January 1992

THE BOSTON HARBOR PROJECT'S EFFLUENT OUTFALL:
Overview of the Issues and Introduction to Phase I of the Monitoring Plan

Massachusetts Water Resources Authority

Environmental Quality Department

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RELATED DOCUMENTS

MWRA. 1991. *Draft Massachusetts Water Resources Authority Effluent Outfall Monitoring Plan Phase I: Baseline Studies.* Massachusetts Water Resources Authority, Boston, MA.

MWRA Outfall Monitoring Task Force. 1991. *Management Document for the Massachusetts Water Resources Authority Effluent Outfall Monitoring Plan Phase I: Baseline Studies.* MWRA Outfall Monitoring Task Force, Boston, MA.

EPA. 1988. *Boston Harbor Wastewater Conveyance System. Supplemental Environmental Impact Statement.* Volume I. Environmental Protection Agency, Region I, Boston, MA.

Kelly, J.R. 1991. *Nutrients and Massachusetts Bay: A Synthesis of Eutrophication Issues.* MWRA Environmental Quality Technical Report Series No. 91-10, June 1991. Massachusetts Water Resources Authority, Boston, MA.

Shea, D. and J. R. Kelly. 1992. *Synthesis of Toxic Contamination Issues in Massachusetts Bay.* MWRA Environmental Quality Technical Report Series No. 92-4. Massachusetts Water Resources Authority, Boston, MA.

Shea, D., D. Lewis, B. Buxton, D. Rhoads, and J. Blake. 1991. *The Sedimentary Environment of Massachusetts Bay: Physical, Chemical, and Biological Characteristics.* MWRA Environmental Quality Technical Report Series No. 91-6, June 1991. Massachusetts Water Resources Authority, Boston, MA.

PREFACE

By the end of this decade, sewage from the Boston metropolitan area will receive primary and secondary treatment on Deer Island and will then be pumped 9½ miles offshore for discharge into Massachusetts Bay. The Massachusetts Water Resources Authority (MWRA) is now constructing the outfall for this discharge. The construction is just one part of a project to improve sewage treatment and rehabilitate Boston Harbor. The project is the result of a process that began in 1982 when the City of Quincy filed suit in Massachusetts Superior Court, charging that wastewater discharges to Boston Harbor violated State law.

The public has questions about the effectiveness of the treatment that the sewage will receive and the environmental consequences of effluent discharge from the new outfall. The purpose of this report is to give the concerned citizen an overview of the issues involved and introduce the monitoring program designed to provide information needed to evaluate the environmental effects of the discharge. Those who wish more detail about the scientific and technical aspects of these issues are referred to the list of related documents on the facing page.

To ensure a scientifically valid and environmentally sound foundation for the monitoring program, the Massachusetts Secretary of Environmental Affairs called for the formation of a task force to oversee the process of developing a detailed monitoring plan. The MWRA Outfall Monitoring Task Force consists of scientists, staff of State and Federal agencies, and representatives of environmental interest groups. The MWRA, working in cooperation with the Monitoring Task Force, has now produced the first element of such a plan in a report titled *Massachusetts Water Resources Authority Effluent Outfall Monitoring Plan Phase I: Baseline Studies.*

The Phase I plan lays the needed foundation for the monitoring program by specifying what should be monitored, where, and how often in the 3 years before the outfall begins discharging effluent into Massachusetts Bay. The information collected during these 3 years will serve as the baseline — the point of comparison — for evaluating data collected after the outfall is in operation. At this time, the Phase I plan has been reviewed by the Task Force and distributed for further scientific and public review. The results of that review will be used to revise the plan and to assist the Task Force in drafting a recommendation to the U.S. Environmental Protection Agency and the Massachusetts Executive Office of Environmental Affairs on the adequacy of the plan.

The MWRA and the Task Force envision that the complete monitoring program will consist of three phases. The predischarge Baseline Studies will be followed by two phases of postdischarge monitoring. Plans for the additional phases will be developed on the basis of results from the Baseline Studies; the process is described in more detail in the *Management Document for the Massachusetts Water Resources Authority Effluent Outfall Monitoring Plan Phase I: Baseline Studies.*

This overview addresses four main questions:

1. Why do we need the Massachusetts Bay outfall? *(Overview of the Boston Harbor Project, Chapter 1)*
2. Where does wastewater go now after treatment and where do we expect it to go once the outfall is in operation? *(The Discharge — Present Conditions and Future Expectations, Chapter 2)*
3. What are the major public concerns and are they justified? *(Possible Effects of the Outfall: Concerns and Predictions, Chapter 3)*
4. How will environmental effects be identified once the outfall begins operating? *(Monitoring and Management, Chapter 4).*

The MWRA, the Task Force, the Environmental Protection Agency, the Massachusetts Executive Office of Environmental Affairs, and a variety of other State agencies, universities, and scientific organizations are working together. Their objective is to implement and maintain a sewage treatment project that balances the needs of the people, the resources, and the environment. The monitoring program is a significant element of that process.

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1. Overview of the Boston Harbor Project

The Massachusetts Bay outfall is part of the overall plan for sewage treatment in the Metropolitan Boston area

Why are we building an outfall in Massachusetts Bay? This is really two questions — Why a new outfall? and Why in Massachusetts Bay? To understand the answers, we must look at the entire plan to provide adequate treatment for sewage from the 43 communities that now discharge waste into Boston Harbor.

The Plan and Schedule for the Project

Secondary sewage treatment and other improvements were ruled necessary to meet the U.S. Clean Water Act

The Boston Harbor Project is the direct result of a Federal Court order issued in 1985. Judge A. David Mazzone of the U.S. District Court ruled that wastewater discharges to Boston Harbor violated the Federal Clean Water Act. To remedy the situation, Judge Mazzone ordered the construction of new sewage treatment facilities and outlined a timetable for this and other parts of the plan to clean up the Harbor (Figure 1.1).

Secondary treatment of sewage will be provided by four batteries of facilities that will come on line in stages. Battery A is scheduled to be completed in 1996, Battery B in 1998, and Batteries C and D in 1999.

When all parts of the Project are complete, sewage will be pumped under the Harbor from collection points, or headworks, to a combined primary and secondary plant on Deer Island. The treated effluent will pass through a 9½-mile (15-km) tunnel bored through rock 400 ft below sea level and will be discharged into Massachusetts Bay. In the past, solids (sludge) separated from sewage during treatment were discharged into the Harbor. Sludge is now shipped by barge to the Fore River Staging Area in Quincy, and converted to fertilizer pellets. The discharge of sludge to Boston Harbor ceased on December 24, 1991.

Relocating the outfall is one of five major steps necessary to comply with Federal regulations

The Project has five main elements:

- **Provide a level of treatment that meets State and Federal standards.** The existing outdated and overloaded primary treatment plants will be replaced with a new plant on Deer Island. This facility will have a capacity of 1.27 billion gallons per day (bgd) for primary treatment and 1.08 bgd for secondary treatment. The capacity at which a plant is rated

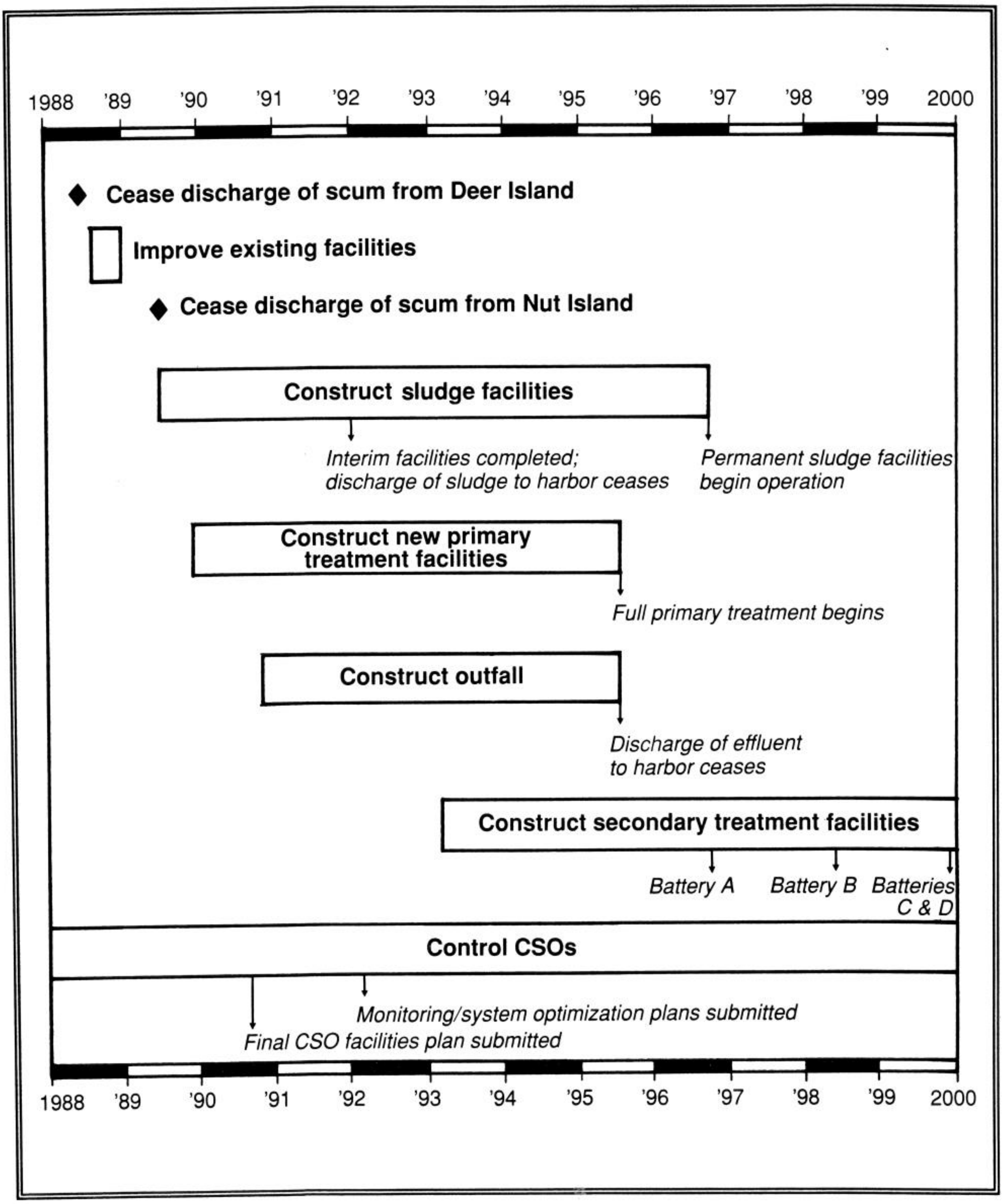


Figure 1.1. In response to the 1985 Federal Court order, the MWRA negotiated a plan and a schedule for cleaning up Boston Harbor.

describes the maximum flow of sewage it can treat under peak conditions. The average flow rate will be lower than the rated capacity.

- **Move the effluent discharge to a site where dilution will be greater.** The effluent outfall will be relocated farther offshore where the water is deeper, thus increasing the dilution of effluent after discharge.
- **Stop discharging sludge.** Solids (sludge) separated from wastewater during processing are converted to fertilizer at the Fore River Staging Area.
- **Remediate the Combined Sewer Overflow (CSO) problem.** The remediation plan will reduce CSO discharges by half. Monitoring has shown that the impact of the CSO discharge is limited to beaches within a few hundred yards of the overflow. CSOs that discharge significant amounts of untreated sewage are being identified. This overflow will be captured and stored in large tunnels so that it can be treated.
- **Reduce the load of toxic contaminants in influent.** The Massachusetts Water Resources Authority (MWRA) is requiring more stringent measures to pretreat industrial wastewater before it goes into sewers. Other programs are under way to reduce the flow of toxins from households and commercial establishments.

It is important to realize that the outfall to be constructed in Massachusetts Bay is only one of these five elements. Taken as a whole, the measures that make up the Project are designed to ensure that the water quality in Boston Harbor will be improved without compromising conditions elsewhere.

Primary and Secondary Sewage Treatment

Discharge of treated sewage into coastal waters requires an NPDES permit

The Federal Clean Water Act requires a sewage treatment plant that discharges wastewater into the coastal environment to have a permit under the National Pollutant Discharge Elimination System (NPDES), which is designed to protect the environment. The terms of an NPDES permit specify that all wastewater discharges from sewage treatment plants must have received secondary treatment. Once the Boston Harbor Project is complete, MWRA discharge from the Massachusetts Bay outfall will fully comply with this requirement.

Primary treatment is a physical process that removes some of the solids from wastewater;

Primary treatment — the level that MWRA effluent now receives under the terms of its interim permit — relies mainly on physical processes such as screening and sedimentation (the process by which heavier particles gradually fall to the bottom of a column of water) to remove suspended material. Secondary treatment uses biological processes to increase the amount of material that is removed from wastewater (see comparison of removal *secondary treatment adds biological processes that remove still more organic material*

efficiencies in Table 1.1). This more advanced form of treatment promotes the growth of microorganisms that are naturally present in wastewater and can consume organic matter. In this two-stage process, wastewater that has received primary treatment is transferred to a tank where the water is aerated to increase the supply of oxygen and stimulate the growth of microorganisms that break down the organic matter. After about 2 hours, the mixture of wastewater and organisms flows into clarifiers (sedimentation tanks similar to those used in primary treatment) where the solids settle. Following treatment, effluent is disinfected to kill or inactivate disease-causing organisms.

Table 1.1. Comparison of efficiencies for primary and secondary treatment of wastewater

Type of Material	Removal Efficiency (%)	
	Primary Treatment	Secondary Treatment
Solids	60	85
Toxins	40	50 - 85*
BOD†	35	85
Nitrogen	5	10 - 15

*Varies from one toxin to another.
†Biochemical Oxygen Demand: A measurement of the amount of dissolved oxygen used by microorganisms as they decompose organic matter.

Siting the Outfall

Screening Criteria

EPA chose a list of possible sites for the outfall on the basis of carefully selected criteria

At the beginning of the process used to select a location suitable for the outfall, the entire marine environment east of Deer Island was considered. The Environmental Protection Agency (EPA) then applied three criteria to narrow the list of candidate sites. To be eligible for further evaluation, each site had to

1. Provide an initial dilution of 50 parts seawater to 1 part effluent in the immediate vicinity of the outfall
2. Protect public health and aquatic life by having a dilution of at least 50 to 1 and by being far enough from shore that a particle could not reach shore on the next incoming tide
3. Avoid sensitive or unique resources.

EPA also eliminated from consideration any site more than 10 miles from Deer Island. Beyond that point, the environmental benefit was considered too small to justify the additional cost of constructing a longer outfall tunnel.

The Siting Process

The process of site selection took over 2 years and included many oportunities for public participation

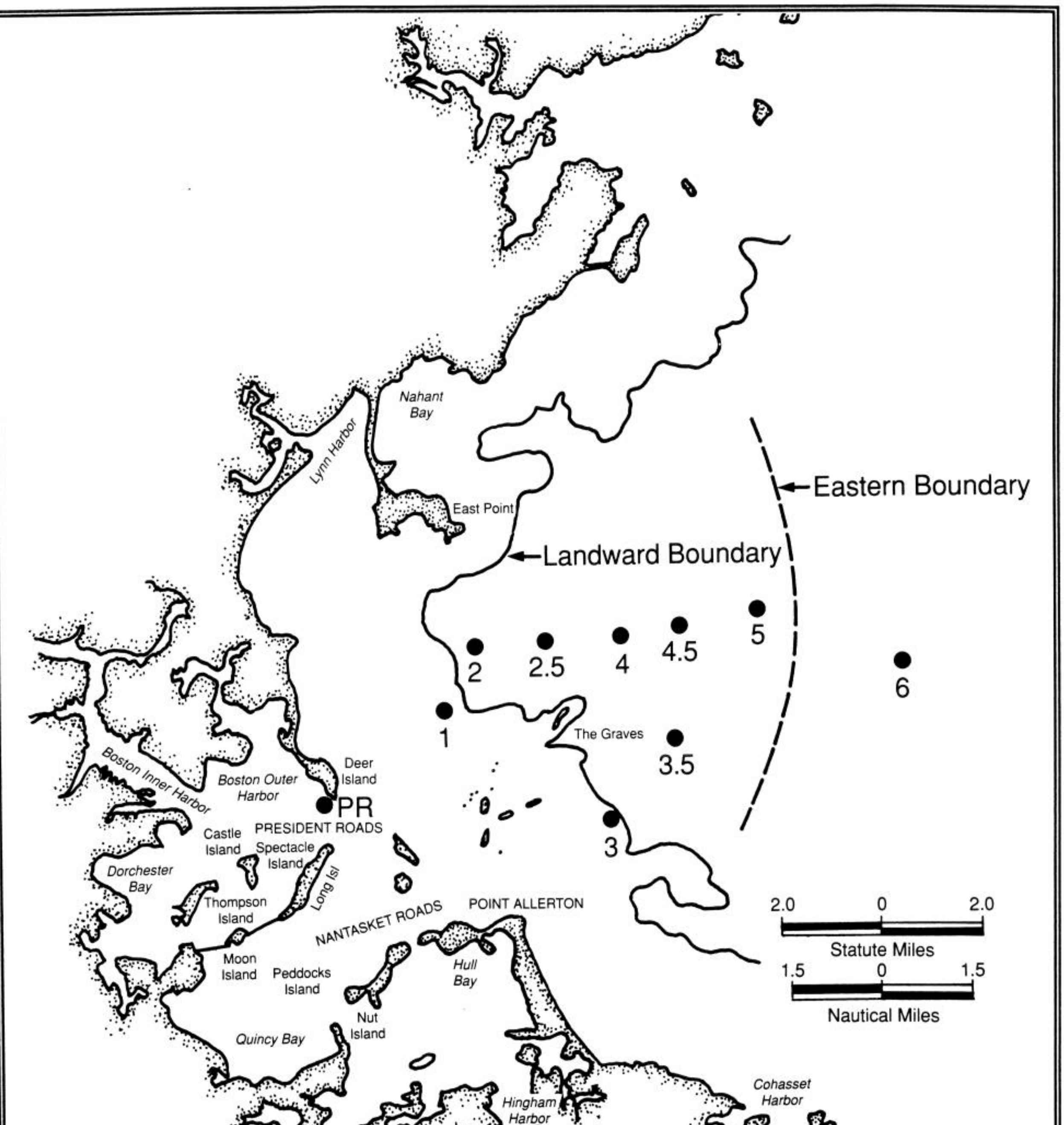
After 2 years of careful study, the proposed site 9½ miles from Deer Island was chosen as the optimum outfall location in Massachusetts Bay. Assessments of the environmental impacts of the project were carried out by the State under the Massachusetts Environmental Policy Act (MEPA) and by EPA under the National Environmental Policy Act (NEPA). Public review and comment are required by both pieces of legislation; in fact, the public participation process was probably the most extensive ever conducted for a project in New England.

> **Information from Studies Aided in the Choice of an Outfall Site**
>
> Studies were conducted from 1986 through 1988 to provide information needed to select an outfall site. Detailed oceanographic studies were made in Broad Sound, Nantasket Bight, and western Massachusetts Bay. The MWRA considered studies conducted previously in Massachusetts Bay; collected new biological, chemical, and physical oceanographic information; and used a computer model of Massachusetts and Cape Cod Bays to predict pollutant concentrations. The model's predictions for each site were compared to State water quality standards, Federal water quality criteria, and other criteria by the Facilities Planning Citizens Advisory Committee. The model's prediction — that Sites 4, 4.5, and 5 (6½ to 9½ miles from Deer Island) had the greatest ability to dilute pollutants — was confirmed by the oceanographic field studies.

Public input to the siting process began in October 1986 when James Hoyte, the former Secretary of Environmental Affairs for Massachusetts, appointed a committee to review and comment on the Secondary Treatment Facilities Plan, of which the outfall siting was one element. The advisory committee consisted of about 27 participants drawn from government agencies, environmental groups, community officials, and other interested citizens. One subcommittee developed the criteria used in the siting process and another worked with the MWRA and its consultant in applying those criteria to areas selected as candidate outfall sites.

EPA conducted a concurrent independent site-selection process summarized in its Supplemental Environmental Impact Statement (SEIS) and depicted in Figure 1.2.

1. First, the landward boundary of acceptable sites was determined by combining the 70-ft-depth contour line (beyond which effluent would



From EPA. 1988. *Boston Harbor Wastewater Conveyance System. Supplemental Environmental Impact Statement.* Volume I. Environmental Protection Agency, Region I, Boston, MA.

Figure 1.2. Candidate sites for the outfall were narrowed down by applying a series of criteria.

receive the necessary dilution of 50 to 1) with predictions based on analyses of particle transport. Sites PR, 1, and 3 were eliminated because of poor dilution characteristics or proximity to shore.

2. Second, the seaward (eastern) boundary was defined on the basis of (1) nearfield dilution, (2) background buildup concentrations of contaminants, (3) achievement of EPA water quality criteria, and (4) outfall length. Site 6 was eliminated because its environmental advantages were too small to justify the additional expense of the longer outfall tunnel. Of the remaining sites, 2, 4, and 5 were chosen for detailed evaluation because they represented a range of conditions within the acceptable area. MWRA, however, evaluated the intermediate sites 2.5, 3.5, and 4.5.

3. Third, the remaining candidate sites were evaluated in terms of effects of primary and secondary effluent. Primary effluent was considered because it will be discharged during the interim period between completion of the outfall and completion of the secondary treatment plant. As a result of this assessment, Site 2 was eliminated because the discharge was predicted to cause unacceptable effects. The SEIS thus recommended that a diffuser be built in the area between Sites 4 and 5. Table 1.2 summarizes how the three candidate sites scored on the variety of criteria applied.

The MWRA produced a draft and a final Environmental Impact Report (EIR), and EPA produced a draft and a final Environmental Impact Statement (EIS). These were reviewed by the Facilities Planning Citizens Advisory Committee, interested citizens, Federal and State agency staff members and legislators, the Technical Advisory Group to the Executive Office of Environmental Affairs, and other scientists. The EIR, which was formally accepted by the State in a Certificate issued by then Secretary Hoyte, concluded that an outfall terminating near Sites 4.5 or 5 would be both environmentally acceptable and feasible to construct. The conclusion of the EIS, which was affirmed by EPA in its Record of Decision, was that a diffuser within an area between Site 4 and a point about ½ mile farther offshore of Site 5 would be environmentally acceptable.

The Site

The chosen site is 9½ miles offshore in 100 ft of water

The Massachusetts Bay outfall site is within the area recommended by both EPA and the State. It is 9½ miles from Deer Island, about 35 miles from Provincetown, and about 15 miles from the northwestern tip of Stellwagen Bank. Stellwagen Bank is a submarine ridge that lies along a line between Cape Ann and Cape Cod; the area around the Bank is being considered for designation as a national marine sanctuary because of its importance as a habitat for fishery species and marine mammals. The site for the end of the outfall was chosen, based on engineering studies, as a sandy area in 100 ft of water.

Table 1.2. Summary of outfall siting criteria for three candidate sites.

	Site 2	Site 4	Site 5
Tunnel length (miles)	5.3	8.1	10.2
Water depth (ft)	73	100	117
Environmental Criteria			
Ability to meet EPA water quality criteria	Good	Good	Good
Ability to meet State water quality standards	Fair	Excellent	Excellent
Avoidance of adverse sediment accumulation	Poor	Average	Excellent
Avoidance of areas of important habitat	Good	Good	Excellent
Ability to protect local species from stress	Average	Average	Good
Ability to prevent taste and odor problems	Excellent	Excellent	Excellent
Conformance with State coliform standards	Excellent	Excellent	Excellent
Maintenance/enhancement of esthetics	Poor	Good	Excellent
Protection of shoreline areas	Fair	Average	Excellent
Protection of commercial on-the-water activities	Fair	Average	Good
Protection of marine archaeology	Poor	Good	Excellent
Construction traffic and noise (depends on the length of the construction period)	Good	Fair	Poor
Engineering and Institutional Criteria			
Reliability	Excellent	Excellent	Excellent
Flexibility (ability to meet future standards)	Average	Good	Excellent
Constructability	Excellent	Good	Fair
Cost (estimated capital cost in millions of dollars)	276	389	468

Also considered were operational complexity, power needs, quantity of dredged material, timely implementation, permitting, and coordination; these criteria did not show differences among the sites.

The Outfall

The outfall system that the MWRA is building is similar to those being used in U.S. cities such as San Diego and Los Angeles and in Sydney, Australia. The major difference is that the Boston outfall must be longer than the others in order to reach deep water. Engineers who had worked on the outfalls in California and Australia helped design the Boston system.

The outfall system consists of a tunnel to tranport the effluent and a diffuser to spead the effluent out when it is discharged; the tunnel is 9½-miles-long and the 55 pipes of the diffuser make up its last 1¼ mile

The system consists of a tunnel drilled through the rock beneath the seafloor to carry the effluent offshore and a diffuser to spread the discharge over as large an area of water as possible (Figure 1.3). The system begins at Deer Island with an approximately 400-ft vertical shaft that will carry treated effluent down to the tunnel, which stretches 9½ miles out into Massachusetts Bay. The last 1¼ miles of the tunnel are intersected by 55 vertical diffuser riser pipes, each about 30 in. in diameter and topped by a diffuser cap with eight openings that release the effluent into the water, which is 100 ft deep.

Ongoing Studies Add to Knowledge about the Bay

The oceanographic studies made as part of the outfall siting process (see box, page 1-5) considerably increased scientific knowledge about Massachusetts Bay. Since 1988, the MWRA and other organizations have conducted additional studies to obtain more information about some of the more complex, less understood processes in the Bay. The siting studies and the follow-on investigations form the basis for the long-term outfall monitoring plan, which is described in Chapter 4.

The best available computer models were used in developing conservative predictions of the outfall's effects. The models considered the effects of water depth and tides, but could not adequately represent all the complexity of the real-world situation. All modeling efforts are, however, iterative. That is, they approach reality in stages, by building on previous results. MWRA's consultants are currently working with the U.S. Geological Survey to construct more realistic models and to apply them to investigate the effects of nutrient discharge from the new outfall.

None of the studies conducted to date indicates that the outfall siting decision was flawed. The MWRA has sponsored two workshops to look particularly at the question of nutrient effects, and has followed the recommendations of the scientific community in planning additional research and long-term monitoring.

Advantages of Moving the Outfall

In addition to helping Boston Harbor, models show that the new outfall will actually reduce the area of Massachusetts Bay that is influenced by sewage effluent

To meet State and Federal receiving-water standards, the discharge has to be relocated from its present position at the mouth of Boston Harbor. By moving the outfall to deeper water, more seawater is available to dilute the effluent as it is discharged. The diffuser design spreads the effluent out, increasing the dilution still more. Because it is necessary to go farther offshore to reach deeper water, the additional benefit of keeping the effluent away from beaches is realized.

For Massachusetts Bay, there is still another advantage. In its present location, the discharge affects not only Boston Harbor but Massachusetts Bay as well. Pollutants move into the Bay with each outgoing tide, and computer models show that dissolved constituents in the effluent now reach the site of the new outfall within 2 or 3 days. The increased dilution at the new site will actually decrease the concentrations of effluent contaminants throughout the

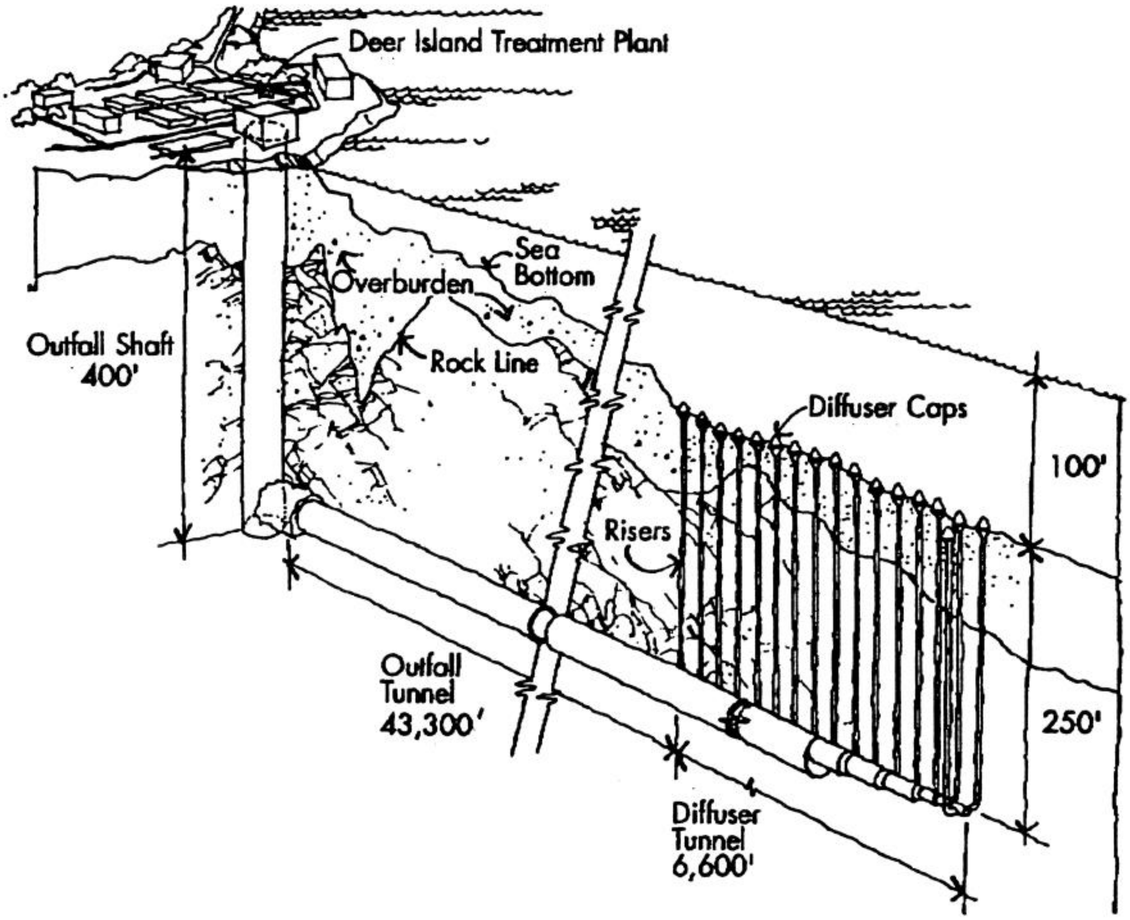
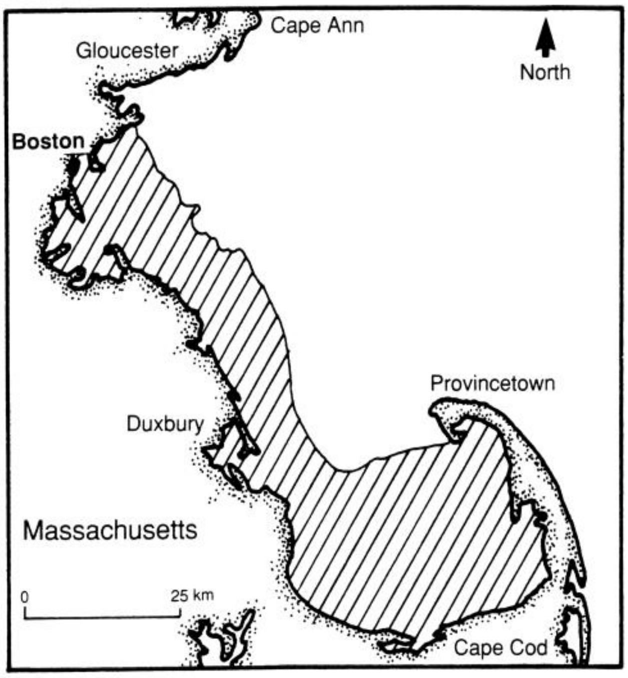


Figure 1.3. The outfall system consists of a tunnel to carry the effluent from Deer Island to the discharge site and a series of diffusers to release and disperse the material.

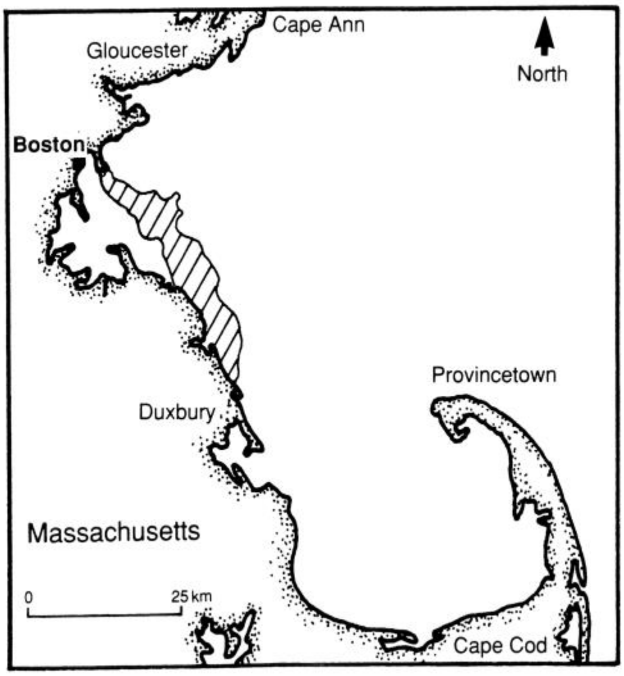
Bay, except in a small area within about 600 ft of the diffuser. That area is much smaller than the one now affected (Figure 1.4).

Conclusion

The MWRA is moving forward with all parts of the plan that the courts have mandated to meet Federal standards for sewage treatment in the Boston metropolitan area and for water quality in Boston Harbor and Massachusetts and Cape Cod Bays.



a. Predictions for discharge at President Roads, site of the present discharge, with southward current.



b. Predictions for discharge at Site 5, near the selected Massachusetts Bay outfall site, with southward current.

Adapted from MWRA. 1988. *Secondary Treatment Facilities Plan.* Massachusetts Water Resources Authority, Boston, MA.

Figure 1.4. For a conservative dissolved contaminant, concentrations near the chosen site were lower and kept to a smaller area than at the current discharge. Shading shows where dilution is less than 500-fold.

2. UNDERSTANDING WHAT HAPPENS TO THE DISCHARGE

This chapter compares what happens now — with the outfall in Boston Harbor — to what will happen when the outfall is relocated

How do we expect the new outfall to improve conditions in Boston Harbor without endangering Massachusetts Bay and Cape Cod Bay? Specific expectations for public and environmental health are addressed in Chapter 3 of this report. To answer the question, however, we must first understand where discharged material now goes and where it will go when the new outfall is in operation.

Boston Harbor is contaminated because the effluent discharges have been minimally treated, the old plants frequently failed and discharged raw sewage, and the wastewater the plants processed in the past contained high concentrations of toxic contaminants. Furthermore, sludge — the solid material removed from the wastewater during treatment — has also been discharged into the Harbor. Sources other than MWRA discharges also add to the load of pollutants in the Harbor.

Much of the material from the current discharges eventually finds its way out into the Bay. This means that improvements in treatment, dilution, and initial load of toxic materials will all combine to reduce the amount of contamination experienced in the Bay as a whole.

The situation immediately around the outfall will be determined by the initial dilution of effluent as it leaves the diffuser. Farther away, outside the zone where initial mixing occurs, the fate of effluent material will be determined by tides, currents, and wind. Information on these factors is available from past and ongoing studies and will continue to be collected and analyzed.

What Happens Now

Wastewater now receives minimal treatment and is discharged into President Roads or Nantasket Roads

At present, wastewater is minimally treated at the Deer Island and Nut Island plants before being discharged. About two-thirds of the wastewater is treated at Deer Island and discharged into President Roads, the narrow channel that lies between Deer Island and Long Island at the entrance to Boston Harbor. The remainder is treated at Nut Island in Quincy and discharged at the western end of Nantasket Roads, the other main shipping channel into the port of Boston.

Transport and Fate of Discharged Material

Because of the way water circulates in Boston Harbor, most contaminants in the effluent are soon carried into Massachusetts Bay

Boston's tides have a range of about 9 ft, which is large compared to the average depth of the Harbor, which is about 19 ft. Most of the water in the Harbor at high tide leaves with the outgoing tide and returns on the following flood tide. As a result, over a period of 8 to 9 days, most of the water in Boston Harbor has flowed out into Massachusetts Bay and been replaced with water from the Bay. Harbor water is thus said to have a *residence time* of 8 to 9 days. The existing effluent discharges into deep channels at the mouth of the Harbor have shorter residence times.

Many small islands are found in and around Boston Harbor, and the water must go around these as the tide goes in and out. Most of the water flows through the deep but narrow shipping channels of Nantasket Roads and President Roads, where the tidal currents are swift. The discharges of effluent and sludge are mixed rapidly in the swift current and spread out around the Harbor and the western part of Massachusetts Bay (Figure 2.1). Thus, most of the contaminants (toxic materials and nutrients) in the MWRA effluent could be transported to Massachusetts Bay by flushing action.

Other Sources of Pollution

Sources other than the MWRA outfall contribute contaminants to Massachusetts Bay

Figure 2.2 illustrates the sources of pollution in Massachusetts Bay for several contaminants. In addition to the MWRA outfalls, there are several other muncipalities and a few industries that have discharge permits issued under the National Pollutant Discharge Elimination System. The present MWRA discharges contribute about half the loading of copper and PAH to Massachusetts Bay. For other contaminants, such as PCBs and lead, the MWRA contribution is less than a fifth of the load. Contaminants are also carried by rivers that empty into the Harbor; by storm sewers, especially those with illegal connections to drains that carry sanitary sewage; and by overflow from CSOs. Other contamination is contributed by matter deposited from the air and carried by groundwater.

What Will Happen When the New Outfall Is in Place

Mixing Close to the Outfall

After discharge, the effluent will mix rapidly with seawater

Because effluent is mostly fresh water, it is lighter than seawater. When discharged at the bottom of the ocean, the effluent rises toward the surface. As it moves upward, it rapidly mixes with the surrounding water, spreading out horizontally and becoming diluted. This process is known as *initial mixing* or *initial dilution.* During summer, the effluent is prevented from

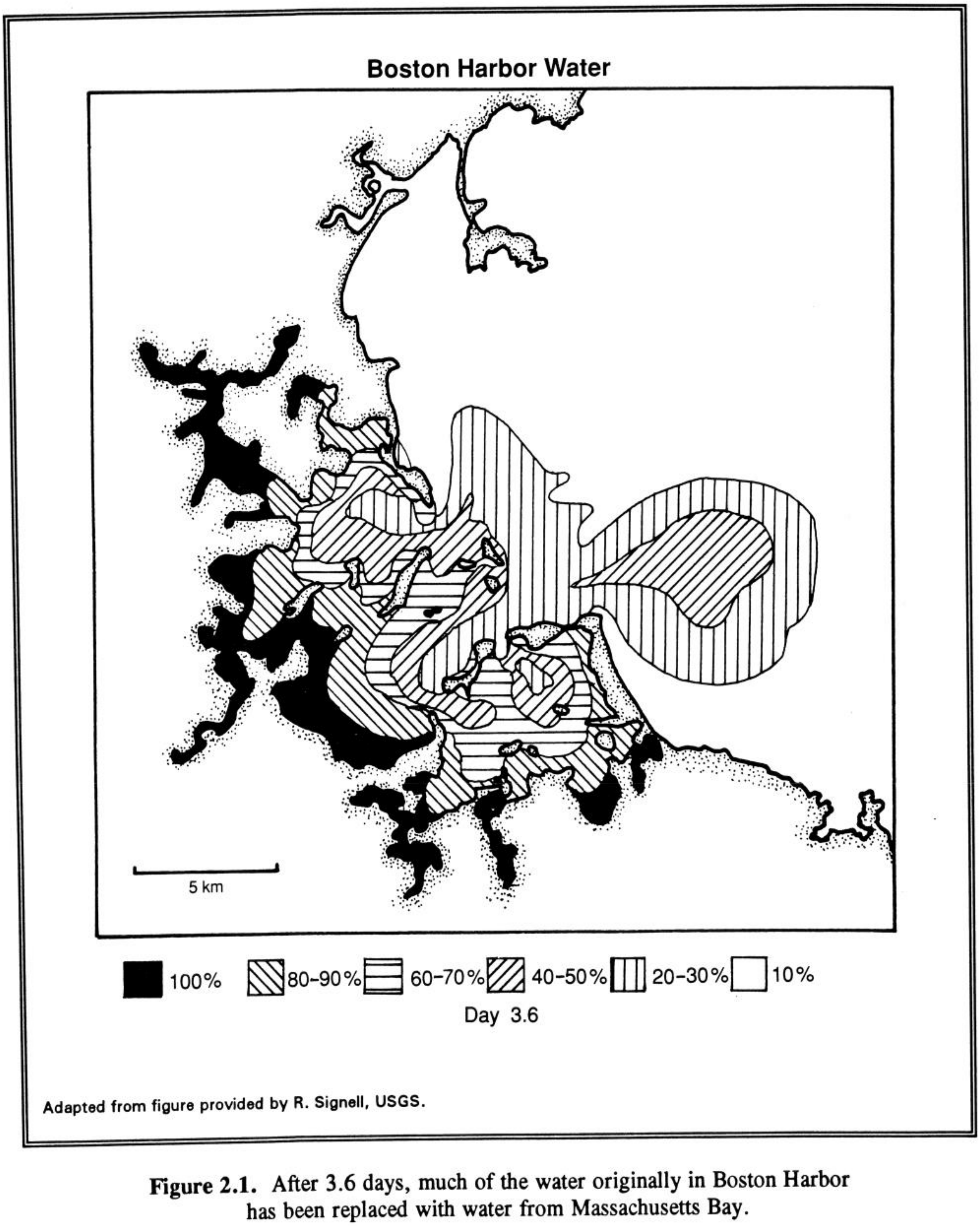
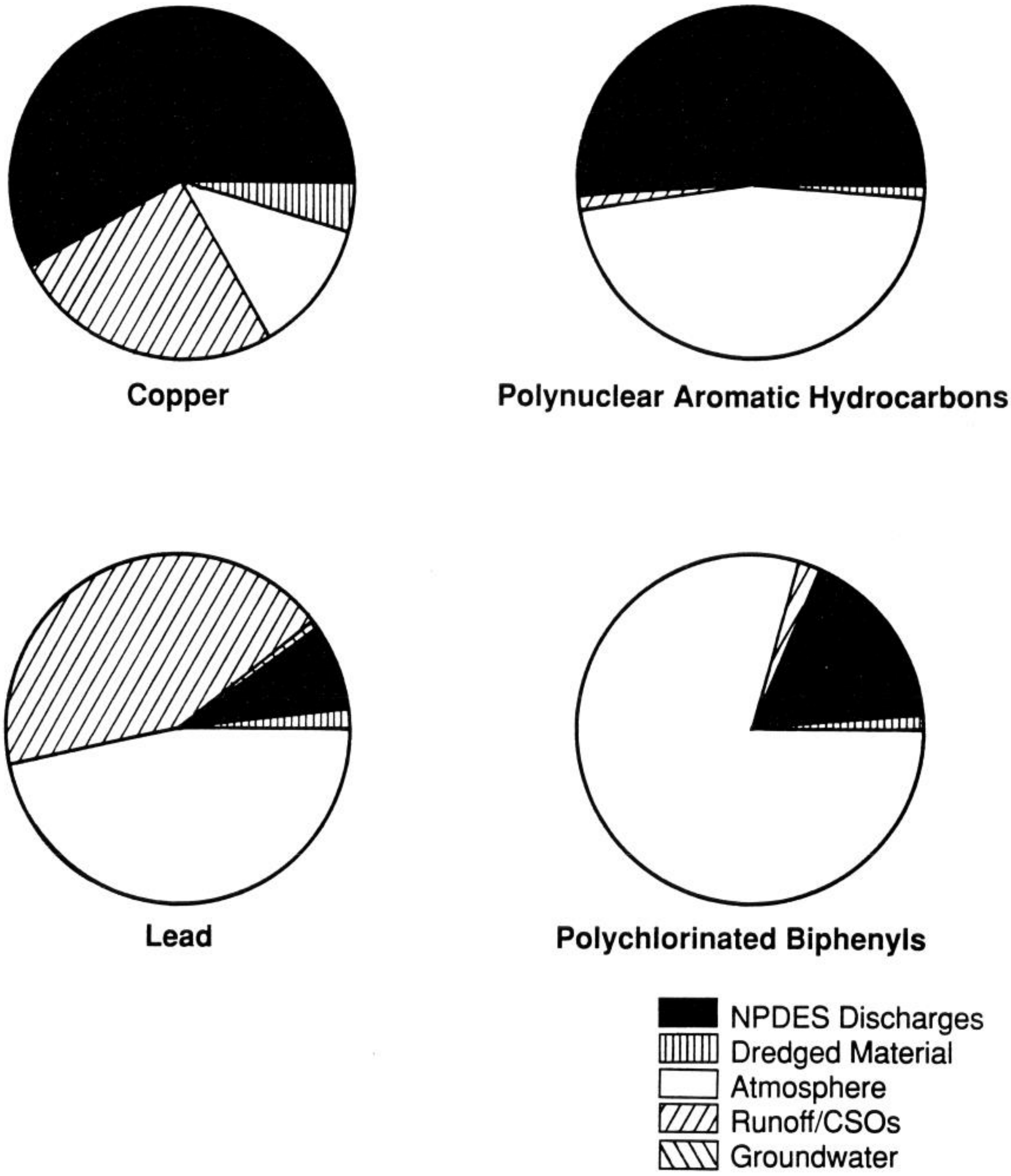


Figure 2.1. After 3.6 days, much of the water originally in Boston Harbor has been replaced with water from Massachusetts Bay.



Adapted from Menzie-Cura and Associates. 1991. *Sources and Loadings of Pollutants to Massachusetts Bay.* Report to the Massachusetts Bays Program, November 1991. Massachusetts Bays Program, Boston, MA.

Figure 2.2. A variety of sources are responsible for contamination in Massachusetts Bay, as illustrated by these examples for representative contaminants.

reaching the surface by the pycnocline — a layering of water with different densities — which acts as a barrier.

Even around the outfall, the water must meet water quality standards and be safe for fish and other passing organisms

Initial dilution from the type of diffuser the MWRA is constructing is very effective. Within about 200 ft of the diffuser, the average dilution is expected to be about 200 to 1 (200 parts seawater to 1 part effluent) and should never be less than 50 to 1. The waters around the diffuser must meet the highest standards of quality established by the State for marine waters, so the effluent cannot cause a violation of these standards outside the mixing zone. Even within this zone, the dimensions of which will be defined by EPA and the Massachusetts Department of Environmental Protection, the applicable water quality standards specify that the water must not harm fish and other organisms passing through the area. If the edges of the mixing zone were set at about 200 ft from the 1¼-mile-long diffuser, the zone would occupy an area of Massachusetts Bay equal to about one-tenth of a square mile.

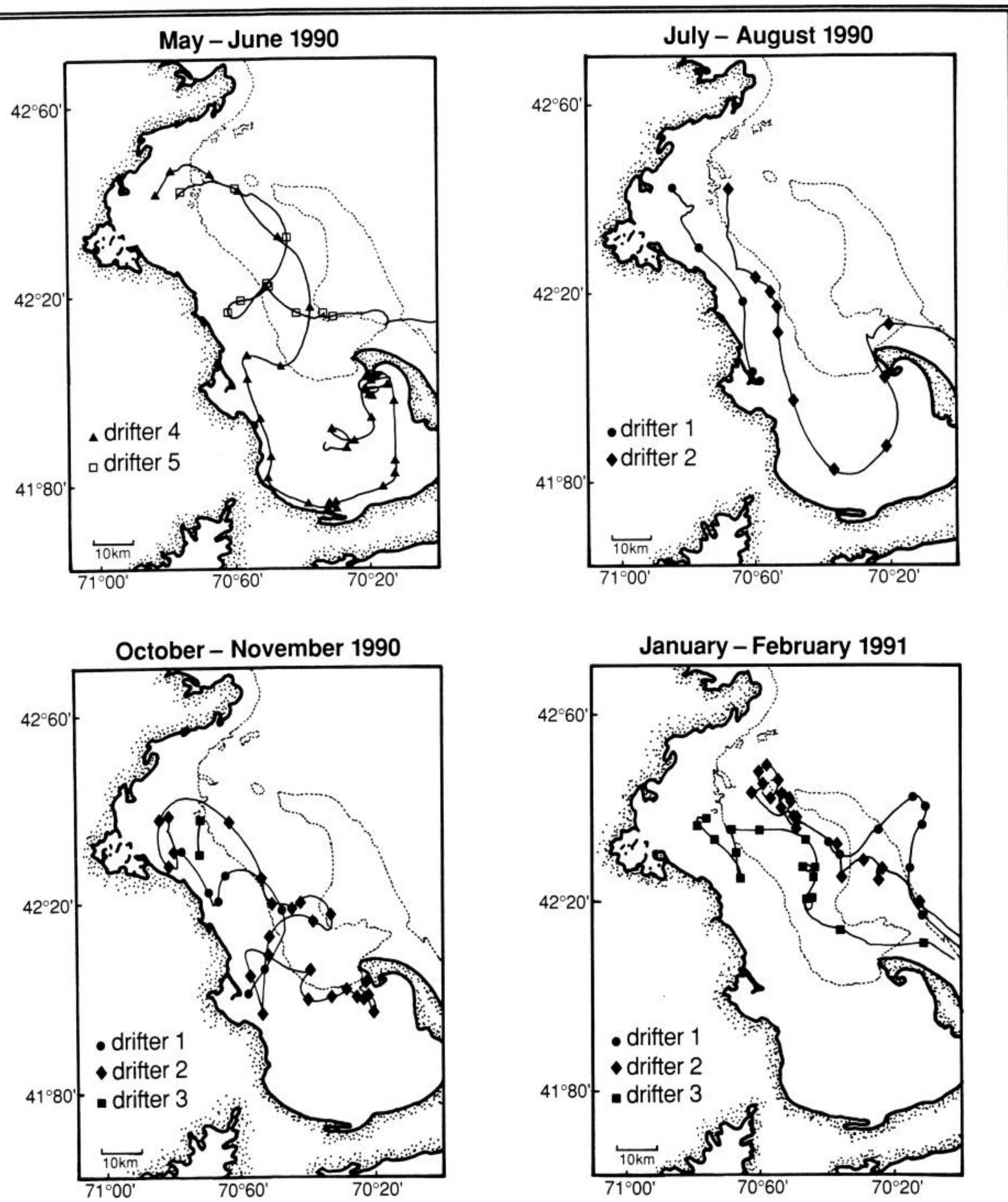
Mixing Farther from the Outfall

The flow of water is variable in direction and contributes to mixing the effluent over Massachusetts Bay

After initial dilution, the constituents of the effluent either begin to sink to the seafloor or continue to be mixed into the seawater of Massachusetts Bay. Some particles in the effluent will settle relatively near the diffuser, whereas dissolved constituents and smaller particles will be carried along with the water. The water movement in Massachusetts Bay and Cape Cod Bay is complex and still under investigation. Measurements of ocean currents in the area of the diffuser during the past 5 years show, however, that there is no strong directional pattern to the flow in that location over a few days (Figure 2.3). That is, the water is as likely to go in one direction as another, with the direction changing about every 3 days as weather systems pass over the area. This variable flow will help to mix the water around the diffuser with that in a larger area of Massachusetts Bay. For example, within 3 miles of the diffuser, dilution of the effluent will be about 400 to 1.

Studies of Water Movement

Both the MWRA and the Massachusetts Bays Program are sponsoring studies to learn more about water movement in Massachusetts Bay and Cape Cod Bay. The Massachusetts Bays Program is a cooperative Federal/State effort to protect these estuarine areas and their resources through better planning and management. It has sponsored studies conducted jointly by the Woods Hole Oceanographic Institution, the University of New Hampshire, and the University of Massachusetts/Boston, with the participation of the U.S. Geological Survey in Woods Hole. The MWRA conducted physical oceanographic investigations for the outfall siting process and is now cooperating with the Geological Survey on a long-term study of Massachusetts Bay.



Adapted from figures provided by R. Geyer, Woods Hole Oceanographic Institution.

Figure 2.3. Drifter tracks provide an indication of how the direction of surface-water flow varies over time and space. Symbols are placed at 1-day intervals.

South of the diffuser, a southward-flowing current can carry surface water to Cape Cod Bay in about 2 weeks; to the east, the current generally flows southward into Massachusetts Bay

South of the diffuser area, the nearshore circulation of southwestern Massachusetts Bay and western Cape Cod Bay is characterized by a southward-flowing coastal current. Studies using drifters, markers that tend to follow the currents, suggest that surface water can move from the Boston area to Cape Cod Bay in about 2 weeks when the coastal current is strong.

East of the diffuser, the currents are influenced by exchange with the Gulf of Maine and in particular by the plume of fresh water from the Merrimack River and rivers in Maine. The plume turns southward into Massachusetts Bay, where it can drive a clockwise current pattern during springtime periods of high river flow. At other times, the current is influenced by the wind and may be farther onshore or offshore.

Conclusion

Massachusetts Bay will not become another Boston Harbor. In fact, because much of the material now discharged to the Harbor is already reaching the Bay, we expect that conditions Baywide will actually improve. This improvement will be due to better primary and secondary treatment, the elimination of sludge from the waste stream, and a lower load of pollutants as a result of source reductions.

3. POSSIBLE EFFECTS OF THE OUTFALL: CONCERNS AND PREDICTIONS

Scientists predict that the outfall will not cause violations of government standards

What consequences could the outfall have for Massachusetts Bay and Cape Cod Bay? Public concern centers on three questions: Will it be safe to swim at beaches in these areas? Will toxic contaminants endanger human or environmental health? How will nutrients from the effluent affect the environment? EPA and MWRA scientists predict that, after the outfall is in use, conditions in Massachusetts Bay and Cape Cod Bay will meet the government standards that pertain to these concerns. In fact, except for the immediate vicinity of the outfall diffuser, conditions Baywide should actually improve.

Beach Safety

Bacterial contamination is not expected to pose a problem at beaches once the outfall is in operation

To be suitable for swimming, water must meet the State water quality standard for fecal coliform bacteria; the presence of these organisms is used to indicate the probable presence of disease-causing bacteria, or pathogens. This criterion specifies that the geometric mean number of these organisms in any representative set of samples must not exceed 200 organisms per 100 mL (about 3.5 oz) of water, and that not more than 10% of the samples may exceed 400 fecal coliforms per 100 mL. In addition to fecal coliform criteria, criteria based on the bacterium *Enterococcus* are sometimes used. For example, the Metropolitan District Commission posts Boston beaches as unsuitable for swimming if counts of *Enterococcus* exceed 33/100 mL. Figure 3.1 shows that the number of fecal coliform bacteria sampled in effluent from the existing Deer

Pathogens in Shellfish Will Not Be a Concern in Massachusetts Bay

Shellfish such as clams, oysters, and mussels are prone to contamination with pathogens because they filter particles out of the water that flows across their gills. In this way, a substantial amount of the water overlying a clam flat could be filtered in the course of a tidal cycle, and microorganisms in that water can be accumulated in the animal's tissue. If the shellfish meat is eaten without adequate cooking, pathogens can cause illness.

The factors associated with contamination of shellfish beds are the same as those for beach contamination. In brief, the effluent will meet standards for control of sewage-associated pathogens, and shellfish beds are a safe distance from other sources of contamination that cause problems in Boston Harbor. As a result, pathogens in shellfish should not be a concern in Massachusetts Bay.

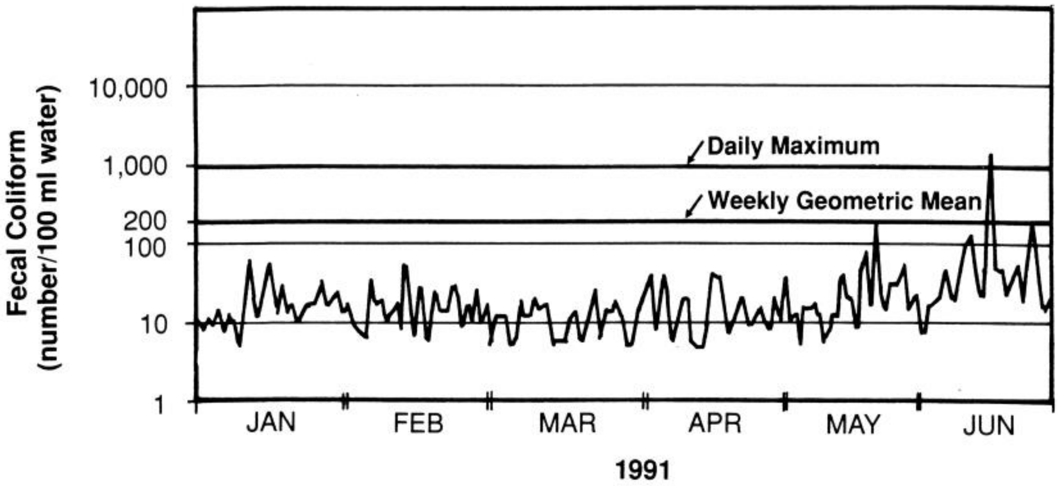


Figure 3.1. Even with current levels of treatment, MWRA effluent is generally within State standards for concentrations of fecal coliform bacteria.

Island primary treatment plant seldom exceeds the standard of 200/100 mL. This means that, even before dilution, effluent is unlikely to pose a threat to beaches because of bacterial contamination. Furthermore, the length of the new outfall tunnel provides an additional safeguard by increasing the distance between the discharge and area beaches.

At Boston Harbor beaches, the major cause of bacterial contamination has been discharge of untreated sewage. One cause of such discharge is failure and overload of the existing treatment plants. After a detailed review of the operational reliability of the recommended design for the new plants, EPA concluded in the Supplemental Environmental Impact Statement (SEIS) that safety features such as standby equipment, extra volume capacity in the clarifiers, and offsite and onsite power supply will be adequate to ensure that plant failure and overload are highly unlikely.

More often, combined sewer overflows or storm drains are the source of pathogens to Harbor beaches. For swimmers, these sources are a problem only because they are very close to beaches in the Harbor. Furthermore, improvements to the existing system have already begun to reduce the problem of untreated overflows.

Results of monitoring and computer modeling have shown that the water of Boston's Outer Harbor and Massachusetts Bay meets the bacterial standard for safe swimming now. Operation of the outfall can only improve conditions thanks to increased dilution, location of the discharge at a distance from beaches, improved treatment and bigger and more reliable treatment facilities, and absence of combined sewer overflows in the vicinity of beaches.

Toxic Contamination

Toxic chemicals such as metals and organic compounds come from both household and industrial sources

Where do toxic chemicals in wastewater come from? Industrial users of the sewage system are a major source, but we, as individuals, also put many potentially hazardous substances down our drains. Drain cleaners, spot removers, oven cleaners, and other household products can be dangerous to the environment. The major toxicants of concern are metals such as copper, mercury, and zinc, and organic compounds, especially polychlorinated biphenyls (PCB) and polynuclear aromatic hydrocarbons (PAH).

We are concerned about these chemicals because they can accumulate in the tissues of living organisms. Such contamination can pose a direct risk to those who eat seafood or — by adversely affecting the animals themselves — can threaten the welfare of the marine environment and its resources.

Comparison with Boston Harbor

Massachusetts Bay will not become as contaminated as Boston Harbor because effluent from the new outfall will carry less toxic material, the new outfall site is a more favorable disposal environment, and — since much of the contaminant load is already reaching the Bay — any increase will be small

One line of reasoning that allows us to predict that toxic contaminants from the new discharge will not present a danger to humans or the marine environment is based on a comparison between the current situation and the conditions that will prevail at the new outfall. At present in Boston Harbor, contaminant levels in tissues of lobster, mussels, and winter flounder, the most studied species, generally meet the standards established by regulatory agencies. Relevant standards are *action levels* used by the Food and Drug Administration to signal when consumption of a species should be banned or a cautionary warning should be issued, and *alert levels* proposed by the Shellfish Sanitation Program to indicate that contamination is high enough to warrant close monitoring.

Despite the fact that standards are not consistently exceeded, Boston Harbor represents the result of years of high contaminant loads discharged into a small area. In contrast, at the new outfall, conditions will be significantly better than in the Harbor. This difference is a result of two groups of factors:

1. Circumstances that lower the load of toxic contaminants in the effluent:
   - Wastewater will receive more advanced and more reliable treatment than wastewater currently discharged into the Harbor.
   - Sludge will no longer be disposed of in the marine environment, as it once was.

- Better industrial pretreatment will continue to decrease the amount of hazardous material that reaches the treatment plant.
- Household hazardous waste may be reduced in response to public education.

2. Characteristics of the outfall site that provide a more favorable disposal environment:
   - Effluent will be diluted more rapidly because the greater depth provides more seawater for initial mixing.
   - Contaminated particles will be spread more thinly because the Massachusetts Bay environment is more dispersive than Boston Harbor.

These factors, combined with the fact that, under present conditions, Massachusetts Bay is already receiving contaminants from Boston Harbor, assures us that contamination in Massachusetts Bay living marine resources will not increase appreciably as a result of the new outfall.

Predictions about Water Column Contamination

During site selection, EPA used a model to predict contaminant concentrations; new evidence suggests that the actual levels will be even lower than predicted

The SEIS prepared by EPA in 1988 as part of the process for selecting a diffuser location made certain predictions about environmental conditions at different sites. After considering the findings of the SEIS, EPA approved the choice of a site 9½ miles from Deer Island. Among the predictions were water column concentrations of selected contaminants. Table 3.1 lists SEIS predictions for water column concentrations of selected contaminants at Deer Island (the present discharge location) and at the candidate site closest to the selected site in Massachusetts Bay. The table also shows the highest concentrations allowed under water quality criteria and, for comparison, the typical concentrations reported in other coastal areas of the United States.

Now we have evidence that the predictions of concentrations of toxic contaminants in the water near the outfall were extremely conservative; that is, there is even less likelihood

EPA Sets Standards for Contaminants in the Water Column

One of the environmental criteria that will be used to assess impact of the new outfall discharge is whether conditions just outside the mixing zone comply with water quality criteria (WQC) set by EPA. Four types of criteria can be used for this comparison: EPA chronic WQC, EPA acute WQC, toxicity criteria, and 10^{-5} human-health-risk carcinogenicity criteria. The SEIS reported predicted concentrations of contaminants at the edge of the mixing zone at each potential outfall site. All sites were predicted to have some violations of criteria, with the fewest being at Site 5, which is very near the site chosen for the outfall.

Table 3.1. Predictions of violations of water quality standards are overly conservative compared to actual measurements.

Contaminant	Deer Island (Outside Mixing Zone)		Massachusetts Bay Outfall	Typical U.S. Coastal Waters	Water Quality Criteria
	Predicted	Observed	Predicted	Observed	
Arsenic	627	498	519	1500	175
Copper	10,359	301	1089	130	2900
Mercury	195	5	30	1	25
Heptachlor	6.39	0.089	0.17	0.01	2.9
Aldrin	4.48	0.05	0.11	0.01	0.79
Dieldrin	1.26	0.62	0.02	0.01	0.76
DDT	2.88	0.067	0.04	0.01	0.24
PCBs	42	7	4.14	1	0.79
Fluorene	1.44	10	8	1	311

All concentrations are expressed as parts per trillion. Water Quality Criteria represent human health criteria expressed as the 10^{-5} Risk Level, except those for copper and mercury, which represent chronic marine water quality criteria for the protection of aquatic life.

The only water quality criteria violated in Massachusetts Bay will be those for PCBs and arsenic, which are also violated throughout U.S. coastal waters

of adverse effects due to toxic contamination than previously thought. This evidence is summarized in the column of Table 3.1 that lists the *observed* values for Deer Island. Water-column predictions from the numerical models appear to overestimate concentrations of contaminants in the water column by factors as high as 50 for metals (mercury) and as high as 80 for organic compounds (aldrin). On the basis of these calculations, the only standards likely to be violated are EPA's carcinogenicity criteria (see box) for arsenic and PCBs. In addition, arsenic concentrations in mussels from Boston Harbor are no different than those in mussels from other parts of the United States, and Action Levels established by the Food and Drug Administration are not now exceeded in Boston Harbor. The water quality criteria for arsenic and PCBs (see Table 3.1) are currently exceeded at reference sites in Massachusetts Bay and throughout the world's oceans, with no corresponding adverse effects.

With respect to the spatial scale of concern for any violations of water quality criteria, any exceedences are predicted to occur very near the outfall diffuser (either within or very near the mixing zone). When the outfall is in operation, the levels of contamination to which animals will be exposed in the water column are not significantly higher than those already present, except for the small area right around the outfall.

Predictions about Sediment Contamination

Predictions about contamination in the sediment are also thought to have been too high; any toxic effects are likely to be short-lived and in a small area

Animals that live in or feed on the bottom of the Harbor or Bay are most influenced by contaminants that accumulate in the sediment. Unfortunately, no government quality criteria have yet been formulated for sediment.

The SEIS did, however, predict concentrations of effluent-derived chemicals in the sediment. To evaluate toxicity to animals, the results were then compared to concentrations reported in the scientific literature. Of the 15 constituents for which information on toxicity was available, only two [DDT and bis (ethyl-hexyl) phthalate] were predicted to occur in concentrations that would directly affect bottom-living organisms. At Site 5, the location nearest the chosen outfall site, the impacts were confined to the mixing zone (about 1.6 km^2) under primary treatment and thus were considered acceptable by EPA. No effects from sediment toxicity were predicted under secondary treatment.

These predictions are very conservative: they assume very little dilution in the sediment, very low removal during treatment, and contaminant concentrations in the effluent that may be about 100 times higher than current levels. Therefore, it is likely that no measurable toxic effects will be found in the sediments; if they do occur, these effects will be temporary, reversible, and confined to a very small area.

Nutrients

Excess amounts of nutrients such as nitrogen and phosphorus can cause adverse effects including blooms of undesirable algae

The main plant nutrients, both on land and in the sea, are nitrogen and phosphorus. On land, fertilizers containing various ratios of these two elements are used to increase production of agricultural crops, lawns, and flowers and vegetables in home gardens. In the marine environment, nitrogen and phosphorus, which are found in sewage, can also stimulate plant growth.

If too many nutrients are added to the coastal environment, problems can result. Nutrient enrichment, leading to excessive growth of algae and depletion of dissolved oxygen, is known as *eutrophication.* Even at lower nutrient levels, changes in the amount or relative composition of nutrients can alter the abundance, distribution, and mix of algae. This alteration can potentially result in an increase in undesirable species such as dinoflagellates that produce the toxin responsible for paralytic shellfish poisoning (PSP), changes in the food webs that support larger organisms such as fish, or both.

These are the issues that are of concern when we contemplate discharging nutrient-containing effluent into Massachusetts Bay.

Unfortunately, the processes associated with eutrophication and species changes are complex and, to a degree, unpredictable. For this reason, the MWRA has made gathering information about these processes a major priority. Over the past 2 years, surveys funded by the MWRA have gathered comprehensive data on nutrients and water quality throughout Massachusetts Bay. Nutrient-related issues are also a focus of the monitoring program, discussed in Section 4, designed to identify environmental changes at an early stage.

Large-scale effects of nutrients from the outfall are believed to be unlikely

Despite the inevitable element of uncertainty, there are some points that can be made about the likelihood of nutrient effects in Massachusetts Bay. It is necessary, however, to distinguish between effects on a broad, Baywide scale and those that could occur as small, localized, and transient events. In general, there are two reasons to predict that no significant Baywide changes will occur.

1. Except locally around the outfall, the new situation will not be very different from the current one. The general circumstances are the same as those outlined for toxic contaminants. In brief, nutrients from MWRA discharges are already reaching Massachusetts Bay because of conditions at the current Boston Harbor outfalls (Figure 3.2). Moving the outfall from the Harbor to the Bay will not substantially (and perhaps not detectably) increase the total amount of nutrients in the Bay. In fact, because nutrients are more likely to be dissolved than are toxic chemicals, proportionally more nutrients than toxic contaminants are probably already reaching the Bay because dissolved forms are more efficiently carried with water as the Harbor flushes. Furthermore, because the nutrients will be discharged into deeper waters below the pycnocline, some of them will never reach the sunlit surface areas where they can be used by algae.

2. Massachusetts Bay is not highly eutrophic now (Figure 3.3). An addition of nutrients would be within the range expected as a result of natural variability.

How Does the Pycnocline Affect Mixing?

In the spring and summer the water column becomes stratified; that is, divided into layers that do not mix with one another. The boundary between the top and bottom layers is known as the pycnocline.

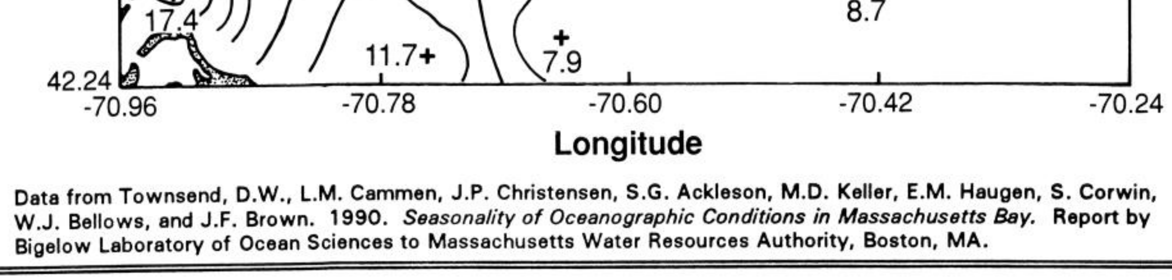
Specific problem areas are discussed in more detail in the sections that follow.

Development of Hypoxia

Hypoxia (or depletion of oxygen) — one possible result of nutrient enrichment — is only of concern when it is severe, widespread, and long-lasting

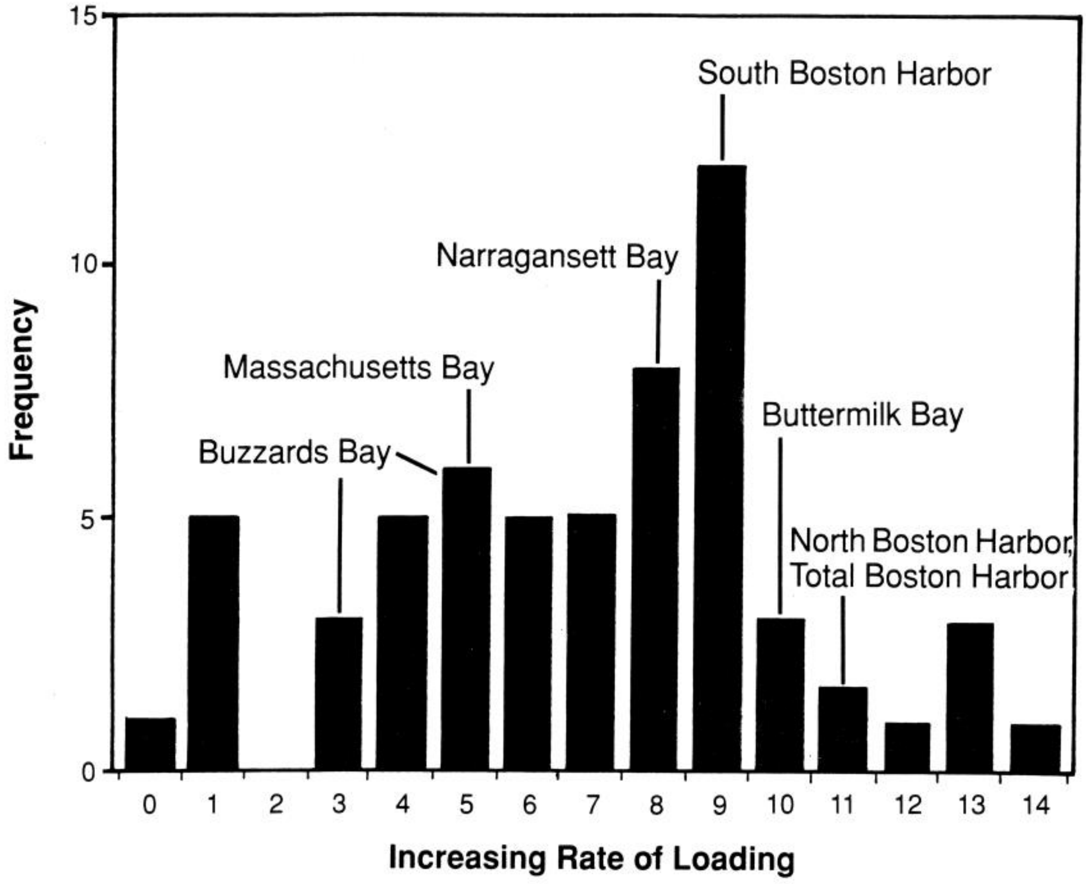
Two factors connected with the outfall could contribute to lowering concentrations of dissolved oxygen in Massachusetts Bay. Decay of organic matter consumes oxygen and, particularly in bottom waters that are isolated from oxygen exchange with the atmosphere, can deplete the supply of oxygen in the water column. When oxygen concentrations reach very low levels, the condition is known as *hypoxia*. A more severe condition, when concentrations essentially reach zero, is known as *anoxia*. Sewage effluent can add to the supply of organic matter in the marine environment in two ways. First, it can contribute organic matter directly. Most of this material is removed from sewage during treatment, but about 10% can remain in effluent. Second, it can contribute nutrients that stimulate growth of algae, which die and decay.

What are the consequences of oxygen depletion? Exposure to hypoxic conditions can be unhealthy for marine organisms that breathe oxygen dissolved in the water, but susceptibility varies from species to species. Animals such as fish, which can easily move from place to place, are unlikely to be affected unless the area of oxygen depletion is so widespread that they cannot escape it. Others, such as many shellfish, can remain in place but isolate themselves from external conditions for a period of time. These animals will not be affected unless the hypoxia is long-lasting. Some species have such short life spans that a population can quickly recover from a hypoxic event. Many bottom-living species are accustomed to fluctuations in oxygen concentration, which occur naturally, and are fairly resistant to hypoxia.



Data from Townsend, D.W., L.M. Cammen, J.P. Christensen, S.G. Ackleson, M.D. Keller, E.M. Haugen, S. Corwin, W.J. Bellows, and J.F. Brown. 1990. *Seasonality of Oceanographic Conditions in Massachusetts Bay.* Report by Bigelow Laboratory of Ocean Sciences to Massachusetts Water Resources Authority, Boston, MA.

Figure 3.2. A contour map of nitrogen concentrations (in micromoles per liter) shows that Boston Harbor (left) acts as a source radiating nitrogen into Massachusetts Bay.



Nitrogen loading values for a range of about 60 coastal ecosystems (including bays, estuaries, and seas) were plotted into a frequency distribution of classes. Each bar (class) on the histogram has a value approximately twice that of the one before it. The positions of some representative systems, including Massachusetts Bay, are indicated. The uncertainty of the loading estimate may be about ± 1 class in the midrange of the distribution and higher at the low end. Adapted from Kelly, J.R. 1991. *Nutrients and Massachusetts Bay: A Synthesis of Eutrophication Issues.* MWRA Environmental Quality Technical Report Series No. 91-10, June 1991. Massachusetts Water Resources Authority, Boston, MA.

Figure 3.3. Eutrophication (as represented by nitrogen loading) in Massachusetts Bay is not high compared to other coastal systems.

The fact that oxygen is subject to seasonal changes is important. During warm weather, hypoxia can develop naturally at the bottom of a stratified water column. Conditions of lowered oxygen concentrations have been observed in Massachusetts Bay. Such conditions are a concern only if they are severe, widespread, and of long duration.

The model predicts that even primary-treated effluent would violate State oxygen standards only once a year, under the most unfavorable conditions

Massachusetts Water Quality Standards require that the amount of dissolved oxygen in the water column not be less than 6 mg/L. The SEIS predicted the lowest oxygen concentrations that would be observed at the candidate sites under a variety of conditions. At the location closest to the final site, the model projected that the standard would never be violated during discharge of effluent that had received secondary treatment. For primary treatment, the standard was predicted to fall to 5.7 mg/L (a violation of the standard) once per year, but only if all the worst environmental conditions occurred simultaneously.

Widespread Increase in Algal Production

Evidence indicates that Massachusetts Bay nutrient levels are similar to those in other coastal areas and an increase would not have major effects

Scientists interested in the issues related to nutrients in Massachusetts Bay recently looked at how rates of production in various areas relate to the amount of available nitrogen (the most important nutrient in coastal waters). Using available data, they plotted these two pieces of information against one another and constructed a curve that gives an indication of where Massachusetts Bay stands now and what would happen if nutrients were increased. First, they found that the present situation in the Bay is in line with what is found in other coastal areas such as Buzzards Bay and Narragansett Bay. Second, they found that the rates are not at a level where an addition of nutrients would have a dramatic effect on production.

Local Blooms of Toxic or Nuisance Algae

Research on the subject of localized blooms of algae, including toxic dinoflagellates, is continuing

What cannot be entirely ruled out is the possibility of localized blooms. This is a concern primarily if the species involved is a member of a particular group of algae, known as dinoflagellates, some species of which can produce the toxins responsible for PSP. If a bloom of one of these species should occur in an area containing shellfish beds, the toxin can be accumulated in the tissue of the shellfish. Although the animal itself is not harmed, the shellfish meat is hazardous to a consumer. State monitoring of shellfish beds protects consumers by closing beds when toxins are present.

Scientists do not have precise knowledge about the interactions of factors that result in blooms of toxic dinoflagellates. PSP outbreaks have occurred in Massachusetts Bay for at least 350 years; the frequency and extent of the toxicity varies for reasons that are not well understood. Recent research indicates that toxicity in Massachusetts Bay is due to springtime blooms of toxic dinoflagellates off the coast of New Hampshire, which then move southward with the ocean currents, sometimes entering Massachusetts Bay. The dinoflagellates do not appear to grow quickly once in the Bay, in spite of nutrient inputs from the existing MWRA sewage discharges and other sources. This may be because oceanographic conditions do not favor this particular alga, and it cannot compete with other species. The nutrients from the new outfall will be trapped in the lower part of the water column at this time of year, so they may be less available to dinoflagellates and other algae than those from the present discharge. Because of these uncertainties, we cannot be certain whether PSP toxicity will become better or worse, or remain unaffected by the outfall. The outfall monitoring plan will utilize the results of ongoing research on this subject.

Another factor to keep in mind is that it is the relative proportions, not just the total amount, of nutrients that can influence what species grow most successfully. Dinoflagellates, as well as other kinds of flagellates that can be nuisance species, may outcompete diatoms, another major group of algae, if silicate (another nutrient) is not available in sufficient quantities. Sewage is relatively low in silicate, and the possibility of adding this compound to the effluent could be considered if dinoflagellate blooms should occur.

Effects of Fresh Water

Fresh water from the discharge will not lower the Bay's salinity more than a natural event such as a rainstorm

Considering that the effluent consists mostly of fresh water, should we be worried about effects of lowered salinity in Massachusetts Bay? The answer is no. The ambient salinity at the outfall site is approximately 31 ppt (parts per thousand). The discharge will be diluted about 100 times within the mixing zone. This will lower the salinity by, at most, 1% of 31 ppt, or less than 0.5 ppt; this is well within the normal range of salinity and much less than the change caused by the runoff after a rainstorm or by the intrusion of fresh water from rivers to the north (the Merrimack, for example).

Conclusion

We are confident that, when the outfall is in operation, the public will be able to swim, eat fish and shellfish, and generally enjoy the resources of Massachusetts Bay and Cape Cod Bay as well as, if not better than, they have in the past.

4. MONITORING AND MANAGEMENT

By law, effluent from the discharge must meet certain standards, and monitoring is required to keep track of conditions in the Bay

How can we be sure that any adverse effects from the new outfall will be identified and corrected? We have two types of safeguards against undesirable consequences caused by discharge from the outfall in Massachusetts Bay. First, the discharge is required by law to meet certain standards; if these standards are violated, penalties will be enacted and measures must be taken to return to compliance. Second, a monitoring program will be in place to provide information on what is happening in the environment.

The Regulatory System

State and Federal regulations govern the outfall and other treatment facilities

The new treatment facilities, of which the outfall is a part, are governed by both State and Federal regulations. They are required to comply with the Federal Clean Water Act and the State Clean Water Act. Discharge from the outfall is regulated by the conditions of a government discharge permit.

NPDES Permit

A discharge permit will set conditions that the discharge must meet; civil and criminal penalties can be enacted for violating these conditions

MWRA must obtain a permit from EPA and the Massachusetts Department of Environmental Protection in order to discharge effluent from the Massachusetts Bay outfall. This permit is issued through the National Pollutant Discharge Elimination System (NPDES) established under the Federal Clean Water Act.

The NPDES permit will regulate the type and amount of pollutants that can be discharged into Massachusetts Bay. Both National effluent limits and State water quality standards are used to determine the limits defined in the permit. A typical NPDES permit includes specific provisions for limitations on pathogens, solids, organic content, and biological toxicity.

The National effluent limits were established by EPA on the basis of the pollutant-removal technology available for a given industry. They are the same regardless of the quality of water that State regulations require in the receiving body (that is, the environment in which the discharge takes place).

Unlike the National limits, limits based on water quality standards depend upon how the State has classified the receiving water. Massachusetts Bay is classified SA — the most highly protected category. Effluent limits in the

NPDES permit must ensure that Massachusetts Bay waters continue to meet the standards for SA waters.

Noncompliance Penalties

The MWRA will be bound by the limits set on its effluent in the NPDES permit. If the MWRA fails to comply with any of the permit conditions, it will be in violation of the Clean Water Act and will be subject to enforcement action. Available penalties include both civil and criminal action. Civil penalties include fines as high as $10,000 for each day the violation continues. EPA can also revoke or modify the permit.

The Monitoring Program

The law also requires MWRA to monitor conditions in the environment

Monitoring will provide the information needed to judge whether the discharge is in compliance with the conditions specified in its permit. As a further safeguard, the monitoring is also designed to verify that the impact of the discharge on the environment is within the bounds predicted by the SEIS.

Any environmental monitoring program involves the collection and analysis of samples to keep an eye on what is happening. This program will measure the loading, movement, and impact and fate of matter discharged from the outfall. When necessary, special studies will be conducted to help interpret the data.

Design and Approval Process

To oversee development of a suitable monitoring program, a Task Force of independent advisors was appointed by the Executive Office of Environmental Affairs

When EPA and the Massachusetts Executive Office of Environmental Affairs, in separate documents, approved construction of an outfall in Massachusetts Bay, both documents spelled out requirements for a monitoring program. The required program is being developed by the MWRA Outfall Monitoring Task Force, which is made up of representatives of

The Monitoring Plan Task Force Represents a Spectrum of Interests

Assoc. for the Preservation of Cape Cod
Center for Coastal Studies
Environmental Protection Agency
Harvard University
Independent Scientific Consultants
Massachusetts Bays Program
Massachusetts Coastal Zone Management
Massachusetts Dept. of Environmental Protection
Massachusetts Div. of Marine Fisheries
Massachusetts Environmental Policy Act Office
Massachusetts Water Resources Authority
Safer Water in Massachusetts
University of Massachusetts
U.S. Army Corps of Engineers
U.S. Geological Survey
U.S. House of Representatives Committee on Merchant Marine and Fisheries
Woods Hole Oceanographic Institution

environmental agencies, academic and scientific organizations, and public interest groups. The MWRA is also represented, but it has no voting privileges.

The Task Force has the ability to seek advice outside its membership. For example, a workshop was recently held to discuss nutrient-related issues. The participants recommended that monitoring be extended farther from the outfall than originally planned and named specific effects that should be studied. These recommendations have been incorporated into the monitoring plan.

The monitoring plan must be approved by State and Federal environmental agencies and will be periodically reviewed by the Task Force

When completed, the monitoring plan must be approved by EPA and the Massachusetts Executive Office of Environmental Affairs. Monitoring will be carried out by scientists who will follow protocols established to ensure that data are consistent and legally supportable. The Task Force will review the program regularly to assess its progress and consider whether any adjustments should be made — for example, to focus more effort on a particular environmental effect.

Centralized coordination of the program is needed as a further safeguard that results are reliable and to make sure that the data are disseminated quickly. The MWRA will fill that role because it is legally required to conduct monitoring and because its own need for information to guide treatment operations will ensure rapid processing of the data. In addition, several mechanisms are already in place to review the MWRA environmental studies for sensitivity to public concerns, cost effectiveness, and objectivity. Periodically, the results of the monitoring will be presented to the public and the scientific community at meetings organized by the New England Aquarium and the Massachusetts Bays Program.

Baseline Monitoring

Results of baseline studies will be used as a comparison point to detect any changes that occur after discharge begins; these studies are described in an MWRA document

The monitoring program is designed to detect change — change in the Massachusetts Bay environment as a result of the effluent discharge. Change can be detected only by comparing one set of conditions with another set; in this case, conditions in Massachusetts Bay before and after the outfall begins operating. In environmental monitoring programs, the *before* conditions are known as the *baseline.*

The MWRA, with the guidance and participation of the Outfall Monitoring Task Force, has produced a document titled *Massachusetts Water Resources Authority Effluent Outfall Monitoring Plan Phase I: Baseline Studies.* That document provides details of a monitoring strategy to describe baseline conditions in Massachusetts Bay so that changes can be detected and related to the outfall after the effluent discharge begins in 1995. The strategy provides for the detection of meaningful changes at levels far below, and thus in advance of, those that could be of great concern.

The Concept of Meaningful Change

The monitoring plan will specify the type and magnitude of change that should be tracked

The term *meaningful change* is used in the monitoring plan in recognition of the fact that not every possible change can, or should be, identified. The biological, chemical, and physical measurements called for in the Phase I monitoring plan were carefully chosen to make it possible to track appropriate features of the offshore environment. A feature was considered appropriate for tracking if it is an important general public concern or is specifically covered by government regulations.

In the context of a monitoring program, the magnitude of the change, as well as its nature, is important. In designing a sampling strategy, consideration must be given to what magnitude of change is expected and necessary to detect. In some cases, regulatory standards specify this information, in others it can be predicted from experience and preexisting data, and in still others it will have to be developed as the baseline study proceeds.

Monitoring Questions

Specific questions are being developed to ensure a scientifically valid monitoring design that addresses public concerns

Monitoring programs, like other types of scientific investigation, are most valid when they are designed to answer specific questions. The questions, known as *testable hypotheses,* must be formulated so that they can be answered yes or no. Furthermore, the answers must be available, at least theoretically, on the basis of the type of data that will be collected.

Design of the baseline monitoring plan began with the general concerns expressed by the public about the effects of the outfall on the environment. These were then combined with the requirements of the regulatory system and reorganized, on the basis of scientific studies and past experience with coastal waters, into four categories:

- Enrichment — of nutrients, organic carbon, and suspended particles
- Exposure of marine life and humans to toxic chemicals
- Exposure of marine life and humans to pathogens
- Visual (esthetic) degradation of the water.

The categories, representing types of perturbation that could occur in the environment as a result of human activities, were then used to derive more specific questions that can be addressed through monitoring. These questions are still a step away from being the final hypotheses required for the monitoring plan. The plan's designers need more information before they can make the quantitative predictions necessary to formulate truly testable hypotheses. The questions were, however, sufficient to decide on measurements to provide appropriate data.

These Possible Environmental Responses, Posed as Questions, Will Be Used To Derive Specific Hypotheses

Public Concern: Is it safe to eat fish and shellfish?

Perturbation: *Toxics*

R-1 Will toxic chemicals accumulate in the edible tissues of fish and shellfish, and thereby contribute to human health problems? (see also R-7)

Perturbation: *Pathogens*

R-2 Will pathogens in the effluent be transported to shellfishing areas where they could accumulate in the edible tissue of shellfish and contribute to human health problems?

Public Concern: Are natural/living resources protected?

Perturbation: *Enrichment*

R-3 Will nutrient enrichment in the water column contribute to an increase in primary production?

R-4 Will enrichment of organic matter contribute to an increase in benthic respiration and nutrient flux to the water column?

R-5 Will increased water-column and benthic respiration contribute to depressed oxygen levels in the water?

R-6 Will increased water-column and benthic respiration contribute to depressed oxygen levels in the sediment?

R-7 Will nutrient enrichment in the water column contribute to changes in plankton community structure (species composition, biomass, and vertical distribution)? Such changes could include stimulation of nuisance or noxious algal blooms and could affect fisheries (see also R-1 and R-15).

R-8 Will benthic enrichment contribute to changes in the community structure (species composition and biomass) of soft-bottom and hard-bottom macrofauna, possibly also affecting fisheries?

Perturbation: *Toxics*

R-9 Will the water column near the diffuser mixing zone have elevated levels of some contaminants?

R-10 Will contaminants affect some size classes or species of plankton and thereby contribute to changes in community structure (species composition, biomass, and vertical distribution) and/or the marine food web?

R-11 Will finfish and shellfish that live near or migrate by the diffuser be exposed to elevated levels of some contaminants, potentially contributing to adverse health in some populations?

R-12 Will the benthos near the outfall mixing zone and in depositional areas farther away accumulate some contaminants?

R-13 Will benthic macrofauna near the outfall mixing zone be exposed to some contaminants, potentially contributing to changes in community structure (species composition and biomass)?

Public Concern: Is it safe to swim?

Perturbation: *Pathogens*

R-14 Will pathogens in the effluent be transported to waters near swimming beaches, contributing to human health problems?

Public Concern: Are esthetics being maintained?

Perturbation: *Visible Degradation*

R-15 Will changes in water clarity and/or color result from the direct input of effluent particles or other colored constituents, or indirectly through nutrient stimulation of nuisance plankton species (see also R-7)?

R-16 Will the loading of floatable debris (e.g., plastics) increase, contributing to visible degradation?

Provisions for Measurements

Monitoring will take place at sites throughout Massachusetts and Cape Cod Bays as well as around the diffusers; a variety of measurements will be made

Measurements will be concentrated in the area immediately around the diffusers (in the nearfield), where changes are predicted to be most likely (Figure 4.1). But sampling is not limited to the immediate area; stations extend into most distant areas of Massachusetts Bay and into Cape Cod Bay (in the farfield), where changes are less likely because the effluent becomes progressively more diluted.

Monitoring will include routine measurements of the following:

- Effluent chemical contaminants and toxicity
- Nutrients and algal species and biomass in the water column (both in the nearfield and at farfield sites throughout Massachusetts and Cape Cod Bays)
- Sediment contaminants and biological communities in the nearfield for biological and chemical changes and in the farfield in areas where long-term focusing of particles is expected and at sites throughout Massachusetts and Cape Cod Bays
- Fish and shellfish contamination and health indices (for example, the prevalence of tumors) in Massachusetts and Cape Cod Bays.

Special studies will investigate water circulation, effluent plume tracking, and special aspects of the fate of toxic chemicals and nutrients.

Many Different Sampling Activities Will Be Conducted under the Monitoring Plan

Effluent
Toxicity tests and pathogens
Chemical and physical analysis (NPDES)

Water Column
Nearfield water quality cruises
Farfield & biology/productivity cruises
Continuous dissolved oxygen

Soft-Bottom Benthos
Surveys
Sediment profile camera imaging
Biology
Chemistry

Tissue Contamination
Winter flounder
  Histopathology
  Chemistry
Lobster
  Histopathology
  Chemistry
Caged mussel chemistry

Special Studies
Water circulation and particle fate
Sewage tracer survey
Benthic nutrient flux/oxygen demand
Hardbottom biology
Plume studies
Detailed effluent characterization
Modeling
Other special studies

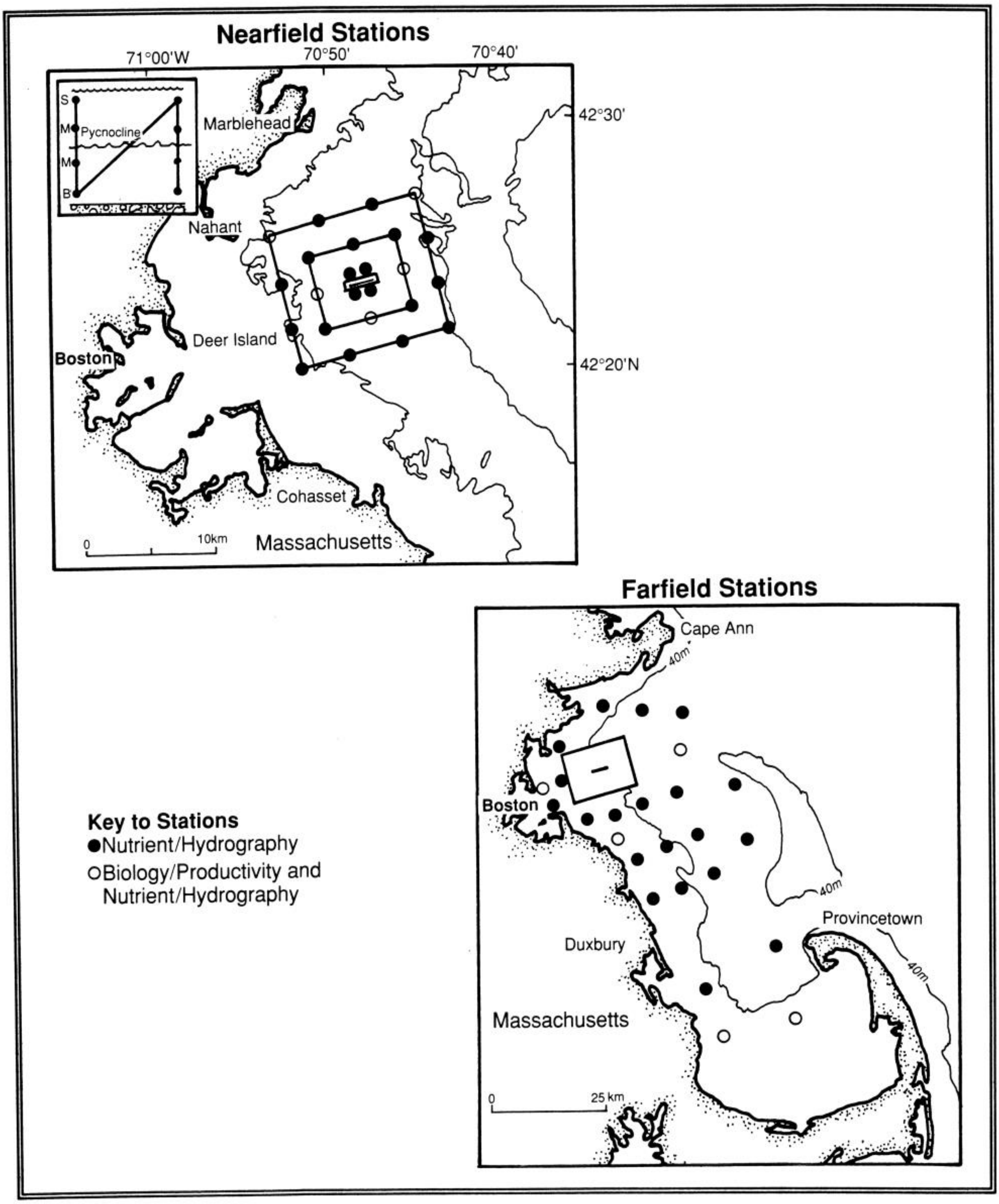


Figure 4.1. These stations will be sampled for nutrient enrichment. The Phase I monitoring plan contains similar maps for other types of measurement.

The Review Process for the MWRA Monitoring Program

The State is developing a review process and addressing other issues that concern policy rather than technical aspects of monitoring

The Phase I monitoring plan focuses on the technical elements of monitoring. It contains a set of proposed questions and measurements to satisfy the requirements of the discharge permit, provide a statistical baseline adequate to assess postdischarge impact, and address other technical and public concerns expressed by the Outfall Monitoring Task Force. As a companion to this Phase I monitoring plan, the Massachusetts Executive Office of Environmental Affairs is developing a review process for the MWRA monitoring program. Policy issues such as mechanisms for making management decisions related to monitoring will be addressed as part of the review.

Postdischarge Monitoring

Once the outfall is in operation, postdischarge monitoring will begin; exact plans will depend on baseline results and permit conditions

The second phase of the monitoring program will begin once the outfall in Massachusetts Bay begins discharging effluent and will continue as long as the outfall is in operation. A plan for this postdischarge monitoring will be developed on the basis of results from the baseline monitoring and the specific provisions of the NPDES permit. A third phase may also be implemented and would be based on any detectable changes that indicate the need for additional monitoring.

Conclusion

MWRA monitoring results will expand scientific knowledge needed to successfully manage all resources in Massachusetts and Cape Cod Bays

The immediate goal of the MWRA outfall monitoring program is to enable detection of effects caused by the discharge of effluent from the outfall. But long-term management of coastal resources is a complex task not limited to regulation of discharges from a single sewage treatment plant. The real challenge is to manage all discharges into the offshore environment and control the harmful effects of all human activities around Massachusetts and Cape Cod Bays. Organizations such as the Massachusetts Bays Program have accepted that challenge. Information from the MWRA monitoring program will serve a broader goal when it is integrated with other sources of data and used to produce a Comprehensive Conservation and Management Plan for the Bays. The MWRA monitoring plan will place another tool in the hands of those responsible for preserving and protecting Massachusetts Bay and Cape Cod Bay.

Acknowledgments

This report is part of the Environmental Quality Department's continuing effort to give the public accurate technical information about the MWRA's activities. This effort is headed by Dr. Michael Connor, Director of the Department.

We wish to thank Ms. Victoria Gibson for her efforts to translate complex technical issues into a form understandable by the nonspecialist. Material for the report was written by MWRA staff, especially Ms. Wendy Smith and Dr. Michael Mickelson, and by Battelle scientists Dr. Damian Shea and Dr. Jack Kelly, as well as by Ms. Gibson. Graphics were produced by Ms. Helen Vickers of Graphics Plus.

Special thanks are due to the many people, both inside and outside the MWRA, who reviewed the report and made suggestions that improved both its technical accuracy and its readability. Members of the Outfall Monitoring Task Force received an earlier draft of the report for comment.

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