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The Boston Harbor Cleanup

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Boston Harbor earned a widespread reputation as "the dirtiest harbor in the nation" during the 1988 presidential campaign. Well before that campaign began, though, efforts were under way to reduce the amount of pollution entering the harbor. The Massachusetts Water Resources Authority was created in 1985 to undertake a massive public works program — including construction of a 1.3 billion-gallon-per-day sewage treatment plant and a sludge fertilizer processing plant — to end the decades-old practice of dumping sewage wastes into the ocean. The program will also cause water and sewer charges to rise dramatically during a fifteen-year period.

The project has raised a host of environmental and public policy issues: How should sludge by-products be disposed of or used by society? What is the proper placement of the effluent outfall for a sewage treatment plant of this magnitude discharging into Massachusetts Bay? What is the appropriate level of treatment to apply to wastewater? How can ratepayers be assured that their money is being spent on the highest environmental priorities?

This aricle represents the opinions and conclusions of the authors, not necessarily those of the MWRA.

Thanks to George Bush's 1988 presidential campaign advertisement, most people know Boston Harbor only as one of the dirtiest in the country. What the political ad failed to mention, however, are the remedial steps being taken to transform the harbor into a useful and attractive resource for the Boston metropolitan area. In this article, after explaining how the harbor became so polluted, we describe the current cleanup program, analyze some of the most important issues that must be resolved in the course of that program, and discuss the benefits of the different cleanup elements to the environmental health of Boston Harbor and Massachusetts Bay.

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History

Boston Harbor and the major rivers leading into it — the Charles, Mystic, and Neponset — have been used for the disposal of sewage wastes for hundreds of years. Looking back to the colonial era, the historian Eliot Clarke observed:

> The way in which sewers were built at this time was, apparently, this. When some energetic householder on any street decided that a sewer was needed there, he persuaded such of his neighbors as he could to join him in building a street drain. Having obtained permission to open the street or perhaps neglected this preliminary, they built such a structure as they thought necessary, on the shortest line to tide-water. . . .
>
> [By the 1820s] such changes have taken place in the contours of the city, through operations for reclaiming and filling tidal areas bordering the old limits, that, from being an easy site to sewer, Boston became one presenting many obstacles to the construction of an efficient sewer system. . . .
>
> As a consequence, the contents of the sewers were dammed back by the tide during the greater part of each twelve hours. To prevent the salt water flowing into them, many of them were provided with tide-gates, which closed as the sea rose, and excluded it. These tide-gates also shut in the sewage, which accumulated behind them along the whole length of the sewer, as in a cesspool; and, there being no current, deposits occurred. The sewers were, in general, inadequately ventilated, and the rise of sewage in them compressed the foul air which they contained and tended to force it into the house connections. . . .
>
> Although at about the time of low water the tide-gates opened and the sewage escaped, the latter almost immediately met the incoming tide, and was brought back by it, to form deposits upon the flats and shores about the city . . . Under certain conditions of the atmosphere, especially on summer evenings, a well-defined sewage odor would extend over the whole South and West Ends of the city proper.[1]

A great leap forward was made in the 1880s when construction of a massive collection and transport system began. Its purpose was simple: to take wastewater away from Boston and the communities along the Charles and Mystic rivers out to where it would do no immediate harm, to Boston Harbor. From the time of its completion in 1904 until after World War II, the metropolitan area's wastewater "treatment" system consisted of nothing more than this collection and transport system. Millions of gallons per day of untreated sewerage were dumped into the harbor.

The system was improved following that war. In 1952, a primary treatment plant was built on Nut Island in Quincy to handle wastewater flows from the southern portion of the metropolitan area. In 1968, another primary treatment plant was constructed on Deer Island, near Winthrop, to handle the northern system. The Nut Island and Deer Island treatment plants were designed to treat average daily flows of 112 million and 343 million gallons per day (mgd), respectively, and maximum peak flows of 280 mgd and 848 mgd.

Problems soon arose. The treatment plants at Nut and Deer islands were owned and operated by the Metropolitan District Commission (MDC), a state agency subject to the budgetary control of the state legislature. Also responsible for the metropolitan area parks, roadways, skating rinks, and swimming pools, the MDC was never able to attract sufficient legislative interest in its nonpark functions (that is, the sewer-works) to garner sufficient funds to maintain and upgrade the new sewage treatment plants. In short order the new plants became old plants subject to breakdowns, inadequate staffing, and poor performance. Plants that might have provided a reasonable level of treatment on their construction were soon inadequate to handle even the initial flows for which they were designed, much less the growth that occurred in the metropolitan area during the 1950s, 1960s, and 1970s. Furthermore, even when the plants worked, they never eliminated the discharge of sludge into the harbor. Upon its separation from the plant's influent, the sludge was simply held in storage tanks pending discharge on the outgoing tides.

The next major development was the passage of the federal Clean Water Act in 1972. The act prescribed the use of secondary treatment for metropolitan areas such as Boston, unless a waiver of that requirement was granted by the Environmental Protection Agency (EPA). The MDC applied for such a waiver, called a 301(h) waiver after the section of the act in which it is set forth, arguing that the benefits of secondary treatment were not worth its costs. Years of delay ensued, with inaction by the EPA on the waiver request, a resubmittal by the state with more information, more inaction by the EPA, and finally a denial of the waiver. In all, the waiver process lasted from 1977 to 1984.

Meanwhile, the lawsuits began. There is the legendary story of William Golden, the city solicitor for Quincy, who was jogging along Wollaston Beach through what he at first thought was seaweed and jellyfish. Golden was horrified to find, on closer examination, that the seaweed and jellyfish were actually untreated human feces. He convinced the mayor of Quincy to sue the commonwealth in 1982 for violations of state law with regard to wastewater discharges into Quincy Bay. In the interim, in 1983, the Conservation Law Foundation of New England started a federal court action against *both* the commonwealth and the EPA, the former for violating the Clean Water Act, the latter for not enforcing the act.

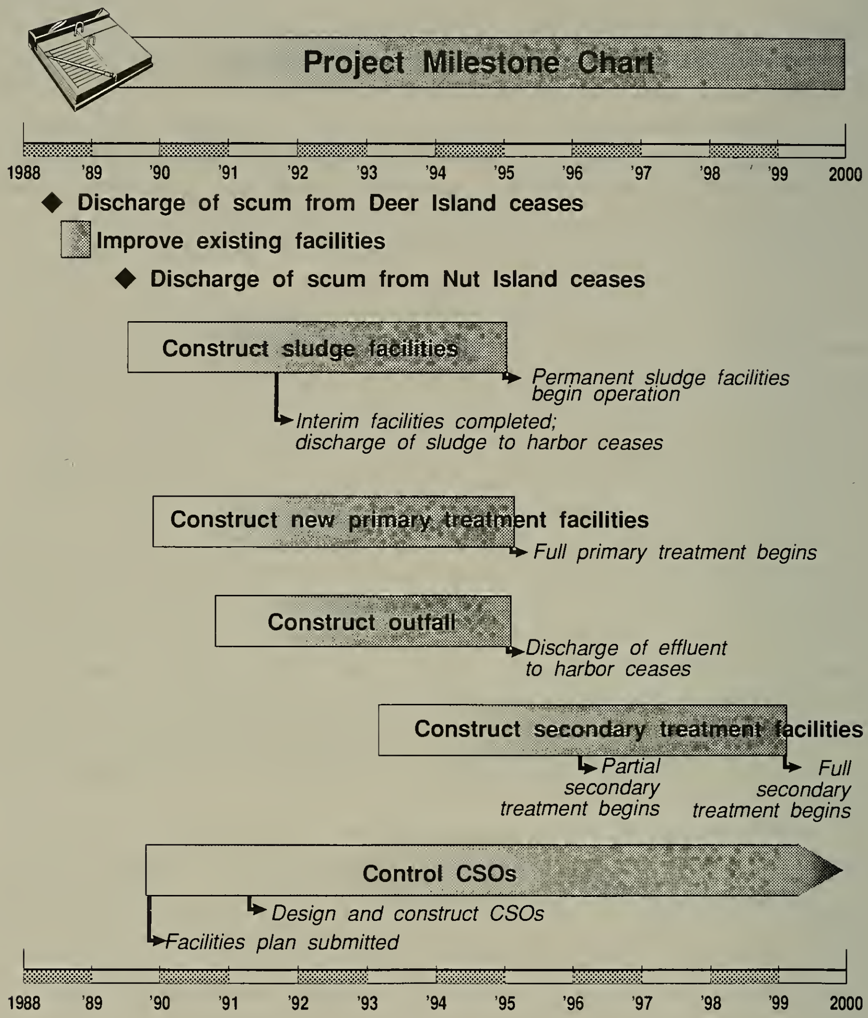
The federal case was held in abeyance while the state case proceeded. State Judge Paul Garrity, finding substantial violations of state law, ordered a moratorium on sewer hookups in the metropolitan area. He was immediately overruled by a higher state court, but his message scared the legislature enough that in December 1984 it created the Massachusetts Water Resources Authority (MWRA), an independent authority with the right to issue revenue bonds and raise rates to secure those bonds. The MWRA was given the responsibility to take over and rebuild the MDC sewer system.

Shortly after the MWRA came into being, the federal court case was revived. This time, in an interesting legal maneuver, EPA was a plaintiff rather than a defendant. The MWRA, as successor-in-interest to the MDC, found itself faced with a federal court order to carry out the provisions of the Clean Water Act. The parties and the court developed a detailed schedule in 1986 with more than one hundred milestones over the next decade against which MWRA's compliance is monitored monthly (see Figure 1).

The Plan

Thus began "the Boston Harbor Cleanup." The cleanup plan is relatively simple in concept: build a new primary and secondary treatment plant to handle wastewater

Figure 1



flows through the year 2025; end the discharge of sludge into Boston Harbor with some kind of landside disposal method; and resolve the problem of the combined sewer overflows (CSOs). These are the relief valves on the old combined storm and sanitary sewer system that release untreated sewage into the rivers and the harbor whenever there is heavy rain.

While simple in concept, implementation is somewhat more complicated, and very costly. The MWRA must:

- Build new primary and secondary treatment plants on Deer Island. The plants must handle an average flow of 500 mgd, and a peak flow of almost 1.3 billion gallons per day. The primary plant must be finished by 1995, the secondary by 1999 (see Figure 1).

- Maintain and improve the existing primary plant at Deer Island while the new facility is built around it ("immediate upgrades").

- Decommission the old Nut Island plant in Quincy, but first drill a five-mile eleven-foot-diameter tunnel between Quincy and Winthrop, under Boston Harbor, to connect the southern sewer system to the new treatment plant at Deer Island.
- Drill a twenty-four-foot-diameter outfall tunnel for the effluent from the new treatment plant out 9.5 miles into Massachusetts Bay.
- Construct a sludge processing plant to manufacture fertilizer pellets from the sewage sludge by 1991.
- Move thousands of workers and tons of construction materials to Deer Island by boat.
- Build a series of tunnels and conduits to connect eighty-eight CSOs along three rivers and the harbor to the new treatment plant.
- Reduce groundwater infiltration and stormwater inflow to the system, which account for more than half of the influent flow in dry weather.
- Raise nearly $7 billion from ratepayers in forty-three communities to pay for all of the above, *quintupling* water and sewer bills over a fourteen-year period.
- Stay on schedule or be subject to federal sanctions, including daily fines of up to $10,000 per violation of the Clean Water Act.

Issues to Be Resolved

The scientific and engineering issues surrounding this complex wastewater treatment project have more than a passing academic interest. While virtually all the components of the plan require a sound scientific and engineering basis, the decisions to be made have serious financial implications for the ratepayers of the Boston metropolitan area, and they also have important environmental consequences for the harbor, Massachusetts Bay, and a number of landside locations. In the following sections, we discuss some of these issues.

Sludge

The purpose of a sewage treatment plant is to separate the solids in the waste stream from the water, purifying the latter while creating a residue of treated sludge. At the new Deer Island treatment plant, like most others in the country, sludge will be produced by two processes. The primary portion of the treatment plant will produce sludge through a physical process, sedimentation, in forty-eight stacked settling tanks. The secondary portion of the treatment plant will use a biological process, the infusion of oxygen into a nutrient-rich suspension consisting of twelve aeration tanks followed by seventy-two secondary clarifiers to separate still more sludge from the plant's influent. Both the primary and secondary sludge will then travel to twenty anaerobic digesters, where the volume of the sludge will be reduced by about 60 percent, creating methane gas in the process.

Each day 1.6 million gallons (200 dry tons) of sludge will leave the anaerobic digesters, requiring disposal in an environmentally sound manner. Basically, four options exist for the disposal of this much sludge. The first, now illegal, is the method that was used for years by Boston, New York, and New Jersey: ocean disposal. While some scientists claim that ocean disposal,[2] if done properly, can achieve good environmental results, Congress has deemed otherwise, and the practice was ordered stopped by 1991.

Option two is to dispose of the sludge by landfilling or land application. While practical in some parts of the country (Omaha, Nebraska, and Tuscon, Arizona, have large land application programs), the densely populated Northeast does not offer opportunities for this method of disposal. There is simply insufficient open space to satisfy the demands of the next several decades.

Option three is incineration. Sludge is an organic material with significant heat value. In theory, the combustion of sludge in an incinerator offers a payback in energy production and reduction of the volume of the material. In practice, though, incineration presents some difficulties. First, siting an incinerator in a metropolitan area is very difficult. Second, with ever stricter air quality standards, incinerators present an operational risk over their lifetime. When air quality regulations change, the incinerator may have to be shut down for an extended period to be retrofitted to meet the new requirements. Also, malfunctioning or improperly operated equipment can present real liability risks for the owner-operator of the facility. In Massachusetts two sewerage districts, South Essex and Greater Lawrence, were forced to close down their newly constructed sludge incinerators because of poor design and operations problems. Finally, while reducing the volume of sludge by a factor of seven, a sludge incinerator produces ash that must be disposed of in a landfill. Most of the toxics present in the sludge when it leaves the treatment plant become concentrated in the ash, making it a difficult material to handle and raising community concern over the siting of the landfill.

Option four for sludge processing is recycling, or beneficial reuse. This is the method chosen for the Boston Harbor cleanup. Two methods of reuse, composting and heat drying, were considered for Boston. In a sludge compost facility, wet sludge is dewatered on belt presses or in centrifuges. It is then mixed with a bulking agent (wood chips), aerated until the pathogens in the sludge are killed off, separated from the bulking agent, and sold as a soil conditioner. With the heat-drying process, the sludge is dewatered as above, then sent through a rotary kiln oven, which drives off excess water and kills the pathogens, producing a pellet or coffee-ground-type product that can be used as a soil conditioner or fertilizer or as a base for commercial fertilizer. Milorganite, produced by the Milwaukee sewer system for over sixty years, is a heat-dried sludge product.

The MWRA chose to rely on heat drying for sludge processing. An initial five-year contract was signed with New England Fertilizer Company, a private firm, to design and operate the fertilizer plant and to market the pellets produced in it. The agency chose to build the processing plant at the former General Dynamics shipyard site in Quincy. It completed construction of this $87 million facility and was able to shut off the sludge discharge lines leading to the harbor on December 24, 1991.

Meanwhile, though, a regulatory issue has reared its head. During the last weeks of the Reagan administration, the EPA promulgated draft regulations that set such strict limits on the use of sewage sludge that sludge in most parts of the country could not be recycled as fertilizer. That the EPA might adopt such an approach, in the face of overwhelming support on the part of environmentalists, sewage treatment districts, and the public to recycle sludge into useful products, was extremely disturbing.

The proposed regulations received widespread criticism at public hearings, with comments focusing on the fact that they were entirely based on overly conservative human and environmental health risk assessments without considering their impact on beneficial reuse programs. The proposed regulations would have forced sewerage agencies to abandon existing beneficial reuse programs to comply with the stringent land application standards. Boston and New York, in the process of planning beneficial reuse programs to end ocean dumping, would have had their options seriously curtailed if the EPA regulations were adopted. Long-standing fertilizer production operations — in Milwaukee, Los Angeles, Atlanta, Dayton, and elsewhere — would have found that the years of experience they had accrued in recycling and the millions of dollars they had invested in fertilizer plants would have been put at risk by the regulations.

While there is legitimate public concern about the recycling of sewage sludge because it contains trace amounts of toxic metals and organics from industrial and household discharges into the sewer system, the problem is not intractable. Improvements in industrial pretreatment, combined with strict enforcement of environmental standards, have reduced and will continue to lower the levels of toxics in the waste stream. Likewise, public education programs and household hazardous waste collection centers will reduce the level of household toxics going down the drain.

In Massachusetts, for example, we have witnessed a substantial reduction in the level of toxics in wastewater. The MWRA has initiated a vigorous industrial pretreatment and source reduction program. Thanks in part to this program and concomitant actions at the federal level, the amount of heavy metals reaching the plant has declined from nearly five thousand pounds per day in 1982 to almost one thousand pounds per day in 1991 (see Figure 2).

There will always be some level of toxics in sewage sludge, and some level of regulation is required to ensure that the concentration of these elements and the public's exposure to them is kept well within safe limits. Research indicates, however, that the levels of toxics in sludge have not presented any health threat when sludge products are used as fertilizer.[3]

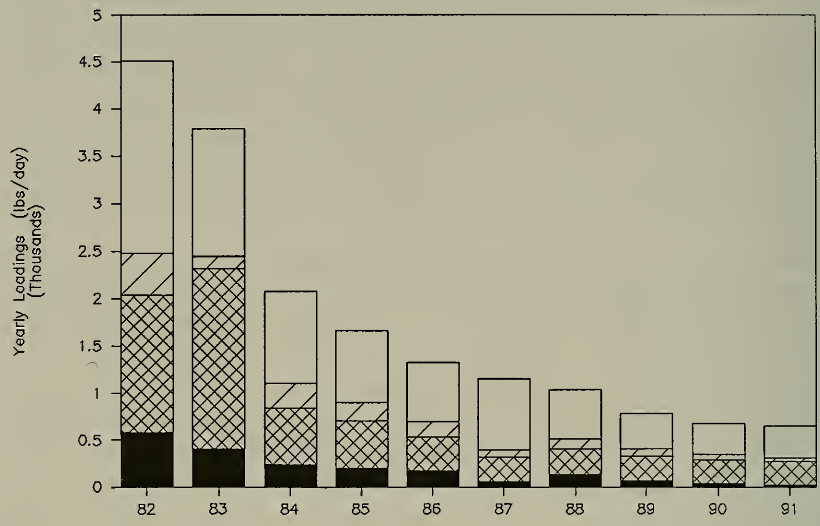
Fortunately, in response to the massive number of public comments received, the EPA undertook a complete review of their proposed regulations. With help from the U.S. Department of Agriculture and others, the EPA plans to issue regulations that will encourage the beneficial reuse of sludge products throughout the country.

Outfall

Perhaps the most challenging construction on the project involves the excavation and construction of the shaft, tunnel, and diffuser sections of the outfall. The effluent will travel through a 450-foot dropshaft into a 24-foot diameter tunnel bored through bedrock and terminating in a diffuser section about nine miles offshore (see Figure 3). The last 6,600 feet of the tunnel forms the diffuser, which consists of fifty-five vertical riser shafts 2.5 feet in diameter. Effluent will be discharged in 100 feet of water with a minimum initial dilution of about 180 during unstratified conditions approximately eight months of the year and 60 to 90 feet, depending on current speed during the most stratified conditions in late summer. Construction of the tunnel began in 1990. As of this date, the fifty-five vertical riser shafts have been completed, and the tunnel-boring machine has begun its long trek under the harbor.

Figure 2

Metal Loadings — Total Discharge



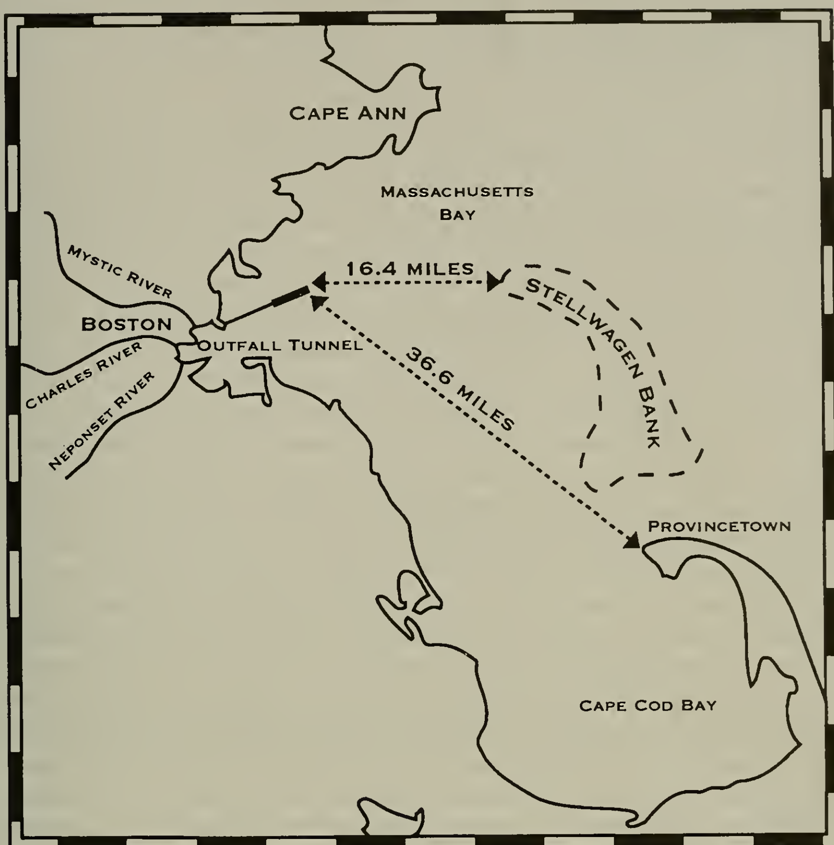
Ironically, the location of the outfall diffusers for the planned secondary facility is in the same general area proposed for a primary plant outfall in the original 301(h) waiver application. The selection of the effluent outfall location was based on the results of a $4 million data collection program, including physical, chemical, biological, and geological oceanography. The effluent discharge area selected represents the most favorable mix of outfall site characteristics. It is well within the large-scale circulation patterns of Massachusetts Bay and therefore provides the most robust long-term mixing. It is in an area of limited potential sediment accumulation and thereby avoids problems associated with concentrating pollutants in nearby bottom sediments.

It is located away from intensely utilized near-shore resources, avoiding the potential for disruption. Finally, the location for the diffuser can be reached by a gravity flow effluent tunnel within a time frame consistent with the spirit of the court-ordered target dates for treatment facility construction.

How far offshore should a sewage outfall be? Besides meeting state water quality standards, the approved site is at the point where the marginal benefits (ambient dilution) increase only slightly, while the marginal costs rise steeply. The outfall location has been criticized by local residents as being too short and by Cape Cod environmentalists as being too long. Local communities are worried that the outfall mightthreaten their beaches and shellfish beds. Cape Codders are concerned that the proposed discharge poses a threat to marine mammal communities on Stellwagen Bank off the Cape's western shore more than sixteen miles away from the proposed discharge.

Figure 3

Discharge of the New Outfall



MWRA measurements of waves and currents indicate that the outfall diffuser is far enough offshore so that vigorous, variable currents will provide adequate dilution and avoid transport onshore toward beaches. Elevated concentrations of toxic contaminants in the water column will not be found near Stellwagen Bank. Field observations were used to calibrate and validate a numerical model of pollutant transport. The model predicts that effluent reaching the North Shore communities from the proposed diffuser site will be diluted 450-fold compared with the 50-fold dilution available for effluent discharged from the current location. In addition, the total amount of material that Boston will discharge to Massachusetts Bay will decline tenfold with the completion of secondary treatment and the cessation of ocean sludge discharge so that long-term chronic impacts on near-shore areas or Stellwagen Bank should be minimal.

In short, the water discharged at the outfall location should not have a detrimental effect on that part of Massachusetts Bay or on any other part of the bay. However, this is an issue that will be closely examined over the coming years. The MWRA has in place a harbor and bay monitoring program to acquire base-line data on the condition of the receiving waters today. Those data will be compared with data collected after the operation of the new treatment plant to demonstrate conclusively the effect of the outfall on the bay. If, as expected, there are no adverse impacts, no further treatment will be necessary. If there are adverse impacts, it may be necessary for the MWRA to invest in more advanced forms of wastewater treatment at its facility on Deer Island or elsewhere.

Level of Treatment

The centerpiece of the cleanup will be the construction of the second largest wastewater treatment plant in the United States, with a capacity of 1,270 million gallons per day. The effluent discharged from the new secondary treatment plant will be dramatically cleaner than the effluent currently discharged from the Nut Island and Deer Island plants. It will have biological oxygen demand (BOD) and total suspended solids (TSS) concentrations of 22 and 21 mg/l compared with the 140 mg/l BOD and the 110 mg/l of TSS from the existing poorly functioning primary treatment plant at Deer Island. In short, the effluent will be clean enough that the seawater at the end of the outfall will meet the classification of "swimmable."

Although the issue of Boston's level of sewage treatment has been considered by the EPA and the federal court, there are likely to be further debates on this topic as water and sewer rates rise in the metropolitan area, particularly, what are the benefits of secondary treatment, and are they worth the $880 million expected cost of the secondary treatment plant? Are there alternatives that are more cost-effective? Is there a way to meet the water quality standards established under federal and state law with less capital investment and/or lower operating costs? Since the MWRA is required by court order to build secondary treatment, we might view the debate as a scheduling issue: How should the construction of the various components of the Boston Harbor cleanup be scheduled to maximize environmental benefits for the next dollar spent? A similar issue is being raised in San Diego, where the city is being required to spend $4.2 billion to build a new secondary treatment plant to replace its current advanced primary system. Several marine scientists from the Scripps Institution of Oceanography have criticized the decision as a diversion of money from solving more pressing water quality problems.[4]

Discussion

How clean will Boston Harbor be as a result of this cleanup program? To answer that question it is necessary to understand what the environmental problems are in Boston Harbor and how the different harbor cleanup program components are likely to affect those problems.

The major environmental impacts from sewage discharge are associated with the four major components of the discharge: toxic contaminants, pathogens, nutrients, and biological oxygen demand. Two of these problems are significant in Boston Harbor:

- Beach and shellfish bed closures owing to bacteria
- High concentrations of toxic contaminants in fish and sediments.

Because the shallow harbor is well flushed twice daily by large tidal flows, there have not been the serious incidents of hypoxia or anoxia caused by nutrient and BOD discharges that plague other estuarine waters, though some isolated portions in the inner harbor do violate water quality standards.

Boston Harbor beaches are closed about 15 percent of the time during the summer, and all shellfish beds are either closed or restricted to master diggers in wet weather. CSOs and storm drains discharge raw sewage to the harbor forty to eighty times per year during and after rainfalls. Fecal coliform bacterial concentrations can exceed 100,000 colony-forming units (CFUs) per 100 ml after heavy rains and persist for four days at concentrations above the standard of 200 CFUs per 100 ml.[5]

Boston Harbor received its moniker of "dirtiest harbor in the nation" on the basis of data collected by the National Oceanic and Atmospheric Administration (NOAA).[6] The concentrations of toxic contaminants in fish tissue and sediments are uniformly high in Boston Harbor, similar to such other major urban harbors as New York and Baltimore. The major contaminants of concern are polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). PCB concentrations in MWRA discharges have declined dramatically in the last decade, but PAHs have not. While Boston Harbor is fairly typical of urban estuaries as regards concentrations of toxic contaminants, winter flounder from the harbor have a high incidence of liver neoplasms.[7] It is presumed that this incidence is caused by sediment contamination.

Table 1 summarizes the extent to which the different MWRA programs — immediate upgrade of treatment plants, cessation of sludge dumping, new treatment plant facilities, new offshore outfall, and CSO facilities — will result in a cleaner harbor. The largest reduction in the water concentration of toxic contaminants will result from the construction of the outfall, because increased dilution will decrease the concentrations of toxic contaminants to about 10 percent of their concentrations in the harbor. Secondary treatment and improved primary treatment incrementally reduce toxic discharges by about the same amount, assuming that most toxic contaminants are associated with particles. These contaminants will then be part of the sludge distribution network in such dilute concentrations that they present minimal risk to the environment. Boston Harbor waters probably will meet water quality standards for toxic contaminants after the completion of these projects, since these waters currently meet most toxic standards most of the time. However, the contaminants remaining in the sediments will continue to provide some risk to fish and shellfish living in these sediments. To estimate the magnitude of this risk, MWRA is funding research to measure the extent of particle transport in Boston Harbor and the flux of metals and organics from contaminated sediments.

Beach and shellfish closures will be significantly improved — in relative order of impact — by the (1) immediate upgrades at Deer Island, (2) CSO facilities, and (3) cessation of sludge dumping. Improvements to Deer Island pumping and operations have already reduced by about half the amount of untreated sewage entering the harbor.[8] Since CSOs have much more impact on the beaches and shellfish beds ringing the harbor, and controlling CSOs would have a more dramatic impact on the visible health of Boston Harbor than secondary treatment, many local citizens are advocating acceleration of the CSO program. However, storm drains owned by the local municipalities account for a significant fraction of bacterial contamination, both from urban runoff and illegal sanitary connections to the storm drains. Without control of

Table 1

Cost and Benefits of Various Harbor Projects
Extent of Improvement

Project	Cost (in $ Millions)	Toxics	Pathogens	Nutrients / BOD
Immediate Upgrades	33	<5%	Untreated discharges reduced by half	Small improvement to BOD
Sludge	650	30% less discharge to the harbor	30% less to the harbor, with major benefit to Winthrop	Improvement, but current problem not large
Primary	1,000	30% less discharge to the harbor	No impact for normal operations: major improvements from ending diversions	50% improvement, but potential problem at outfall site
Secondary	880	30% less discharge to the harbor	Little impact	Some improvement near discharge, but may worsen algal problems in far field
Outfall	360	Same amount, but concentration will be 10 times less in Mass Bay because of dilution	Pathogen concentration will be 10 times less and far from beaches	Oxygen declines will be less, but the site may be more sensitive
CSOs	2,200	About 5% less discharge harborwide, but larger local impact near overflow	One hundred–fold improvement near discharge; 25% reduction in beach closings harborwide	10% improvement near overflow
Stormwater	?	Less than 5% improvement harborwide	One hundred–fold near discharges. 40% reduction in beach closings harborwide	Negligible

Note: Impacts based on estimated load reductions.

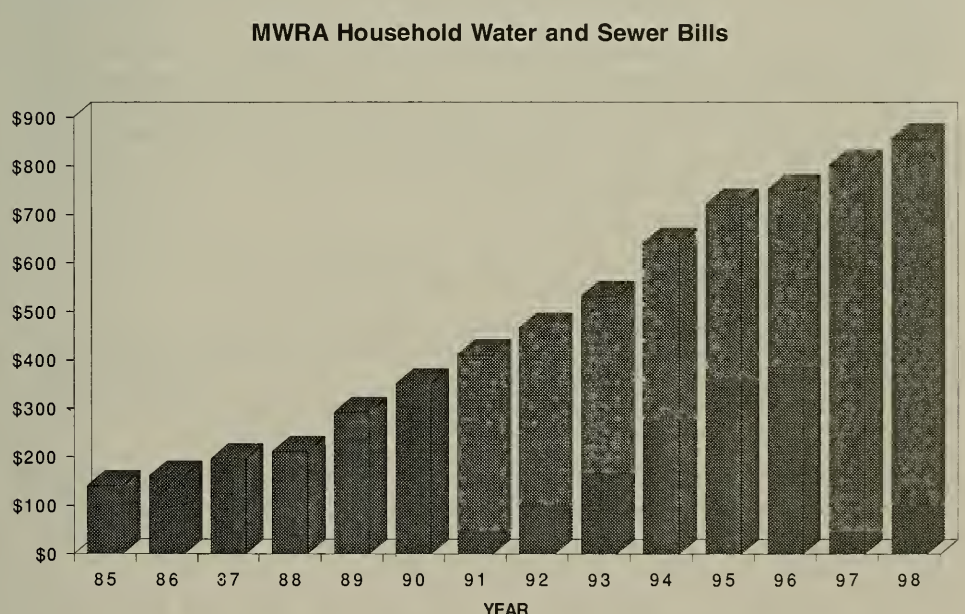
these other sources of pollution, even complete elimination of CSO discharges will not result in a clean harbor.

Dissolved oxygen concentrations should be sufficient in both Boston Harbor and Massachusetts Bay with the new outfall to meet water quality standards regardless of level of treatment. The long-term impact of increased coastal discharges of nutrients on the kinds of phytoplankton growing in the region is more problematic. In the past several years, coastal waters around the world from the Adriatic Sea to the Irish coast to Peconic Bay have suffered from the outbreak of nuisance algal blooms. The assimilative capacity of coastal waters for nutrient discharges is a challenging research question.

This cost-benefit comparison shows that improving current facilities, ending sludge discharges, and using the new outfall have significant benefits for their costs. On the other hand, stormwater control will mostly benefit localized areas at a proportionally higher cost. The marginal benefits of full secondary treatment as compared to CSO remediation or nutrient removal are more difficult to quantify and tend to focus on different issues in different areas (for example, beach closures in the harbor versus ecosystem effects in the bay). A more quantitative agenda of priorities for these programs will depend on the final design of the CSO facilities and early results from MWRA's ongoing monitoring of the harbor and the bay.

Despite uncertainty surrounding the issues discussed above and others that are certain to arise in any environmental project as large and as complicated as the Boston Harbor cleanup, the MWRA has made significant progress and remained on schedule. The project has already resulted in a cleaner harbor. MWRA spent more on capital improvements in its first four years of existence than the MDC was permitted to spend in the previous twenty years. A number of "immediate upgrade" projects required to improve the interim performance of the treatment plant have been completed. These projects have already decreased the amount of grit and scum discharged to the harbor by four thousand gallons per day and reduced the discharge of coliform bacteria to the harbor. The decline in toxic discharges has resulted in winter flounder in the harbor with dramatically reduced incidence of fin erosion and liver disease.[9] In addition, the increased pumping capacity at Deer Island has reduced the

Figure 4



number and amount of CSO discharges dramatically, so that area beaches are the cleanest they have been since measurements began in the 1930s.[10] But the largest improvement to the harbor occurred when sludge dumping ended in late 1991. A later improvement will occur in 1995 with the completion of the outfall and the first phase of plant construction.

Since the authority's inception in 1985, water and sewer ratepayers have seen their average bills rise from about $140 a year to over $500 a year. That yearly price tag is expected to reach $750 in current dollars by 1996 and $855 in current dollars by the year 1998 (see Figure 4). Two thirds of the capital costs is determined by the court schedule. Federal and state cost-sharing will contribute only a small percentage of the total cost, so most of the costs of the Boston Harbor cleanup will be borne by the ratepayers. Unless the federal government gets back into financially supporting the Clean Water Act, ratepayers will face extraordinarily high sewerage rates. Given these projected increases and the constraints of borrowing money in capital markets, the MWRA will need to carefully weigh the expected benefits of various aspects of the cleanup program to give the highest priority to investments that yield the greatest water quality improvements. ❧

Notes

1. E. C. Clarke, *Main Drainage Works of the City of Boston* (Boston: Rockwell and Churchill, City Printers, 1885), 7, 12.
2. National Research Council, Board on Ocean Science and Policy, *Disposal of Industrial and Domestic Wastes: Land and Sea Alternatives* (Washington, D.C.: National Academy Press, 1984).
3. Technical Committee of Northeastern Regional Research Coordinating Project NEC-28, Soil Research, "Criteria and Recommendations for Land Application of Sludges in the Northeast," Bulletin 851 (University Park: Pennsylvania Agricultural Experiment Station, 1985); L. E. Sommers, R. C. Lehrman, H. C. Selznick, and C. E. Pound, "Principles and Design Criteria for Sewage Sludge Application on Land," in *Sludge Treatment and Disposal* — vol.2, *Sludge Disposal,* EPA-625/4-78-012 (Cincinnati: EPA, 1978), 57–112.
4. M. Sun, *Science,* 246, 1989, 440–443.
5. A. C. Rex; K. E. Keay; W. M. Smith; J. J. Cuva; C. A. Menzie; M. S. Steinhauer; and M. S. Connor, "The State of Boston Harbor: 1991" (Boston: MWRA, 1992).
6. National Status and Trends Program, "A Summary of Selected Data on Chemical Contaminants in Tissues Collected During 1984, 1985, and 1986," Technical Memorandum NOS OMA 38 (Rockville, Md.: NOAA, 1987); National Status and Trends Program, "A Summary of Selected Data on Chemical Contaminants in Sediments Collected During 1984, 1985, 1986, and 1987," Technical Memorandum NOS OMA 44 (Rockville, Md.: NOAA, 1988).
7. R. A. Murchelano and R. E. Wolke, *Science,* 228, 1985, 587–589.
8. Rex et al., "The State of Boston Harbor: 1991."
9. Ibid.
10. Ibid.