. The decrease in copper and zinc concentrations in the water correlates specifically with the decrease in effluent metal loadings into the Harbor, suggesting that the improvement in water quality is associated with the decrease in effluent loadings.

Zinc and copper concentrations in the Harbor have declined.



Source: Sung 1991

Fig. 3-2

The concentrations of zinc and copper measured in water samples taken in the inner and northwest portions of the Harbor. Concentrations reported here are averaged based on the volumes of the inner and northwest portions of the Harbor.

C. Sediment Quality

Concentrations of contaminants in sediments have decreased.

Water in Boston Harbor should recover from the effects of pollution much faster than bottom sediments. This is because water in the Harbor is flushed regularly by the tides and is therefore renewed over a period of days to weeks. In contrast, sediments remain in place, so natural cleansing processes take years to decades. In fact, once a contaminant is no longer entering the water, the sediments can themselves become a source of toxic materials as the contaminants leach out into the overlying water. Researchers at the Massachusetts Institute of Technology, Woods Hole Oceanographic Institution, and University of Massachusetts/Boston have shown that organic contaminants such as petroleum hydrocarbons are already being released from the sediments into the water. The rate of this release is still under investigation, but it will probably be slow enough to pose no threat to water quality while gradually decreasing the levels of contaminants in the sediments.

D. Marine Life

Toxic contaminants measured in fish and shellfish have also decreased.

Since they process large volumes of water through their feeding structures, filter-feeding animals like mussels often concentrate toxic metal and organic compounds in their tissues in a process called bioaccumulation. Because mussels stay attached in one place, they are useful for comparing conditions in different areas. How much of a toxic contaminant accumulates in the tissues of a mussel indicates the relative level of the contaminant in that particular area of the water.

Since 1987, the MWRA has measured the accumulation of contaminants in mussels placed in various regions of the Harbor. Mussels set out near Deer Island in 1991 and 1992 had lower levels of most organic compounds than those tested in 1987 (see Fig. 3-3). For example, there was a marked decrease in low molecular weight PAHs over time. Low molecular weight PAHs are organic chemicals predominantly found in petroleum-based products.

There has been a decrease in the concentration of organic contaminants measured in mussels at Deer Island.

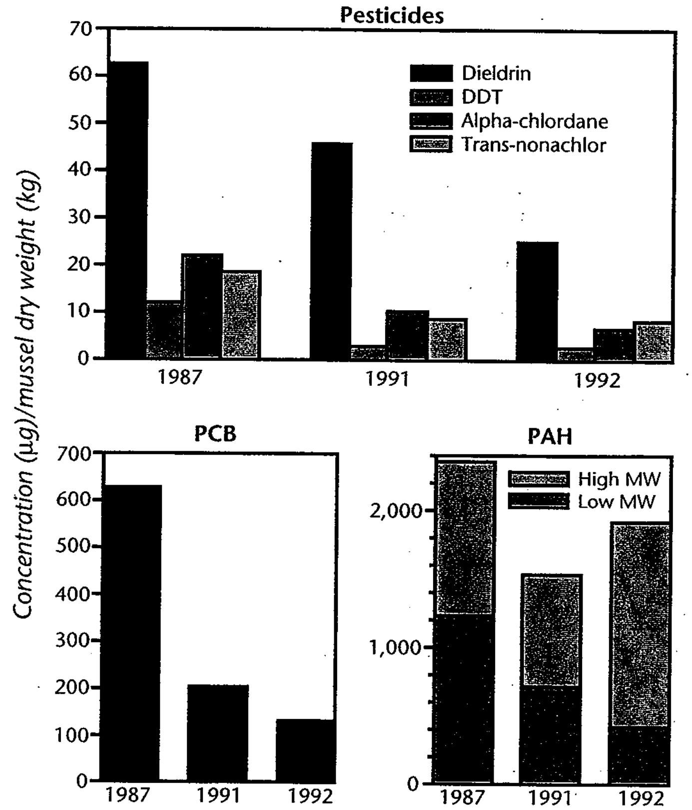


Fig. 3-3

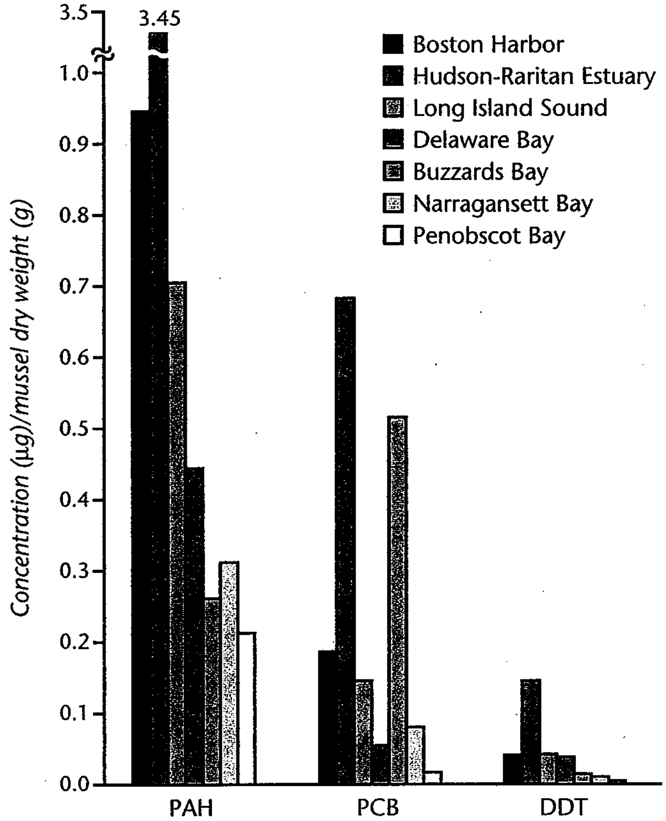
Concentrations of pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) measured in mussels set out at Deer Island in 1987 (for 30 days) and in 1991 and 1992 (for 60 days). Only shallow water samples are included for 1991. In samples where an individual PAH was not detected, it was assumed present at the method detection limit.

The results of MWRA's bioaccumulation studies are supported by similar results reported by the National Oceanic and Atmospheric Administration (NOAA). In its Mussel Watch program, NOAA compiles data on concentrations of contaminants in mussels collected from different coastal locations throughout the Unites States. At Deer Island, one of Boston Harbor's mussel watch sites, there has been a statistically significant decrease in PAHs measured in mussels over the past six years. Low molecular weight PAHs have decreased by 30%, and total PAHs by 18%.

As shown in Fig. 3-4, mussels measured in Boston Harbor have levels of organic contaminants similar to those in other estuaries on the East Coast.

Because of their living and feeding habits, winter flounder are particularly susceptible to a contaminated environment. They live on the bottom of the Harbor, feeding on small animals found on or in the sediments. Flounder are therefore exposed to contaminants directly (from the environment) and indirectly (from their prey). They have been shown to undergo a progressive liver disease whose extent is closely correlated with levels of exposure to chemical contaminants. This species is therefore an important bellwether for the biological effects of coastal contaminants on bottom-feeding fish. For the past three years, the Authority has sponsored research at Woods Hole Oceanographic Institution into the prevalence of disease in winter flounder collected in Boston Harbor. Tumors in Harbor flounder appear to be less frequent now than they were in the early 1980s, as are other indicators of liver disease caused by pollution (see Fig. 3-5).

Organic contaminant concentrations are similar in mussels sampled in various urban harbors.

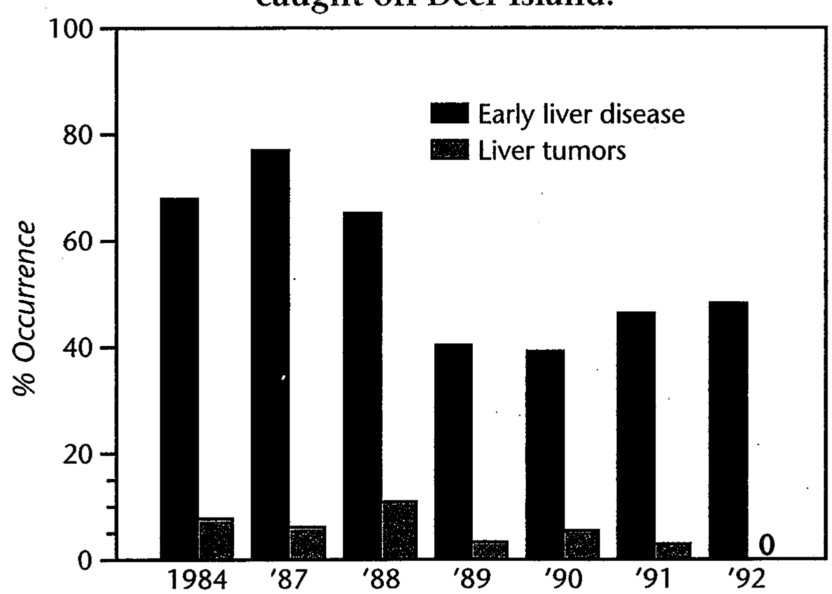


Source: NOAA Mussel Watch 1991

Fig. 3-4

Average concentration of PAHs, PCBs, and DDT and its breakdown products measured in mussels collected for Mussel Watch in 1991.

Liver diseases have declined since 1984 in winter flounder caught off Deer Island.



Source: Moore et al. 1993

Fig. 3-5

No tumors were detected in flounder collected at Deer Island Flats in 1992. However, these results must be interpreted with caution. The fish sampled in 1992 were younger than those sampled in previous years and a substantial percentage of them exhibited early liver disease. Young fish may well develop tumors as they age.

E. Remaining Problems

There is, however, a limit to the environmental benefits that can be achieved without new facilities that have both the capacity and technology to handle the region's sewage adequately. One way to look at this is through measurements of dissolved oxygen.

Nevertheless, water quality problems continue.

Marine organisms breathe oxygen that is dissolved in seawater. Depletion of dissolved oxygen in the water or in sediments can cause loss of habitat, or induce stress and the eventual death of marine organisms. Oxygen is also used during the decomposition of the organic material released into the water from sewage treatment plants. Dissolved oxygen problems are therefore aggravated by sewage discharges, particularly in shallow estuaries such as the Harbor.

Since oxygen plays a role in so many biological processes, it can be used as an integrated measure of the health of a water body.

MWRA routinely measures dissolved oxygen in the Harbor. Beginning in late summer 1991, the program was expanded to include measurements made at dawn, when oxygen levels are expected to be lowest. This is because aquatic plants produce oxygen in daylight (photosynthesis), and consume it at night (respiration), so dissolved oxygen levels are lowest after a whole night of oxygen consumption with no production. Measurements made at mid-day therefore tend to be higher than those made at dawn, and may underestimate the extent of dissolved oxygen problems. Similarly, dissolved oxygen tends to be lower near the bottom of the water column than near the surface, both because sea-floor organisms use oxygen from the water and because the bottom of the water column is some distance away from the atmospheric source of oxygen.

As Table 3-3 shows, DO measurements less than the State Class SB standard (5 mg/l) were most frequent in bottom samples taken at dawn.

Dissolved oxygen measurements in the Inner Harbor.

Percent of D.O. measurements below standard	Dawn	Mid-Day
Surface	16.3	4.8
Bottom	22.4	12.4

Table 3-3

Samples from the summers of 1991 and 1992.

Surveys in all parts of the Harbor show that dissolved oxygen averaged about 1 milligram per liter lower during the early morning hours than during mid-day. This result suggests that most surveys carried out in the past have substantially underestimated the severity of dissolved oxygen problems in Boston Harbor.

Secondary treatment will remove substantially more oxygen-consuming materials from the sewage than the present level of treatment. A really dramatic improvement, however, cannot be expected until the discharge is moved offshore where it can receive sufficient dilution.

4

In Boston Harbor, both secondary treatment and an outfall are required to meet discharge standards.

CONTINUING SYSTEM IMPROVEMENTS

In order to meet the requirements of the Clean Water Act, the MWRA is building a secondary treatment plant on Deer Island. However, the Harbor will not dilute even secondary effluent to the point where state and federal water quality standards are met. The outfall therefore has to be relocated from its present position at the mouth of Boston Harbor to deeper water where more seawater will be available to dilute it.

A. The new Secondary Treatment Plant

Construction of the new Deer Island treatment facilities (including the outfall tunnel) will cost approximately $3.5 billion. The new facilities will replace the old Deer Island and Nut Island plants. Some elements of the old Deer Island plant will be incorporated into the new plant, while others will be torn down; the Nut Island plant will be replaced by a headworks to screen sewage flow from the southern part of the system. This flow will then be transported 5 miles across the Harbor to Deer Island via an 11-foot diameter tunnel now being constructed beneath the Harbor floor.

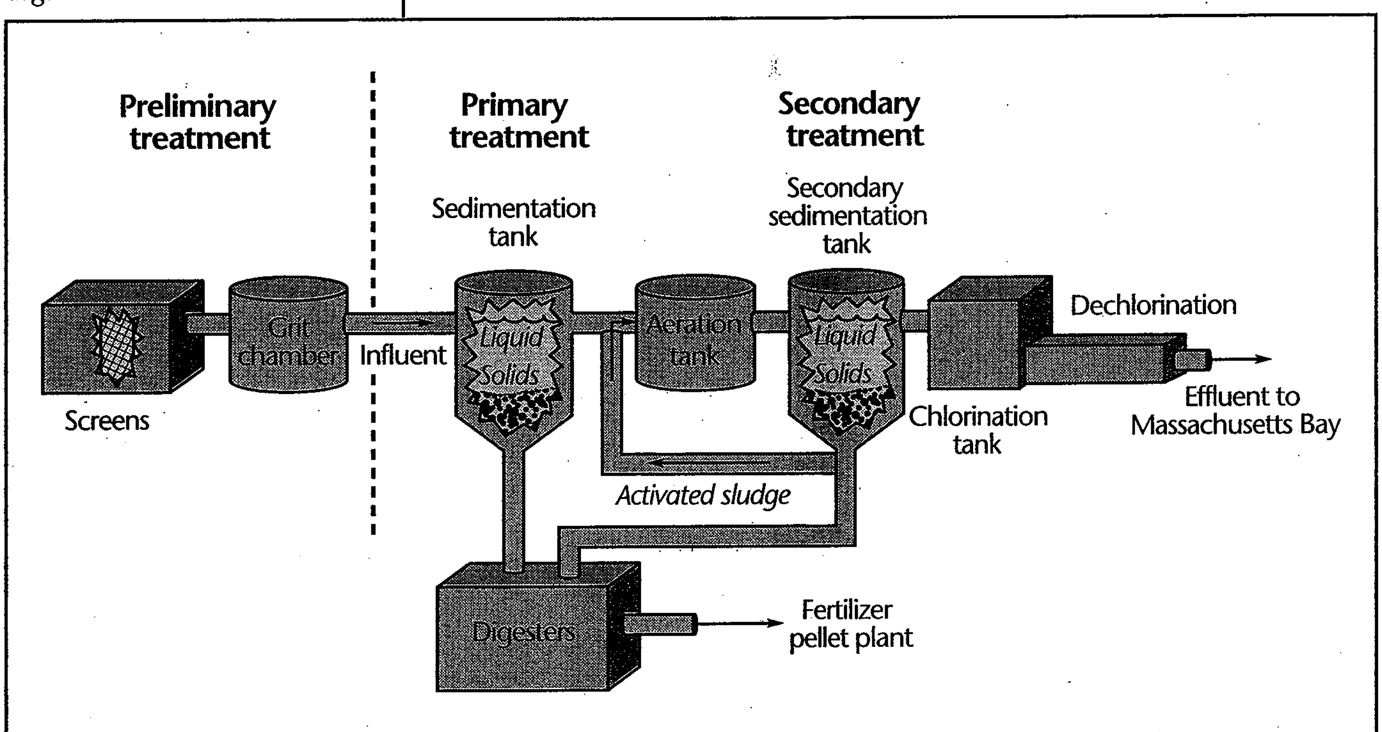
The new plant will be large and technologically sophisticated.

The centerpiece of the system, the new Deer Island plant will be the second largest in the nation and have sufficient capacity to handle the region's sewage flow for the foreseeable future. It will have a capacity of 1,270 mgd for primary treatment and 1,080 mgd for secondary. The current daily average flow reaching the Deer and Nut Island plants combined is approximately 400 mgd, though flow can exceed 700 mgd during wet weather.

The new plant will also provide more sophisticated treatment. Primary treatment relies mainly on physical processes such as screening and sedimentation (the process by which heavier particles settle to the bottom of a column of water) to remove solids. The effluent is then disinfected with chlorine to kill disease-causing pathogens before being discharged into a body of receiving water.

Fig.4-1

Secondary Wastewater Treatment



Secondary treatment at the new plant will use biological processes to increase the amount of solids removed from wastewater (see Fig. 4-1). After primary treatment, the wastewater will be oxygenated in the aeration tank to promote the growth of naturally occurring microorganisms that consume organic material. The wastewater will then flow into secondary sedimentation tanks where the solids settle. Some of this secondary sludge will be returned to the aeration tank to maintain the level of bacterial activity and thereby optimize the consumption of organic matter. The remainder will be added to the primary sludge before being further broken down in digesters. The treated sludge will be shipped off-island and turned into fertilizer pellets. Following treatment, the remaining effluent will first be disinfected with chlorine and then dechlorinated before being discharged into the ocean.

More solids and BOD are removed by secondary treatment than by primary treatment (see Table 4-1). The improved solid removal will also serve to slightly decrease the amount of nitrogen in the effluent, as some nitrogen is removed as solids.

Percent removal from primary and secondary treatment.

Type of Material	Primary	Secondary
Solids	60	85
Toxic Contaminants[a]	10-46	32-95
BOD	35	85
Nitrogen	5	10-15

Table 4-1

[a] Varies with contaminant.
Data from MWRA 1988, Secondary Treatment Facilities Plan, Appendix A.

Effluent quality will improve dramatically when two batteries of secondary treatment are on-line (see Fig. 4-2).

Anticipated pollutants loadings as different stages of the project are completed.

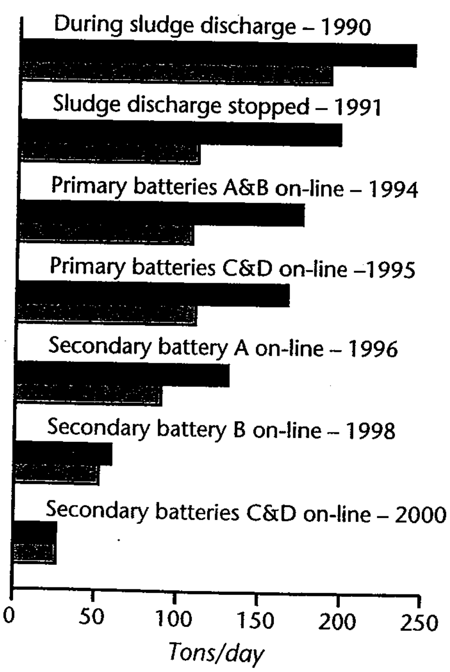


Fig. 4-2

Data from combined Deer and Nut Island effluent and sludge loadings were used for 1990; combined effluent data were used for 1992; future loadings are based on projections by Metcalf and Eddy, Inc.

Secondary Treatment at Clinton

Located 50 miles west of Boston, the MWRA's secondary treatment plant in Clinton—which serves the communities of Clinton and Lancaster—is quite separate from the rest of the Authority's sewerage operation and has no direct connection to the water quality in Boston Harbor. Moreover, with an average daily flow of 3 mgd, the plant is clearly on a much smaller scale than its counterparts on Deer Island and Nut Island. Clinton's secondary treatment, however, provides excellent evidence of what can be expected from the new Deer Island plant once it moves to full secondary treatment in 1999.

The effluent from the Clinton plant is discharged into the South Branch of the Nashua River, a small body of water that could easily suffer intense degradation from sewage contaminants. Since the completion of a recent upgrade in June 1992, the plant provides treatment that meets discharge limits on all criteria (see Table 4-2). At points close to the outfall, the river water is now cleaner than it is several miles upstream.

Effectiveness of Clinton plant's secondary treatment

Characteristic	Effluent before upgrade[a]	Interim limit	Effluent after upgrade[b]	NPDES limit[c]
Biological oxygen demand (mg/l)	52	50	4.8	20
Suspended solids (mg/l)	28	35	5.9	20
Settleable solids (ml/l)	0.1	0.1	0	0.1
Fecal coliform (#/100 ml)	270	200	10	200
Residual chlorine (mg/l)	1.1	0.2-1.5	0	0.03

Table 4-2

[a] Average concentration, June - December 1990
[b] Average concentration, June - December 1992
[c] National Pollution Discharge Elimination System

The large reduction in the fecal coliform count is due to improvements in the plant's chlorination system. More relevant for analysis of what can be expected from the introduction of secondary treatment at the new Deer Island plant are the results for biological oxygen demand removal. Primary treatment will never have this sort of dramatic impact on oxygen-consuming material.

Construction of the new plant follows the schedule laid out by the federal court (see Fig. 4-3).

The new Deer Island plant is being built in accordance with the court schedule.

Court Schedule

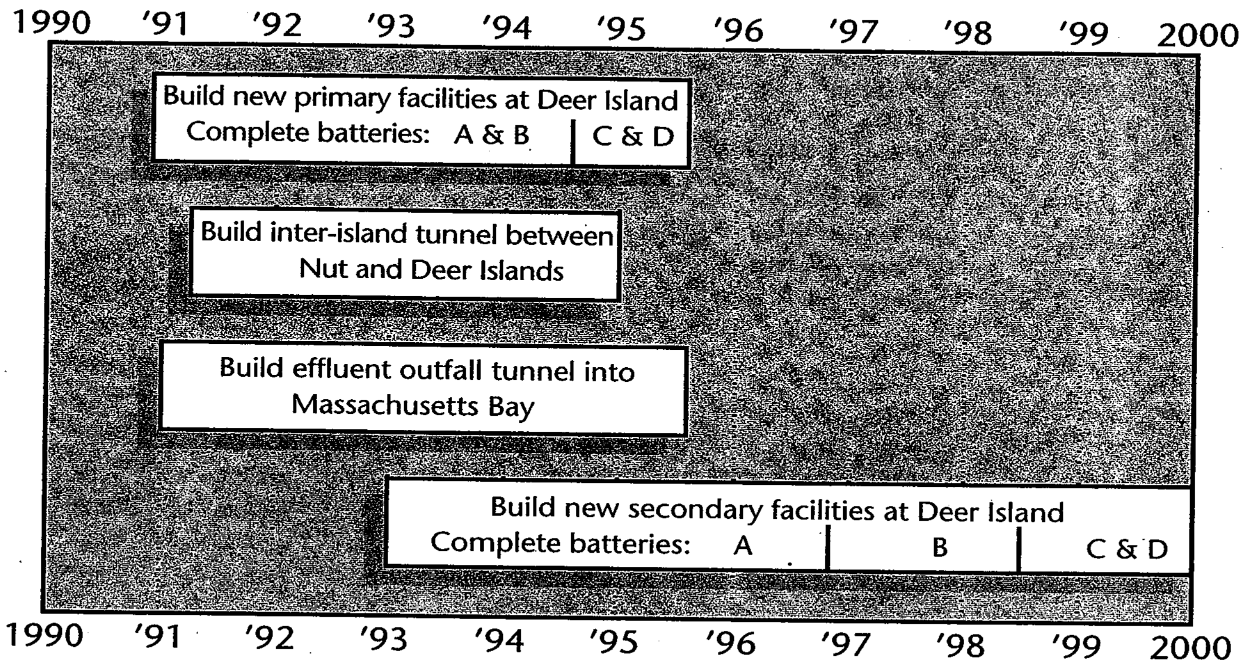
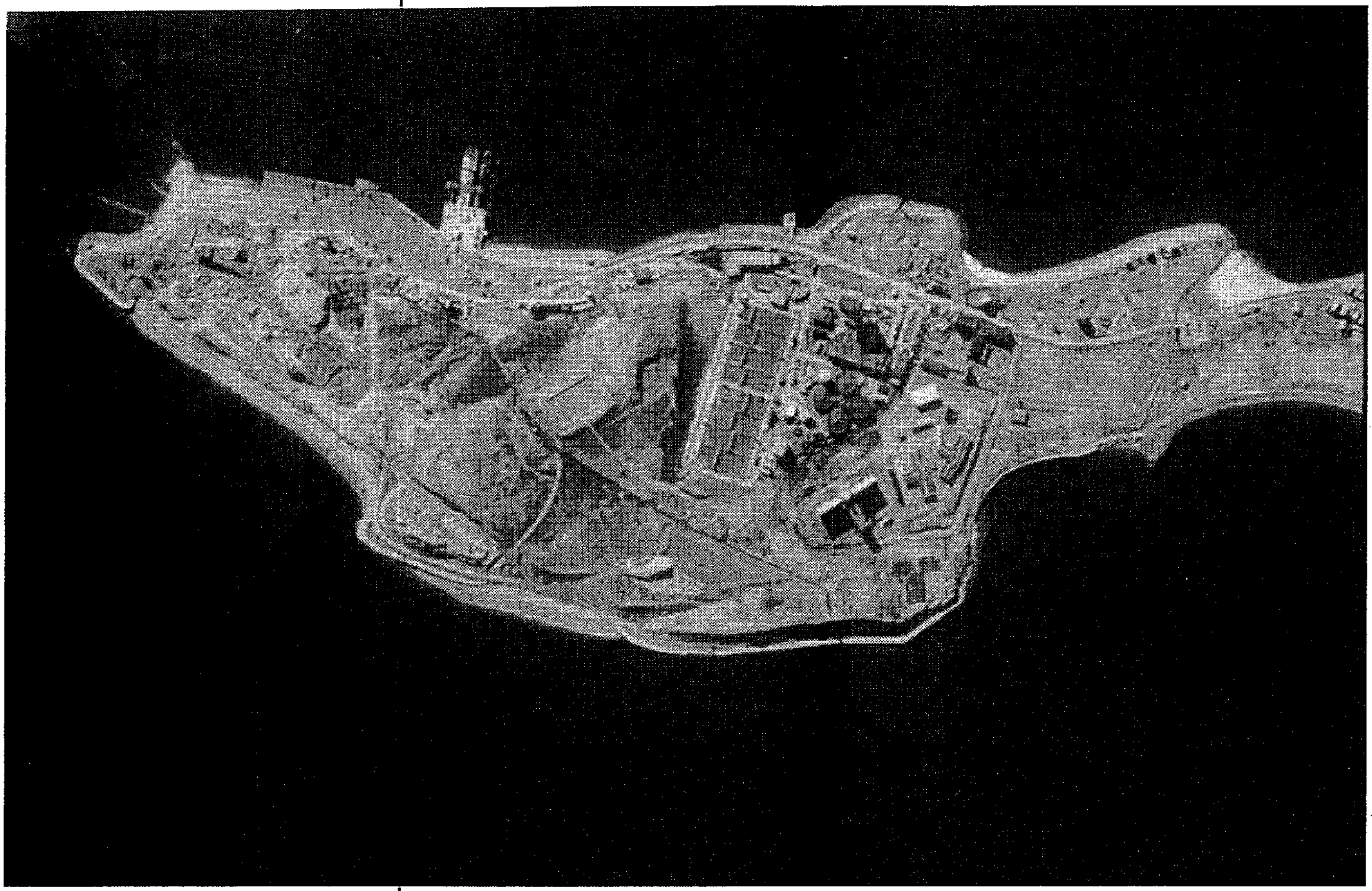


Fig. 4-3

Deer Island, 1990 and 1992



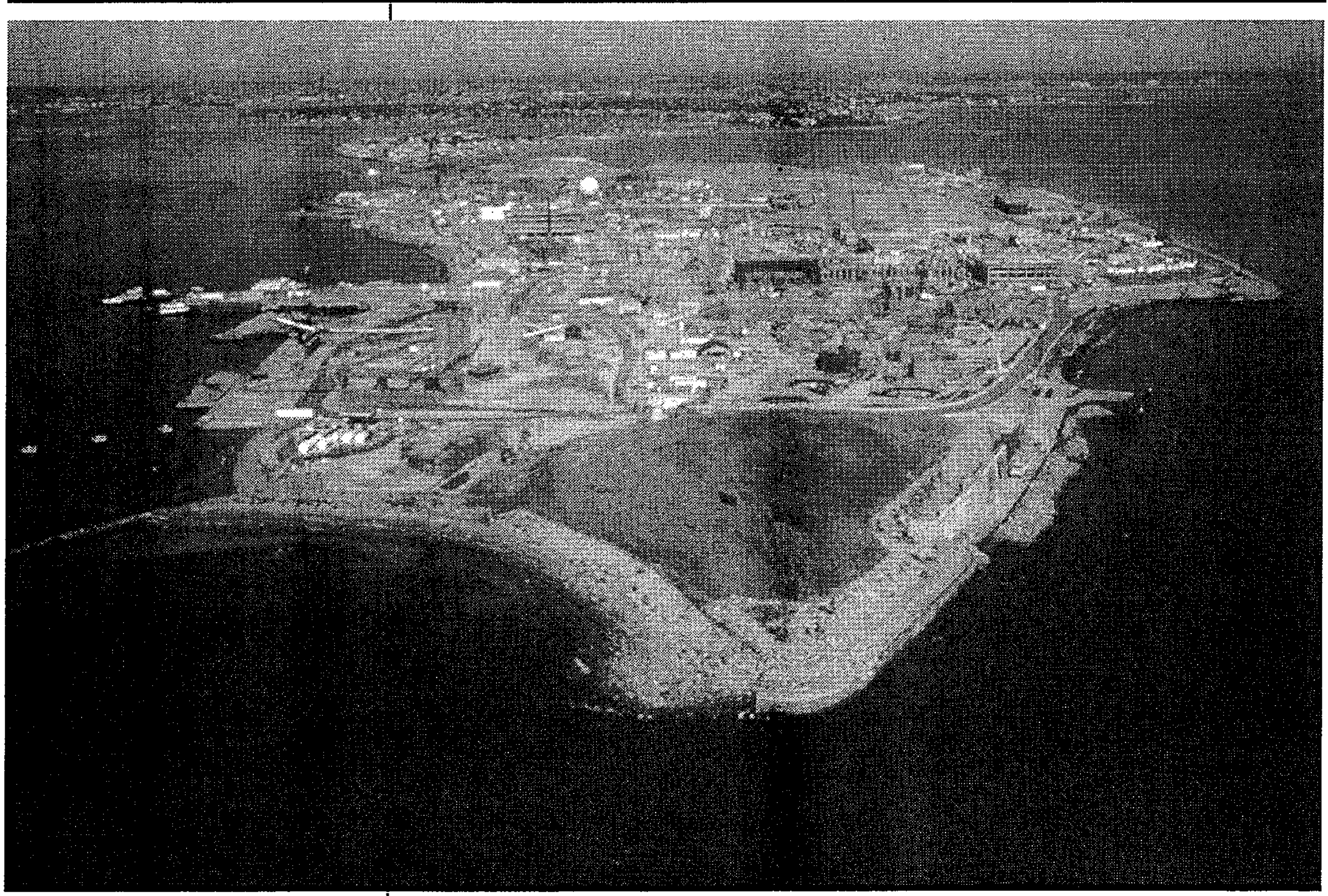


Fig. 4-4

Top photo taken January 1990. Bottom photo taken October 1992.

B. The new Outfall Tunnel

The new outfall tunnel will cost approximately $380 million and be the largest of its kind ever built. As shown in Fig. 4-5, the tunnel begins with a 30-foot diameter vertical access shaft at Deer Island. This shaft extends 420 feet below sea level. The effluent will flow down this shaft and then enter the 24-foot diameter tunnel, which runs under the ocean floor 9.5 miles out into Massachusetts Bay. Along the last 1.25 miles, effluent will travel up through 55 vertical riser pipes, bored 240 feet down through the ocean floor and connected to the tunnel. The risers will disperse the effluent into the ocean, which in this area is over 100 feet deep.

The new outfall tunnel will discharge cleaner effluent into deeper waters.

Extensive exploratory borings were taken to gather information about the type of rock and soil along the proposed route. The excavation is being done by a 3,000-hp tunnel boring machine (TBM) made by the same company that is supplying the boring machines for the "Chunnel" currently being constructed between England and France beneath the English Channel. Over 26 feet wide and 40 feet long, the TBM weighs about 600 tons.

The TBM was fully assembled and tested at the manufacturer's Wisconsin plant, and then disassembled and shipped to Boston through the Great Lakes to the Erie Canal, down the Hudson River and up the coast to Boston. Once at Deer Island, the machine was lowered down the access shaft in sections and reassembled at the rock face.

The new outfall tunnel discharges into the deeper waters of Massachusetts Bay.

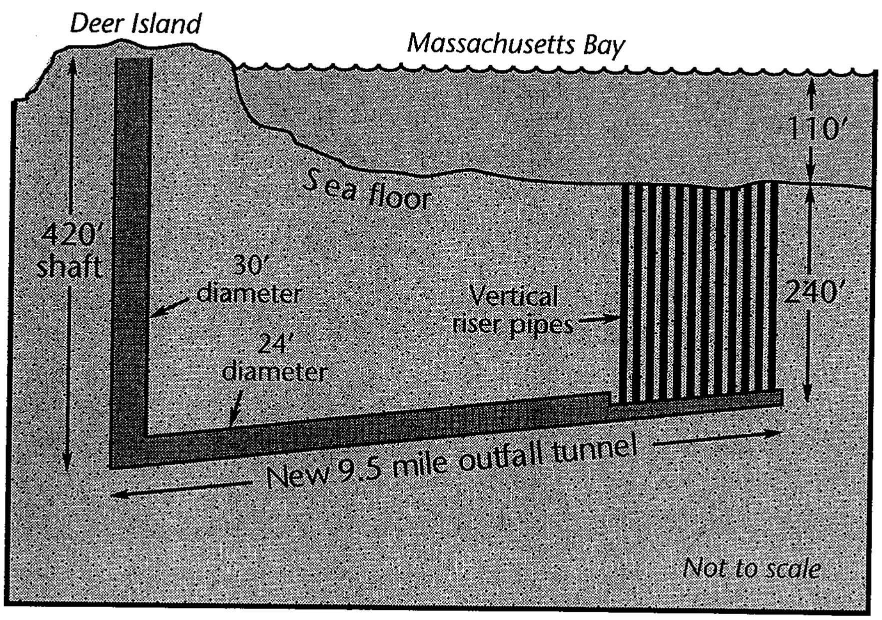


Fig.4-5

C. Siting the new Outfall

Effluent from Deer Island is currently discharged within Boston Harbor, at a site approximately half a mile offshore, where the water is 30 feet deep. In contrast, the new effluent outfall will be 9.5 miles offshore, at a point where Massachusetts Bay is 100 feet deep. As part of the new outfall siting process, existing data on the oceanographic conditions of Massachusetts Bay were compiled, field studies were conducted to collect new data, and computer models were used to predict pollutant concentrations in Massachusetts Bay from different outfall sites. Chosen out of seven candidate sites, the new outfall is located where it will provide sufficient dilution of the effluent to protect public health and aquatic life. It is also far enough from shore to keep effluent away from beaches and shellfish beds.

The new outfall was sited on the basis of environmental and engineering criteria.

The computer model used in the outfall siting process predicted that Boston Harbor and nearby shorelines to the north and south are more affected by the present discharge than they will be by the new outfall. The modeling effort is ongoing: the U.S. Geological Survey (USGS) and HydroQual Inc. are working on a more sophisticated model of water motion in Boston Harbor, Massachusetts and Cape Cod Bays. So far, predictions from the new model confirm those made earlier, and suggest that more of the shoreline is impacted by the present near-shore outfall than will be by the future off-shore outfall.

As Fig. 4-6 shows, when effluent is released from the new outfall rather than at the existing outfall site, (1) the area of concentrated wastewater is only 0.5 square miles versus 77 square miles, (2) the predicted concentrations of effluent in Boston Harbor and along the north and south shores are considerably lower, and (3) the predicted concentration of wastewater in most of Massachusetts Bay and Cape Cod Bay does not change.

Predicted dilution of effluent.

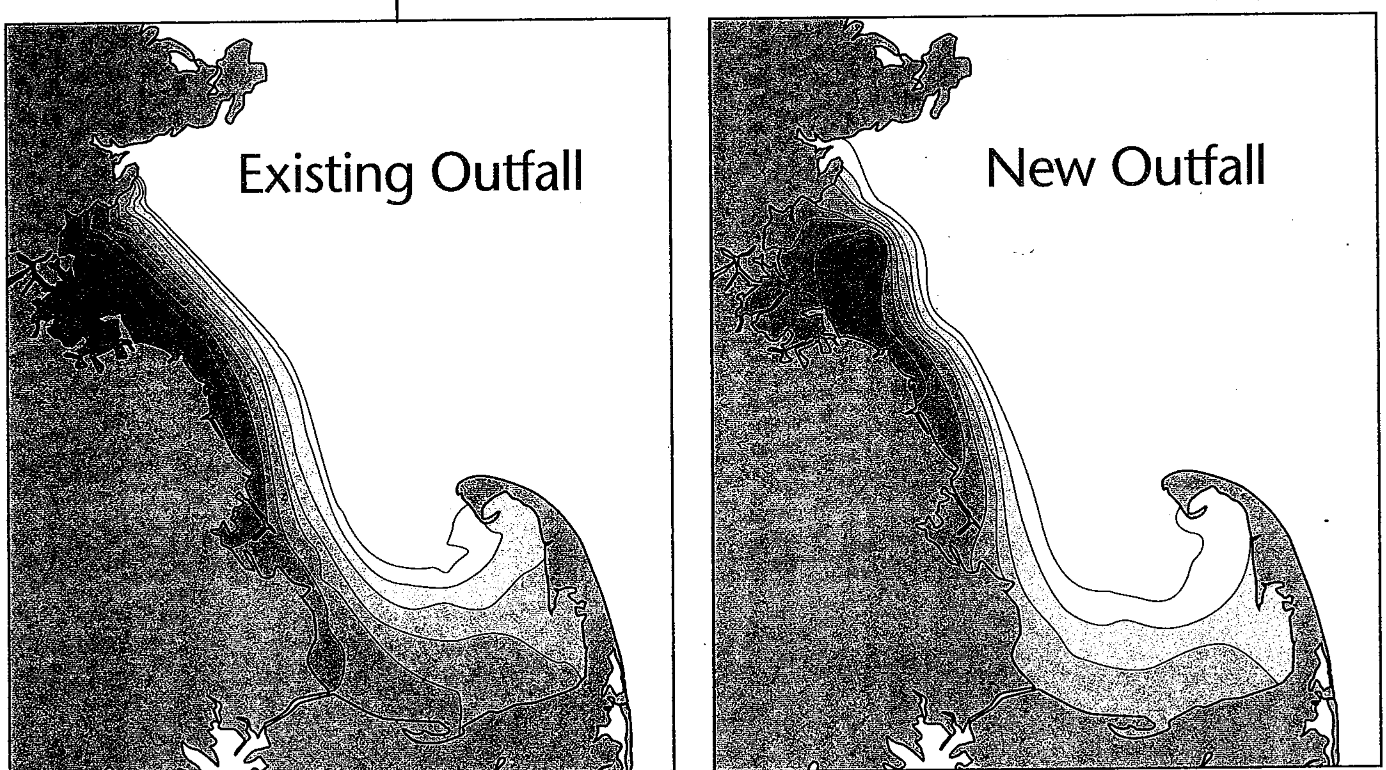
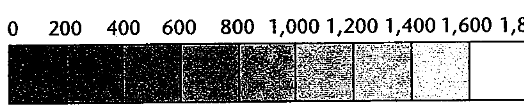


Fig. 4-6



The USGS model was used to simulate winter conditions in Massachusetts Bay. This shows the predicted dilution of current effluent loads released from either the existing or the new outfall site.

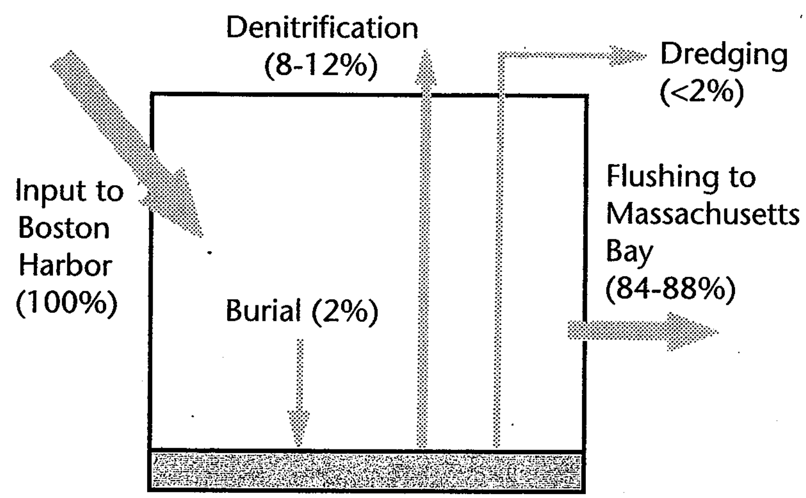
Outfall Siting and Massachusetts Bay

It is important to realize that most of the material released in the effluent stream is already transported out into Massachusetts Bay. This is because Boston Harbor is effectively flushed by the tides. However, since Boston Harbor is much smaller than Massachusetts Bay and dilution is therefore much less, contaminants are more concentrated in the Harbor than in the Bay.

Only about one third of the particles currently released by the treatment plants actually settle in the Harbor. For example, sewage-associated bacterial spores have been found distributed in the sediments of Massachusetts and Cape Cod Bays, indicating that a considerable amount of material currently leaves the Harbor.

The quick flushing of the Harbor can also be seen by the movement of nitrogen out of the Harbor into Massachusetts Bay. More than 85% of the nitrogen that now enters the Harbor is flushed out into Massachusetts and Cape Cod Bays (see Fig. 4-7). This means that changing the point of effluent release to the new outfall site will not have a significant effect on the concentration of nitrogen in the Bays.

Most of the nitrogen that enters the Harbor is flushed out.



Source: Kelly and Nowicki 1992

Fig.4-7
Several studies conducted by researchers from Battelle Ocean Sciences, the University of Rhode Island, and the Marine Biological Laboratory have shown that approximately 10% of the nitrogen input is released as nitrogen gas into the atmosphere through a microbial process called denitrification. However, the bulk of the nitrogen is exported to Massachusetts Bay.

A comprehensive outfall monitoring project ensures early response to changes in marine conditions.

D. Outfall Monitoring

The MWRA monitoring program is designed to detect and evaluate the environmental effects of the new effluent outfall. The program serves to check that the new outfall's benefits are as great or greater than those predicted in outfall siting studies. A feature is considered appropriate for tracking if it is an important technical or public concern or is specifically covered by government regulations. The monitoring strategy provides for the detection of meaningful changes in biological, chemical, and physical measurements at levels far below, and thus in advance of, those that could be of great concern.

The monitoring program began in February 1992 with studies designed to measure environmental conditions during the three years before the new outfall begins discharging effluent into Massachusetts Bay. The information collected during pre-discharge monitoring will serve as the point of comparison for determining whether any changes occur once discharge begins.

Measurements are concentrated in the area immediately around the diffusers, where changes are predicted to be most likely. Sampling is not limited, however, to the immediate area: measurements extend into distant areas of Massachusetts and Cape Cod Bays. The further away from the outfall, the less likely changes will occur, both because the effluent becomes progressively more diluted and because solid-associated contaminants either break down or settle out.

To ensure a scientifically valid and environmentally sound foundation for the monitoring program, the MWRA Outfall Monitoring Task Force consists of scientists, staff of State and Federal agencies, and representatives of universities and environmental interest groups (see Table 4-3).

Organizations involved in the Outfall Monitoring Task Force

Association for the Preservation of Cape Cod
Cape Cod Commission
Center for Coastal Studies
Environmental Protection Agency
Harvard University
Massachusetts Audubon Society
Massachusetts Bays Program
Massachusetts Coastal Zone Management
Massachusetts Department of Environmental Protection
Massachusetts Division of Marine Fisheries
Massachusetts Environmental Policy Act Office
Massachusetts Institute of Technology
National Marine Fisheries Service
Safer Water in Massachusetts
U.S. Army Corps of Engineers
U.S. Geological Survey
University of Massachusetts/Boston
Woods Hole Oceanographic Institution

Table 4-3

Scientific Studies in Massachusetts and Cape Cod Bays

Baseline monitoring

Water quality monitoring

- hydrographic conditions (e.g. temperature, salinity, dissolved oxygen, light)
- nutrient concentration (e.g. nitrogen, phosphorus, carbon)

Sediment monitoring

- benthic organisms
- sediment conditions

Marine life

- plankton populations and growth
- fish pathology
- lobster surveys
- mussel bioaccumulation

Special studies

- modeling
- nutrient exchange with the water column
- red tide causative factors
- Cape Cod Bay phytoplankton
- seawater mixing
- sediment transport

Scientists retrieve water samples during an outfall monitoring survey.

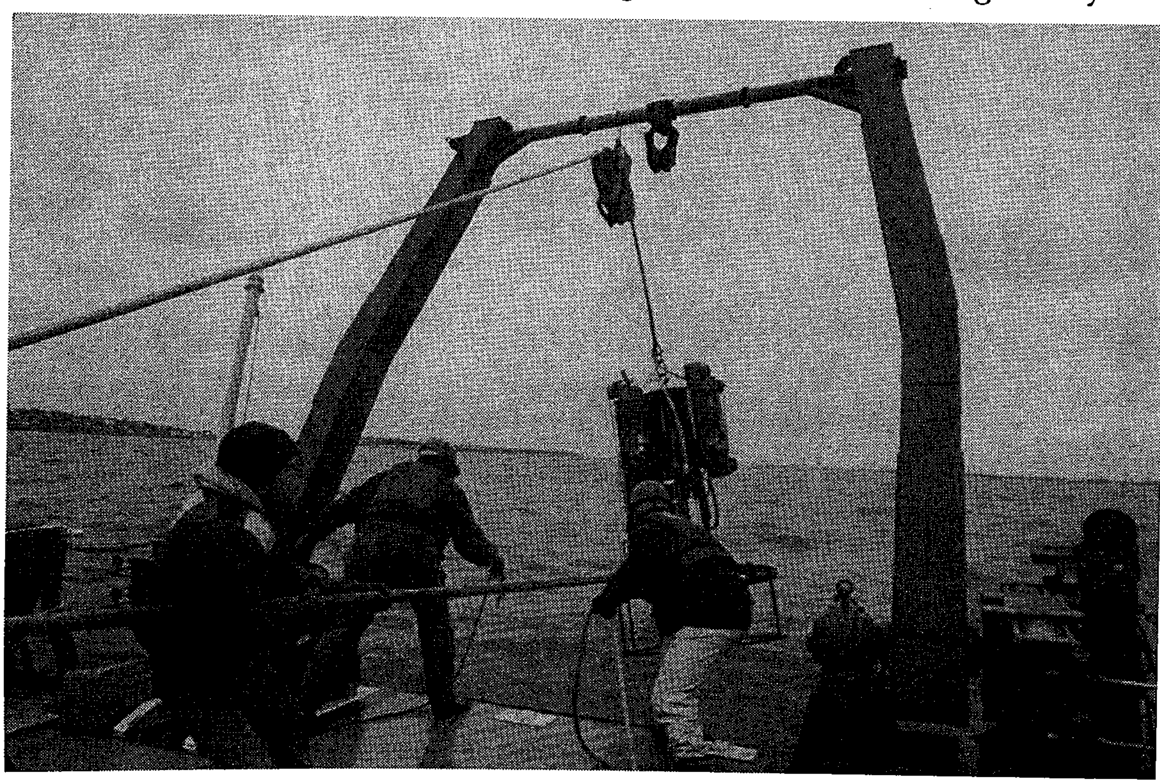


Photo by: John Ryther/Battelle

Fig. 4-8

Long-term management of coastal resources is a complex task including much more than the regulation of discharges from a single sewage treatment plant. The real challenge is to manage all discharges into the offshore ecosystem and control the harmful effects of all human activities around Massachusetts and Cape Cod Bays. Information from the monitoring program will be used in conjunction with the Massachusetts Bays Program to help regulatory agencies serve the broader goal of the long-term protection of the marine environment.

The overall goal must be comprehensive protection of the marine environment.

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