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Combined Sewer Overflow Receiving Water Monitoring: Boston Harbor and Its Tributary Rivers

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Massachusetts Water
Resources Authority

Environmental Quality Department
Technical Report No. 93-4

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by
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Environmental Quality Department
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Executive Summary

Background

This report summarizes water quality measurements in areas of Boston Harbor and its tributary rivers (the Mystic, Charles, and Neponset) affected by combined sewer overflows (CSOs). The work is a continuation of a sampling study begun in 1989, and represents an intensive monitoring effort--with the analysis of approximately 2,000 samples and 10,000 measurements of water quality collected between October 1990 and September 1991.

Although a major purpose of this study was to satisfy the CSO receiving water monitoring requirements of the Massachusetts Water Resources Authority's (MWRA) National Pollution Discharge Elimination System (NPDES) permit, this is the third year of a long-term monitoring program to measure changes over time as pollution abatement projects are implemented. Although a CSO Facilities Plan has not yet been implemented, other projects and activities which cumulatively have had significant effects on water quality have been implemented over the past three years. These include the construction and operation of CSO treatment facilities at Fox Point and Commercial Point, the continued detection and elimination of illegal sewer connections to storm drains, continued construction of separate storm and sanitary sewers, improved maintenance of CSO tidegates and regulators, increased pumping capacity at the Deer Island Treatment Plant, improved chlorination at Deer Island, the shutdown of the large CSO on Moon Island, and the cessation of sludge disposal in the harbor.

In some areas studied for this report, the data still reflect "before," or baseline water quality conditions. In other areas the data reflect changing environmental conditions.

The important elements of the design of this monitoring program were

1. The receiving waters of all the CSOs in the greater Boston area were included--tributary rivers, the inner harbor, and the outer harbor, regardless of the municipal ownership of the discharges. Thus the effects of CSOs belonging to different municipalities but discharging into the same bodies of water could be understood in an integrated way.

2. The monitoring emphasized measuring the densities of sewage indicator bacteria (fecal coliform and *Enterococcus*) and dissolved oxygen levels. This is because fecal coliform, the bacteria present in raw sewage, have presented the most egregious violations of water quality standards. The primary public concern about CSOs is the potential danger to public health from infectious disease because of exposure to sewage-contaminated water during swimming, and the contamination of shellfish beds.

3. Frequent (daily) sampling at each location enabled us to measure short term changes in water quality during dry and wet weather.

4. The large number of sampling stations allowed assessment of spatial variation within a body of water, including sites both near CSOs and distant from CSOs.

5. The data analysis incorporated anthropogenic and natural environmental factors, to help determine the relationships among variables that affect water quality. Thus the effects of flows and loads through wastewater and CSO treatment facilities were considered, as well as rainfall, tide, water temperature, and salinity.

Results from Five Geographic Areas

One difference between this report and the first CSO monitoring report is that Quincy Bay is not included here. Because the Moon Island CSO was shut down, there were no CSOs discharging into Quincy Bay during this monitoring period. Water quality monitoring in Quincy Bay will be reported in a separate document, along with results from other studies ("before" and "after" bacterial monitoring in the former sludge plume, water quality in Hingham Bay and the Fore River).

CSOs affect a large area, discharging along the shoreline into streams, rivers, estuarine areas, shipping channels, and bathing beaches throughout metropolitan Boston. Since it was not possible to sample all bodies of water simultaneously, the CSO receiving waters were divided into five geographic areas: the inner harbor, Dorchester Bay and the Neponset River, the Charles River, the Alewife Brook and Mystic River, and Constitution Beach. Summaries of the results from each area follow.

Inner Harbor

This area includes the inner harbor from the mouth of the Charles River seaward inside a line from the southern tip of Governor's Island to Fort Independence. The biggest flows are from a large CSO (BOS-070) at the head of Fort Point Channel, from the Prison Point Treatment Facility (MWR-203) located at the mouth of the Charles River, and from the Somerville Marginal Treatment Facility (MWR-205) located at the mouth of the Mystic River.

Bacterial contamination of the inner harbor was associated with rainfall, and the level of contamination varied among different areas of the harbor. The inner harbor was impacted by discharges of sewage after a moderately heavy rainfall, with the degree of bacterial pollution varying dramatically at different locations. The areas most affected by rain-associated bacterial contamination were near large CSOs (Fort Point Channel and the Mystic River) and near the mouth of the Charles River. These geographic differences are illustrated by comparing statistical (regression) analyses of the relationship between bacteria counts in the water and rainfall at two different locations in the inner harbor. In Fort Point Channel, about one-quarter of an inch of rain would, on average, raise the fecal coliform count above the 200 colonies/100 ml water quality standard, while at the mouth of the inner harbor, near the airport, it would, on average, take more than two inches of rain before fecal coliform counts would exceed standards. The greater the distance from the rivers and large CSOs, the less contaminated were the harbor's waters. The effect of rainfall was cumulative over time, with the numbers of sewage bacteria in the water correlating best with the amount of rain falling the same day plus the previous two days.

Stations located very close to the two largest CSOs in the Mystic River and in Fort Point Channel never met the 200 colonies per 100 milliliter fecal coliform standard, but 50%-75% of the samples collected at stations located in the main ship channel did meet this standard. High counts caused by wet weather discharges prevented any location in the inner harbor from meeting the Massachusetts swimming standard for marine waters (90% of the samples should have fewer than 400 colonies of fecal coliform per 100 milliliters).

Low dissolved oxygen levels are a problem in some areas of the inner harbor. Levels of dissolved oxygen in the bottom waters were chronically below standards near the Somerville Marginal Outfall in the Mystic River, and were below standards in more than 25% of the measurements at the mouth of the Charles River and in Fort Point Channel. Hurricane Bob was followed by dissolved oxygen levels substantially lower than normal even at the water's surface, presumably because oxygen-using sediments were stirred up from the bottom into the water.

The patterns of relationships among rainfall, salinity, tidal currents, and sewage indicator bacteria counts are all consistent with combined sewer overflows as a major source of sewage to the surface waters of the inner harbor. Bacteria counts in the bottom waters at the mouth of the inner harbor show different patterns with rainfall and tidal currents, suggesting a different source of contamination to these waters, perhaps sludge.

Neponset River and Dorchester Bay

This area includes northern Dorchester Bay (Old Harbor), southern Dorchester Bay, and the lower Neponset River. Sampling stations included sites near the CSOs along Carson Beach, near the two largest CSOs in Dorchester Bay (Commercial Point and Fox Point), offshore, and in the Neponset River.

Levels of bacterial contamination varied greatly at different locations in Dorchester Bay. As was true for the first monitoring period (1988-1990), beaches off South Boston and the waters of Old Harbor were the least contaminated areas, generally meeting water quality standards for swimming. The most severely contaminated areas were in southern Dorchester Bay and the Neponset River.

Two new CSO treatment facilities in southern Dorchester Bay have significantly improved water quality. Since the Fox Point and Commercial Point CSO screening and chlorination facilities began operating in 1990 (Fox Point) and 1991 (Commercial Point), average fecal coliform counts at sites near those outfalls have decreased dramatically. At two nearby beaches, Tenean Beach and Malibu Beach, the proportion of water samples that exceeded the fecal coliform standard for swimming decreased steadily from 1989 through 1991.

Bacteria counts at different Dorchester Bay beaches have different relationships with rainfall. Fecal coliform counts at South Boston beaches are correlated with rainfall, consistent with CSOs as the source. The relationship between rainfall and bacteria counts is less consistent at Tenean Beach. Although rainfall is associated with high bacteria counts at Tenean Beach, elevated counts also occurred during dry weather. Potential sources of contamination in addition to the Fox Point and Commercial Point CSOs include the Neponset River or nearby Pine Neck Creek.

Charles River

In the Charles River, no CSOs are located upstream of the Watertown Dam. Although 22 CSOs are identified and permitted, most of the overflow points do not, in fact, discharge. Most of the combined sewage entering the Charles River is screened and chlorinated at the Cottage Farm CSO Treatment Facility. Combined sewage is also screened and chlorinated at the Prison Point Treatment Facility and discharged into the inner harbor at the mouth of the river, downstream of the Charles River Dam. The Muddy River/Stony Brook is a significant source of contaminated stormwater and untreated combined sewage to the river.

CSOs and non-CSO sources contribute significantly to bacterial pollution in the Charles. Wet weather sampling near the Cottage Farm and Prison Point discharges showed that sewage bacteria were not higher near those discharges than at upstream locations, indicating effective chlorination of the discharges. The Stony Brook is a significant source of pollution from stormwater and some CSOs in the Charles. Aesthetic degradation of the Charles Rivers results from sewage slicks and floatables discharged from the Cottage Farm Treatment Facility and untreated CSOs. On average, water in the Charles did not meet state fecal coliform standards in any weather condition. Not only were the swimming standards exceeded, but the less stringent water quality standards for recreational boating were typically not met. Rainfall-related but non-CSO sources to the river, such as contaminated stormwater, are significant contributors to the degradation of the Charles River.

Low dissolved oxygen levels in the bottom waters of the Charles River Basin remain a problem. While dissolved oxygen levels measured at the surface of the river were generally within water quality standards, the bottom waters of the basin were virtually anoxic and dead because entrained salt water prevents more oxygenated waters from reaching the bottom. Although this year's monitoring did not coincide with a discharge from Cottage Farm of the magnitude observed in previous years' monitoring, the occasional discharge of large quantities of organic matter is likely to continue to exacerbate dissolved oxygen problems in the river.

Mystic River/Alewife Brook

The main CSO inputs into the Mystic River are from discharges into the Alewife Brook, which flows into the upstream Mystic; and from the Somerville Marginal Treatment Facility, which discharges just downstream of the Amelia Earhart Dam at the mouth of the river.

Alewife Brook remains one of the most polluted streams in the greater Boston area. It receives flow from storm drains and CSOs, and is impacted upon by industrial pollution well. Monitoring this year continued to confirm that the stream is grossly polluted, with average sewage indicator bacteria levels during wet weather as much as 10 times higher than standards.

The freshwater segment of the Mystic River is affected by sources of sewage indicator bacteria other than CSOs. The freshwater segment of the Mystic River is upstream of the Earhart Dam. Bacteria counts near potential CSO discharges were similar to counts upstream of the Alewife Brook confluence and upstream of all CSOs. On average, bacteria counts in this section of the river met water quality standards during this relatively dry monitoring period. In the marine segment of the Mystic River, average sewage indicator bacteria counts near the Somerville Marginal Outfall were higher than water quality standards. Average counts at this location were very similar during both wet and dry weather. Thus, while disinfection of wet weather discharges from the Somerville Marginal Treatment Facility effectively reduced the load of bacteria into the water, some dry-weather sources of sewage to this area remained.

In the Mystic River, levels of sewage indicator bacteria were generally not significantly different in 1991 from 1990.

Constitution Beach

Constitution Beach, located in Orient Heights near the Logan Airport, is in many ways a microcosm of the pollution problems affecting Boston Harbor beaches. Before a CSO screening and disinfection facility began operations in March 1987, untreated combined sewage was discharged near the swimming area during rainstorms, causing high bacteria counts in the water and beach closures. After the CSO treatment facility began operating, problems with beach contamination were reduced, but not eliminated. A sampling study in 1989 revealed that a large storm drain emptying at the beach was a significant source of bacteria to the beach. The Boston Water and Sewer Commission found that the sanitary sewers from many neighborhood residences were connected to the storm drain rather than to the sewer system. After these improper connections were repaired, contamination at the beach decreased even further. Continuing inspection of the storm drains has been revealing more illegal sewer connections, and as these are located and repaired, the water quality at the beach should continue to steadily improve.

Overview

Despite the large amount of variation in water quality among the different areas studied, as well as local variation within each body of water, there were some general trends.

- The areas least contaminated by sewage indicator bacteria were generally the most distant from shore. As noted last year, CSOs and other near-shore sources are the most significant sources of untreated sewage to Boston Harbor. This reflects the more effective operation of the two sewage treatment plants, whose offshore discharges at one time were responsible for high levels of sewage indicator bacteria in the outer harbor.

- The areas with the worst bacterial contamination were the rivers and localized areas in the inner harbor. CSOs particularly impacted upon Fort Point Channel, the lower Charles River Basin, Alewife Brook, the upper Mystic River, and the marine portion of the Mystic River. Additional sources of pollutants, such as contaminated storm drains, and other unknown sources, contributed to the degradation of upstream segments of the Charles River, the Neponset River, and Tenean Beach.

- Disinfection of CSOs by new treatment facilities at Fox Point, Commercial Point, and Constitution Beach has substantially reduced contamination of nearby beaches, but aesthetic degradation by slicks and “floatables” persists.

- Beaches in South Boston generally met water quality standards and were "swimmable", but the presence of small and infrequent untreated combined sewage overflows prevents shellfishing.

Acknowledgments

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1. Introduction

1.1 Background

Sewage pollution from combined sewer overflows (CSOs) has been identified as a major contributor to the degradation of water quality in Boston Harbor and its tributary rivers (MDC 1980, 1981, 1982a,b,c; EPA 1987; MWRA 1990, 1991c). One of the most problematic aspects of remediating pollution from CSOs has been identifying the effects of these discharges and where and under what environmental conditions the impacts occur. These difficulties arise from logistical problems, such as predicting a rainstorm with enough accuracy to deploy people to sample an overflow, as well as from sampling and statistical problems resulting from the great variability associated with environmental conditions. Two simple facts--that a single body of water often has many sources of contamination and that water moves--make it very difficult to determine the source(s) of pollutants in a water sample. In the Boston area, our incomplete understanding of how the ancient and labyrinthine sewer system functions adds an additional layer of complexity.

Although several scientific and engineering studies have measured or modeled the amounts of pollutants entering Boston-area waters from combined sewers and the effect on the receiving waters, most of these efforts have been relatively short term or limited in scope to one or a few CSOs. Longer term, ongoing water quality surveys have been conducted by the Massachusetts Department of Water Pollution Control (DWPC), the Metropolitan District Commission (MDC), the Massachusetts Division of Marine Fisheries (DMF), the New England Aquarium, and local municipalities. However, none of these water surveys was designed to assess the receiving water effects of combined sewer overflows.

The work reported here was performed to satisfy the CSO receiving water monitoring requirements in the Massachusetts Water Resources Authority's (MWRA) NPDES (National Pollution Discharge Elimination System) permit [Outfall Identification and Monitoring Requirements, Permit No. MA0102351(M-44), Part I, page 13, Section b.(2)]. The conditions of the permit require MWRA to (a) "assess compliance or non-compliance with water quality standards during wet weather and dry weather and minimum dilution conditions (for receiving waters); and (b) provide an assessment of individual overflow impacts on the receiving waters." However, it was also our intention that the data gathered should be used as part of a long-term monitoring program to measure changes in water quality over time as pollution abatement programs are implemented. Much of the data collected here can be viewed as baseline information, although significant improvements in wastewater treatment were implemented during the two-year monitoring period. Finally, some of the data and patterns discovered should be useful in refining plans for CSO control facilities.

1.2 Elements of the Monitoring Plan

The MWRA receiving water monitoring plan incorporated five important elements:

1. The plan comprised the entire Greater Boston CSO area, including all tributary rivers, the inner harbor, and the outer harbor. This broad coverage allowed an integrated, coordinated approach to sampling water bodies that were affected by CSOs belonging to several municipalities.

2. Water column monitoring focused on measuring densities of the sewage indicator bacteria, fecal coliform and *Enterococcus*, and dissolved oxygen. We chose sewage bacteria because they are very sensitive indicators of the presence of raw sewage, and their densities in water are correlated with infectious disease hazards. The potential danger to public health from exposure to sewage-contaminated waters during recreational activities (swimming, boating) and from contamination of shellfish beds has been identified as the primary public concern about CSOs. In fact, past work has shown that the most egregious violations of water quality standards in the Boston area have been fecal coliform violations (MDC 1982c; MWRA 1990, 1991e). Use of indicator bacteria densities as the primary measure of water quality in sewage-impacted waters has the additional advantage of being inexpensive and relatively rapid. The testing is done in-house by MWRA, which facilitates flexibility, optimal sample handling, and quality control.

   Our focus on monitoring indicator bacteria in the receiving water may prompt some concern that the potential problem of toxic pollution from combined sewers is being neglected. However, measurements of toxic pollutants in receiving waters and toxicity testing of combined sewage have shown that acute toxicity from sewage-derived priority pollutants in the water column is not a major problem in most Boston-area waters (MDC 1980; MWRA 1990, 1991a,b). Toxic materials may, however, accumulate in the sediments and produce environmental damage. How much various waste discharges contribute to toxic pollution, how patterns of water circulation affect movement of sediments, and how toxic chemicals in sediments affect aquatic life are complex problems, as shown in a MDEP (Massachusetts Department of Environmental Protection)-sponsored study of the Fox Point CSO (MDEP 1990). MWRA completed a study in which levels of organic compounds and metals in Dorchester Bay sediments were measured, together with potential sewage source tracers (MWRA 1991d), to begin assessing the effects of CSOs on levels of toxic materials there.

3. The study design incorporated frequent sampling--six days/week, enabling us to measure short-term variation during dry weather and wet weather.

4. The relatively large number of sampling stations allowed assessment of spatial variation within a body of water. The stations were located to permit assessment of nearfield and farfield effects of CSOs.

5. The data analysis incorporated both anthropogenic and natural environmental factors, allowing us to determine the relationships among variables that affect the densities of indicator bacteria in the receiving waters in different ways. Anthropogenic variables measured included flows and loads through wastewater treatment plants and facilities for treating the overflow from combined sewers. Natural variables included rainfall, tide, water temperature, and salinity.

1.3 Organization of the Report

This report is divided into six sections, including this introduction (Section 1); a materials and methods section that describes the sampling design, technical methods, and data analysis (Section 2); and five sets of results and discussion, one for each geographic area monitored. These areas are the inner harbor (Section 3), the Neponset River and Dorchester Bay (Section 4), the Charles River (Section 5), the Alewife Brook and Mystic River (Section 6), and Constitution Beach (Section 7). A concluding statement is in Section 8.

2. Materials and Methods

2.1 Field and Laboratory Methods

2.1.a Sampling Area, Location of Combined Sewer Overflows and Sampling Stations

The study area of the fall 1990-summer 1991 CSO receiving water monitoring program included Boston Harbor and the segments of its tributaries that are affected by combined sewer overflows (CSOs). Figure 2.01 shows the locations of CSOs. The bodies of water sampled include the inner harbor, the outer harbor, and rivers tributary to Boston Harbor. A total of 50 stations were sampled (Figure 2.02). Table 2.01 lists the geographic landmarks used for triangulation, the latitude and longitude as determined by Loran-C, and the approximate distance to the nearest CSO for all the stations.

2.1.b Sampling Schedule

We divided the study area into five geographic subareas. These areas were (1) the inner harbor, (2) the Neponset River and Dorchester Bay, (3) the Alewife Brook and Mystic River, (4) the Charles River, and (5) Constitution Beach. During the colder fall, winter, and spring months, sampling was limited to unfrozen waters accessible from shore. During the more intensive monitoring in the summer of 1991, sampling focused on one geographic area at a time. Each area was monitored for approximately three consecutive weeks, during which time we sampled six days/week, Monday through Saturday. We attempted to collect samples from all stations within an area each day.

2.1.c Sample Collection

Detailed field methods including quality assurance and quality control procedures are described in the MWRA Harbor Studies Field Standard Operating Procedure (MWRA 1989a). Most samples were collected from a small motorboat, although some stations required sampling from a bridge, dock, or dam, and two beaches.

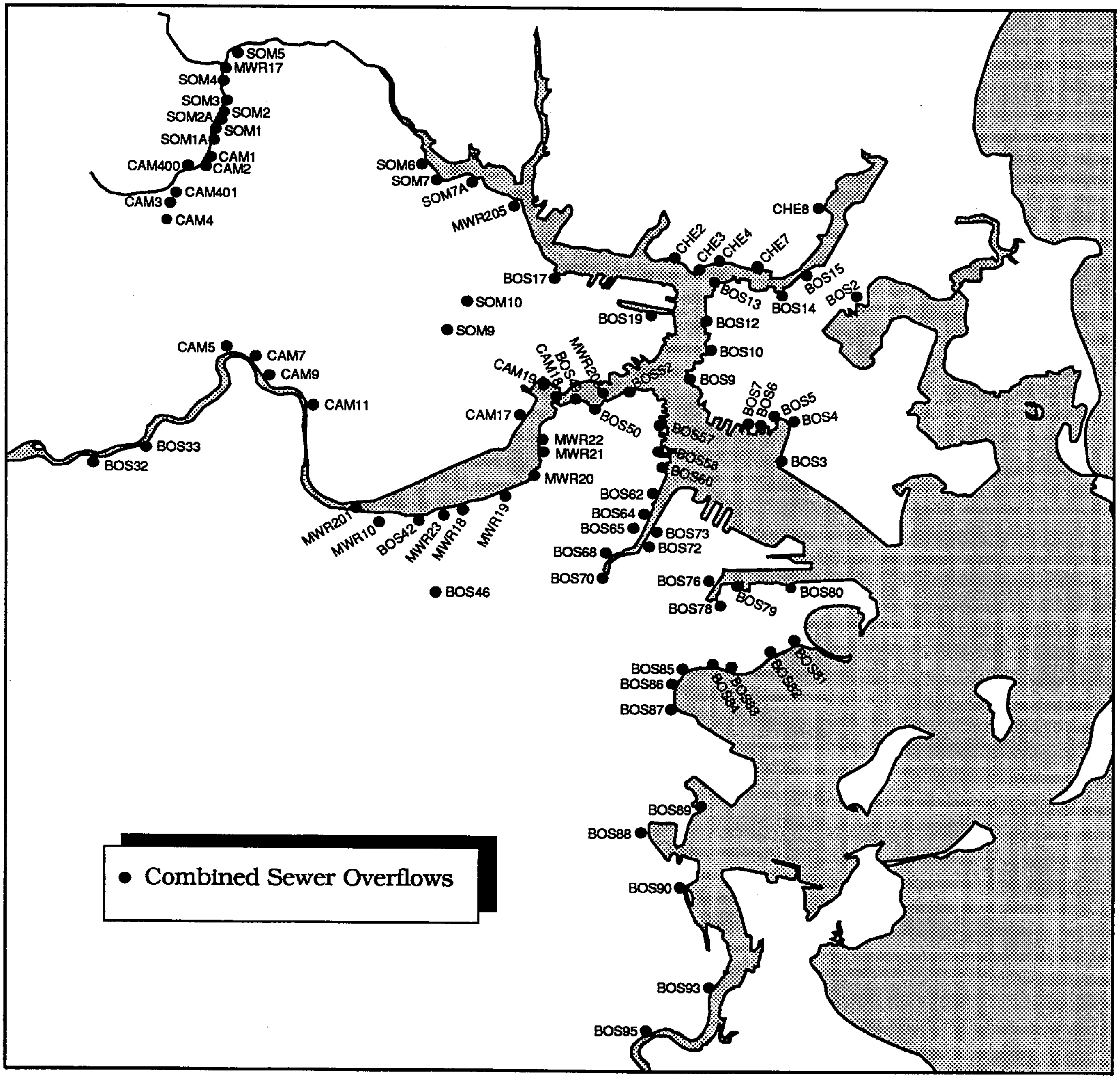


Figure 2.01. Locations of combined sewer overflows (CSOs) in Boston Harbor and its tributary rivers.

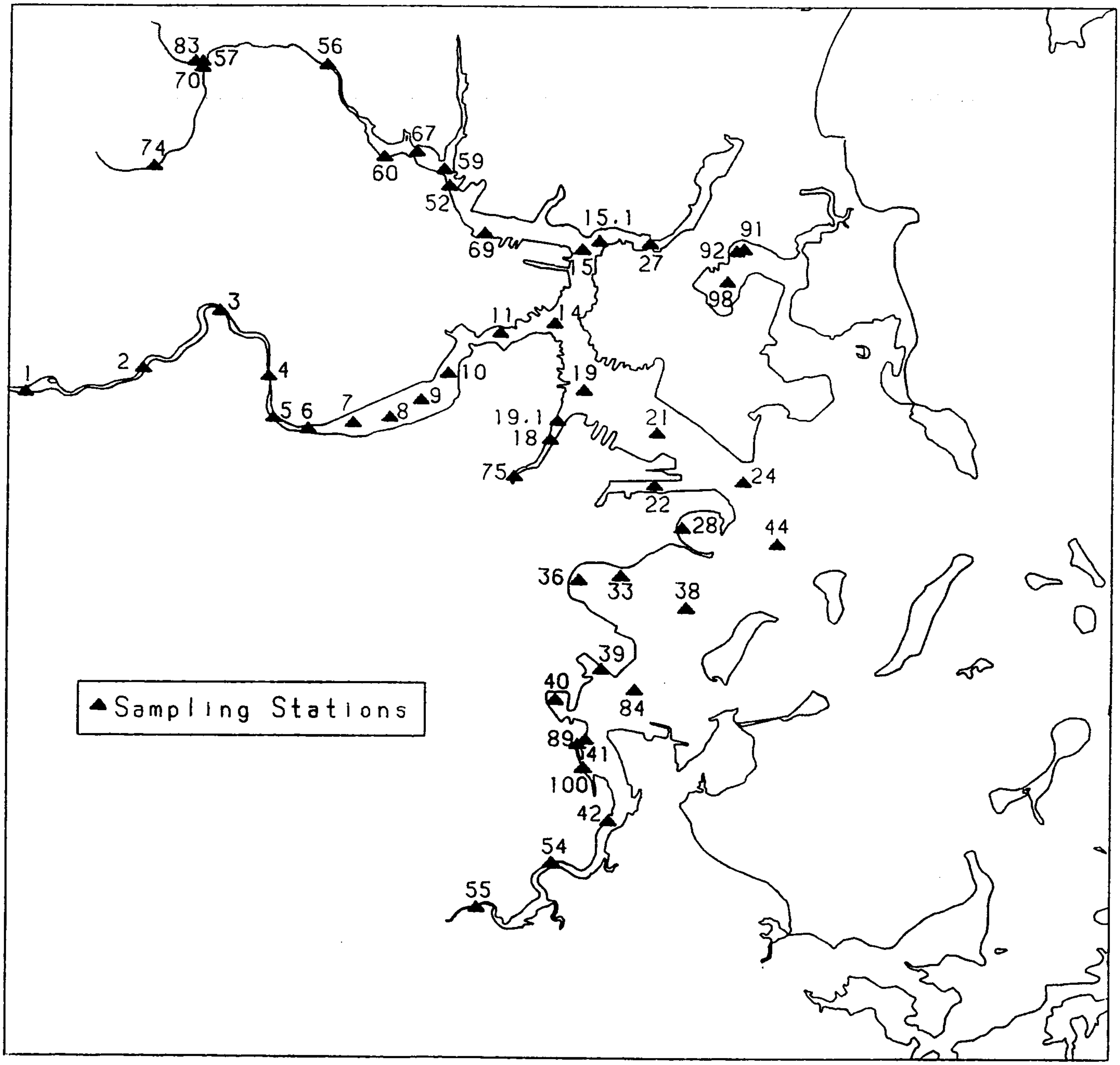


Figure 2.02. Map of water quality monitoring stations, 1990-1991.

Table 2.01. Stations for the MWRA CSO receiving water monitoring program, fall 1990 through summer 1991.

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
Alewife Brook						
70	Midchannel, off SOM-004.	42° 24.86'	71° 07.99'	SOM-004	5 m	1990, 1991
74	Off ramp to Alewife T station. Midchannel from bridge.	42° 23.84'	71° 08.66'	CAM-401	~100 m	1990, 1991
Charles River						
1	Newton Yacht Club, at red buoy #12.	42° 21.54'	71° 10.45'	upstream of CSOs		1990, 1991
2	10 m downstream of BOS-033 midchannel.	42° 21.78'	71° 08.80'	BOS-033	10 m	1990, 1991
3	Downstream of CAM-005 at hairpin bend in river. Tall apartment building dead ahead, directly opposite brown and blue building on Cambridge side. Midchannel.	42° 22.37'	71° 07.74'	CAM-005	100 m	1990, 1991
4	Midchannel midway between River St. and Western Ave. bridges.	42° 21.70'	71° 07.06'	CAM-011	100 m	1990, 1991
5	Downstream of stone building, 10 m from Cambridge shore at bend in river. Right edge of Howard Johnsons aligns with left edge of stone building.	42° 21.27'	71° 06.99'	upstream of MWR-201		1990, 1991
6	Immediately downstream of BU Bridge, midchannel. Downstream edge of boathouse is aligned. Steeple of BU building on Boston side is aligned with peak of roof.	42° 21.15'	71° 06.51'	MWR-201	10 m	1990, 1991
7	10 m off MIT boathouse. Left side of boathouse is edge on. Left edge of Prudential aligns with right edge of brown skyscraper.	42° 21.33'	71° 05.88'	BOS-042	250 m	1990, 1991

Table 2.01, continued.

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
8	Immediately downstream of Harvard Bridge. Opposite MIT dome: smokestack aligns with tree to left of dome. Left edge of Sheraton Hotel aligns with right edge of largest brick apartment building.	42° 21.27'	71° 05.37'	Stony Brook		1990, 1991
9	Midchannel, midway between Harvard and Longfellow Bridges. Church steeples on Boston side align. On Cambridge side, middle smokestack aligns with right edge of brick building.	42° 21.45'	71° 04.93'	MWR-019	200 m	1990, 1991
10	Downstream of Longfellow Bridge, opposite MWR-022. Midchannel. Large smokestacks on Cambridge side align, leftmost "salt and pepper" bridge posts align.	42° 21.72'	71° 04.55'	MWR-022	200 m	1990, 1991
11	Opposite BOS-049. Between drawbridge and Science Museum. Midchannel. Opposite "WAM-73" graffiti on Cambridge side. Lamppost on southern side lines up with vertical windows on brick building.	42° 22.14'	71° 03.84'	BOS-049	50 m	1990, 1991
12	Footbridge upstream of Watertown Dam	...	...	Upstream of all CSOs		1990, 1991
Dorchester Bay						
28	Pleasure Bay, sampled by wading from beach.	42° 20.12'	71° 01.33'	BOS-081	1.5 km	1991
33	Carson Beach, at end of fence by L-Street Bath-house.	42° 19.63'	71° 02.18'	BOS-083	0-5 m	1991
36	Carson Beach, 100 m off righthand corner of Carson Beach bathhouse aligned with sign for BOS-086.	42° 19.59'	71° 02.75'	BOS-086	0-5 m	1991
38	Dorchester Bay, mid Old Harbor.	42° 19.30'	71° 01.28'	BOS-082	1.5 km	1991

Table 2.01, continued.

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
39	Savin Hill Cove, U/MASS Sailing Program dock.	...	...	BOS-089	100 m	1991
40	Malibu Bay, 50 m offshore of BOS-088.	42° 18.37'	71° 03.08'	BOS-088	50 m	1991
41	Old Colony Yacht club, 50 m offshore of sign for BOS-090.	42° 17.98'	71° 03.08'	BOS-090	50 m	1991
44	Between Spectacle Is. and airport; 10 m from green buoy #5.	42° 19.95'	71° 00.01'	BOS-081	1 km	1991
84	Offshore of Columbia Point, at red buoy #12.	42° 18.47'	71° 02.00'	BOS-089	0.5 km	1991
Inner Harbor						
14	Mouth of Charles R. Left edge of Custom House Tower aligns with right edge of State Street Bank. Bunker Hill Monument aligns with corner of Pier 2.	42° 22.23	71° 03.09'	BOS-052 MWR-203	100 m	1991
15	Confluence of Mystic R. and Chelsea R. Lower red stack behind Mystic Pier aligns with Hancock Tower. 6th vertical member on bridge after tall strut aligns with tallest Edison stack.	42° 22.98'	71° 02.71'	CHE-003	300 m	1991
15.1	Chelsea River, off McArdle Bridge.	...	...	BOS-013	100 m	1990, 1991
18	Fort Point Channel, off south side of Summer St. bridge.	42° 21.04'	71° 03.15'	BOS-064 BOS-070	100 m 1 km	1991
19	Mouth of Fort Point Channel. Directly off Harbor Tower closest to water. Airport tower is between Citgo sign and "B" on drydock.	42° 21.54'	71° 02.69'	BOS-062 BOS-070	500 m 1 km	1991
19.1	Center of northern (harbor) side of Northern Ave. Bridge.	42° 21.23'	71° 03.05'	BOS-062 BOS-070	200 m 1 km	1990, 1991

Table 2.01, continued.

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
21	Airport tower is edge-on. Top of old Hancock building aligns with right edge of new Hancock tower.	42° 21.10'	71° 01.69'	BOS-003	700 m	1991
22	Reserved Channel, midchannel by bay #B-3.	42° 20.56'	71° 01.72'	BOS-079	100 m	1991
24	Mouth of Inner Harbor by airport; 10 m off red buoy #10.	42° 20.59'	71° 00.48'	BOS-080	0.5 km	1991
27	Chelsea R. midchannel between grassy pier and low tin sheds.	42° 23.04'	71° 01.79'	BOS-014	200 m	1991
52	Mystic River, downstream of Amelia Earhart Dam, off MWR-205. Upstream of RR bridge. Directly aligned with control tower at locks.	42° 23.63'	71° 04.55'	MWR-205	10 m	1990, 1991
69	Mystic River, 50 m directly off BOS-017. Near Schraffts and pier.	42° 23.15'	71° 04.06'	BOS-017	50 m	1990, 1991
75	Fort Point Channel, off south side of Broadway Bridge.	42° 20.68'	71° 02.63'	BOS-068 BOS-070	100 m 500 m	1990, 1991
Mystic River						
56	100 m upstream of Rt. 93 bridge, midchannel.	42° 24.88'	71° 06.25'	SOM-005 SOM-006	2 km[u] 2 km[d]	1991
57	Confluence of Alewife Brook and Mystic R., midchannel.	42° 24.92'	71° 07.99'	SOM-004 MWR-017	100 m	1991
59	Confluence of Mystic and Malden Rivers.	42° 23.80'	71° 04.62'	SOM-007A	700 m	1991
60	Mystic R. Basin, 100 m directly off MDC sailing dock and SOM-007.	42° 23.93'	71° 05.46'	SOM-007	30 m	1991
67	Immediately downstream of Route 28 bridge, midchannel.	42° 23.98'	71° 05.00'	SOM-007A	100 m	1990, 1991
83	1/4 mile upriver from Alewife/Mystic confluence, Mystic River, midchannel at storm drain.	42° 24.92'	71° 08.10'	upstream of CSOs		1991

Table 2.01, continued.

Station	Description	Latitude	Longitude	Nearest CSO	Distance to CSO	Year Sampled
Neponset River						
42	Downstream of BOS-093, midchannel, midway between bridges.	42° 17.13'	71° 02.36'	BOS-093	200 m	1990
54	Downstream of BOS-095, at Granite Ave. Bridge.	42° 16.70'	71° 03.13'	BOS-095	10 m	1990, 1991
55	Above dam in Milton/Lower Mills, at chocolate factory.	42° 16.30'	71° 04.16'	upstream of CSOs		1990, 1991
89	Off Victory Park footbridge.	...	...	BOS-090	10 m	1990, 1991
100	Tenean Beach, middle.	...	...	BOS-090	0.5 km	1991
Constitution Beach						
91	Near storm drain.	42° 22.98'	71° 00.48'	BOS-002	700 m	1991
92	Offshore of bathhouse.	42° 22.96'	71° 00.58'	BOS-002	600 m	1991
98	Marshy area near CSO.	42° 22.65'	71° 00.71'	BOS-002	200 m	1991

[u]CSO was upstream of sampling station. [d]CSO was downstream of sampling station.

(Pleasure Bay and Tenean Beach) were sampled by wading out to a depth of 1 m. Sample volume was 200 ml. Grab samples were collected 0.25 m below the water's surface at all stations. Where the depth of the water was greater than 4 m, a grab sample of bottom water was also collected 0.5 m above the bottom sediment. Surface samples were collected aseptically by hand directly into sterile sample jars. Bottom samples were collected in a Kemmerer sampler (Wildco) or an Alpha water bottle (Wildco) and transferred aseptically to sterile containers. Samplers were disinfected with 95% ethanol between samples. Immediately after collection, all water samples were placed in a cooler with ice-packs and stored until processing in the laboratory. Most samples were processed within 3 h of collection, and all were processed within 6 h of collection.

2.1.d Field Measurements

Temperature, conductivity, and salinity were measured in the field with a YSI model 33 portable S-C-T meter. Field measurements of dissolved oxygen were made with a YSI model 58 dissolved oxygen meter (calibrated in air). For each sample, the time of day that it was collected was noted and the corresponding point in the tidal cycle derived from a tide chart. Other field observations included approximate wind speed; precipitation; presence of visible pollutants such as sewage and oil; and presence of a plume, odors, and floatables.

2.1.e Meteorological Data

Data on rainfall measured at Logan Airport were obtained from the National Weather Service.

2.1.f Microbiological Methods

Detailed laboratory methods with quality assurance and quality control procedures are described in the Harbor Studies Laboratory Standard Operating Procedure (MWRA 1989b).

Fecal Coliform

Fecal coliform bacteria were enumerated by the membrane-filter procedure (APHA 1989, Section 9222 D). Water samples were diluted in phosphate buffer (pH 7.2) as necessary, and filtered through 0.45-µm filters (Millipore). Filters were then placed on m-FC Agar (Difco) containing 0.01% rosolic acid. We incorporated a resuscitation step of a 2-h incubation at 35°C (APHA 1985) before transferring cultures to incubate at 44.5°C in a circulating water bath. After incubation of 24 h ±2 h, plates were examined at low power under a binocular microscope (10-15X magnification) and blue colonies counted.

Cultures of *E. coli* (ATCC 25922) were used as positive controls.

Enterococcus

We enumerated *Enterococcus* by the membrane-filter technique (APHA 1989, Section 9230 C), using m-*Enterococcus* agar (Difco). Water samples were diluted and filtered as described above, and cultures were incubated at 35°C for 48 h. All light red and dark red colonies were counted at 10-15X magnification.

Cultures of *Enterococcus fecaelis* (ATCC 29212) were the positive controls.

2.2 Data Analysis

Detailed descriptions of how the data were recorded, validated, and manipulated are in the appendix.

The data analysis had three basic goals. The first was to provide a descriptive picture of the concentrations of sewage indicator bacteria and dissolved oxygen in the water, and relate these data to geographic location and government water quality standards. This descriptive analysis can be used to compare findings with past and future work. The second goal was to determine the relationships among the pollution indicator variables (fecal coliform, *Enterococcus*, and dissolved oxygen) and environmental variables, including natural and anthropogenic parameters (e.g., rainfall, tide, salinity, temperature, treatment plant flow and loads). The third goal was to relate our observations of water quality to modeled and/or measured flows and loads through individual CSOs or groups of CSOs.

The data from each geographic area were analyzed separately and the results are reported in separate sections of this report.

2.2.a Descriptive Analysis

Because our data for indicator bacteria counts were lognormally distributed (typical for environmental microbiological measurements), a proper measure of central tendency in these populations is the geometric mean. Geometric means and their associated 95% confidence intervals were calculated for the measurements made at each station during a sampling period. Thus we could determine if the geometric means of fecal coliform and *Enterococcus* counts, measured at different times or locations, were significantly different. The geometric means and associated confidence intervals of fecal coliform and *Enterococcus* counts by year, depth, and station within geographic areas are provided in tables in each section of this report.

In this report, descriptive data for fecal coliform and *Enterococcus* counts and dissolved oxygen levels are displayed as percentile box plots. These plots are a way of presenting the frequency distributions of a group of measurements. In this report, a "box" comprises measurements from one individual sampling station and depth. Figure 2.03 illustrates how the frequency distribution is indicated in the box plots, and Figure 3.03 (page 3-7) is an example of a box plot. Each horizontal line in a box indicates a value (read on the vertical axis) that includes the indicated percent of the data. Values are shown for the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles. Single measurements beyond this ranges (outliers) are indicated as dots. For example, in Figure 3.03, the first box on the left represents all the fecal coliform counts from surface samples collected at Station 75 during the fall-winter sampling period. Within this group of measurements, 90% (the top horizontal line) of the fecal coliform measurements were less than 2,000 col/100 ml; 75% were less than 700 col/100 ml; 50% were less than 400 col/100 ml; 25% were less than 200 col/100 ml; and 10% of the measurements were less than 90 col/100 ml. Single measurements beyond these ranges (outliers) are indicated as dots.

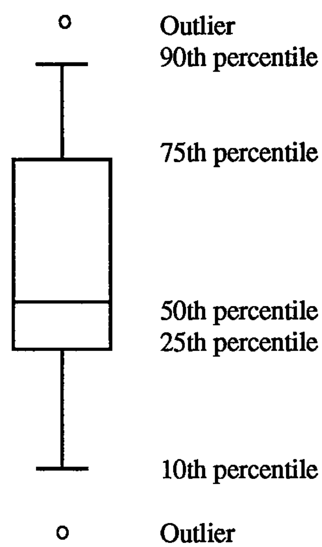


Figure 2.03. Percentile distributions indicated on boxplots.

The box plots enable one to see the range and central tendencies of the data immediately and to visually compare results among sampling stations. These plots are particularly appropriate for displaying fecal coliform data because the Massachusetts fecal coliform standards are written in terms of percentiles: class B and SB waters, suitable for swimming, should have a geometric mean fecal coliform count of 200 col/100 ml or less, with 90% of the samples having less than 400 col/100 ml. Thus waters meeting fecal coliform standards will have a geometric mean count of 200 col/100 ml or less, and, on the box plots, the top horizontal line on the box (the 90^{th} percentile) will be below 400 col/100 ml.

The fecal coliform and *Enterococcus* count data are displayed on a logarithmic scale in all the box plots. The dissolved oxygen data are shown on a linear scale.

Descriptive statistics (means and geometric means, confidence intervals, frequency distributions, etc.) and figures were generated using the SPSSX statistical package (SPSS Inc., Chicago IL) on the MWRA VAX (Digital Equipment Corp., Maynard, MA), Lotus 1-2-3 (Lotus Corp., Cambridge, MA), Excel (MicroSoft Corp., Redmond, WA), Cricketgraph (Cricket Software, Malvern, PA), MacDraw (Claris Corp., Mountainview, CA), and Aldus SuperPaint (Silicon Beach Software, Inc., San Diego,CA). We used the statistical package SOLO (BMDP Statistical Software, Los Angeles, CA) to produce percentile box plots.

2.2.b Comparative Analyses

We used an exploratory analytical approach to determine relationships among environmental variables and pollution indicators. This inductive approach is often the most productive way to discover patterns and relationships in environmental data sets, which have a large number of uncontrolled variables. The ultimate goal of our analysis is to make progress toward determining causal relationships among different environmental factors and levels of pollution in the waters studied.

Data from each geographic area and year were analyzed separately, and the following analytic steps were followed for each area. Data from surface and bottom samples were analyzed separately. The first step of an analysis was to produce a large correlation matrix, intercorrelating all the variables listed in Tables 2.02 and 2.03 (plus log-transformed fecal coliform and *Enterococcus* counts). All samples from all stations within a geographic area (e.g., the inner harbor, the Charles River) were included together in one correlation matrix. Then matrices were produced for the data collected at each individual station. All these matrices were examined for patterns of significant correlations.

Based on the results of the correlation analyses, we selected significant explanatory variables (e.g., rainfall, treatment-plant flow, salinity) for linear regression analysis of counts of pollution indicator bacteria. Some of these analyses showed interesting and significant trends, and are presented in the Results sections of this report.

Finally, multiple regressions were performed, with log-transformed counts of fecal coliform and *Enterococcus* as the dependent variables, and the variables listed in Tables 2.02 and 2.03 as potential explanatory variables. Multiple regression is the only statistical technique that can apportion the variance in a dependent variable among a group of explanatory variables. A stepwise multiple regression determines the order of importance among variables in explaining the variance in a dependent variable. Only those multiple regressions that yielded highly statistically significant, interpretable results are presented in this report.

Correlation analyses, regression analyses, t-tests, and multiple regression analyses were carried out with SPSSX and SPSS Graphics.

2.2.c Comparison of Measured or Modeled CSO Flows and Loads to Receiving Water Data

Some of our samples were collected when measured or predicted overflows from nearby combined sewers occurred. Although we attempted to do statistical correlation analyses of the water quality measurements with measured and modeled overflows from the CSO treatment facilities and from individual CSOs, we did not obtain meaningful results from these analyses. This was because there were usually too few overflow events during a sampling period to calculate a correlation (the minimum number of data points required is three), and because the large variability in these data meant that many overflows would have to be monitored in order to derive a statistically significant correlation. For these reasons, our analysis of the impact of individual CSOs and CSO treatment facilities on the receiving water is limited to descriptions of the changes in water quality observed after overflows or rainfalls.

Table 2.02. Parameters measured during the MWRA CSO receiving water monitoring program.

Variable	Description
STATION	Station numbers used in the field monitoring; for full description of station locations, see Table 2.01
SAMNUMBER	Sample number
SAMDATE	Date sample was taken
SAMTIME	Time of day sample was taken, in 24-hour military time
TIDE*	Coded variable giving the state of the tide when samples were taken; codes are as follows: 1: Slack high tide 2: High water, ebb tide 3: Low water, ebb tide 4: Slack low tide 5: Low water, flood tide 6: High water, flood tide 9: Sample taken in a freshwater system (e.g., the Charles River) above the influence of the tides
DEPTH	Water depth (ft) when sample taken
DEPTHSAM	Water depth (ft) at which sample was taken
TEMP*	Water temperature (°C)
DO*	Dissolved oxygen (mg/l)
CONDUCT*	Conductivity (µmhos)
SALINITY*	Salinity (ppt)
MF1	mFC fecal coliform counts for first of two laboratory duplicate filtrations (col/100 ml)
MF2	mFC fecal coliform counts for duplicate filtrations (col/100ml)
MFAV	Arithmetic average of the duplicate filtrations for fecal coliform (col/100 ml)
ME1	mENT *Enterococcus* counts for the first of two duplicate filtrations (col/100 ml)
ME2	mENT *Enterococcus* counts for duplicate filtration (col/100ml)
MEAV	Arithmetic average of the duplicate filtrations for *Enterococcus* (col/100 ml)

*Variables used in multiple regression analysis.

Table 2.03. Additional rainfall and sewerage variables used in the analysis.

Variable	Description
Rainfall Variables[1]	
LORN	Daily rainfall recorded at Logan Airport, in inches Measured by National Weather Service
LORNP2, LORNP3, LORNP4, LORNP5, LORNP6	Additive rainfall variables Calculated from rainfall measured at Logan Airport Formula: RAINPx = RAIN1 + RAIN2 ...+ RAINx
LORNM1, LORNM2, LORNM3, LORNM4, LORNM5, LORNM6	Delayed single day variables Formula: RAINMx = RAINx
Sewage Variables[2]	
DIFLOW	Daily flow through Deer Island POTW, in MGD
DIEFF	Daily effluent fecal coliform counts per 100 ml from Deer Island POTW
DILOAD	Deer Island fecal coliform loading Formula: DILOAD (Fecal coliform/Day) = Flow (MGD) * 10^6 * 3.785 L/G * 10(100 ml/l) * Effluent(Fecal coliform/100 ml)

[1] "RAIN" substitutes in the formulae for "LORN" RAIN1 = rain on that date, RAIN2 = Rain day before, ... RAIN6 = rain 5 days before.
[2] Deer Island WWTP variables are from treatment plant logs.

3. The Inner Harbor

This section includes the inner harbor area from the Amelia Earhart Dam at the mouth of the Mystic River seaward inside a line from the southern tip of Governor's Island to Fort Independence. One site upstream of the Charles River Dam and one site in Dorchester Bay are also discussed.

3.1 Results, Fall and Winter 1990, Spring 1991, and Summer 1991

Raw data and additional tables and figures are given in Appendix A. Only figures and tables that illustrate meaningful trends are included in this section.

3.1.a Sampling Locations and Rainfall

Figure 3.01 shows the location of the stations sampled in the inner harbor. Between October 29, 1990, and April 11, 1991, sampling sites were limited to unfrozen waters that were accessible from shore (six sampling stations). More stations were monitored in the inner harbor during the summer monitoring period. Figure 3.02A shows the amount of rain that fell each day during the fall-spring sampling period, and Figure 3.02B shows the rainfall during the August 1991 sampling. This summer monitoring period included Hurricane Bob, on August 19.

3.1.b Indicator Bacteria Counts

Fall 1990-Spring 1991

Geometric mean counts with corresponding 95% confidence intervals are shown in Table 3.01. The highest counts were at the head of Fort Point Channel and in the Charles River.

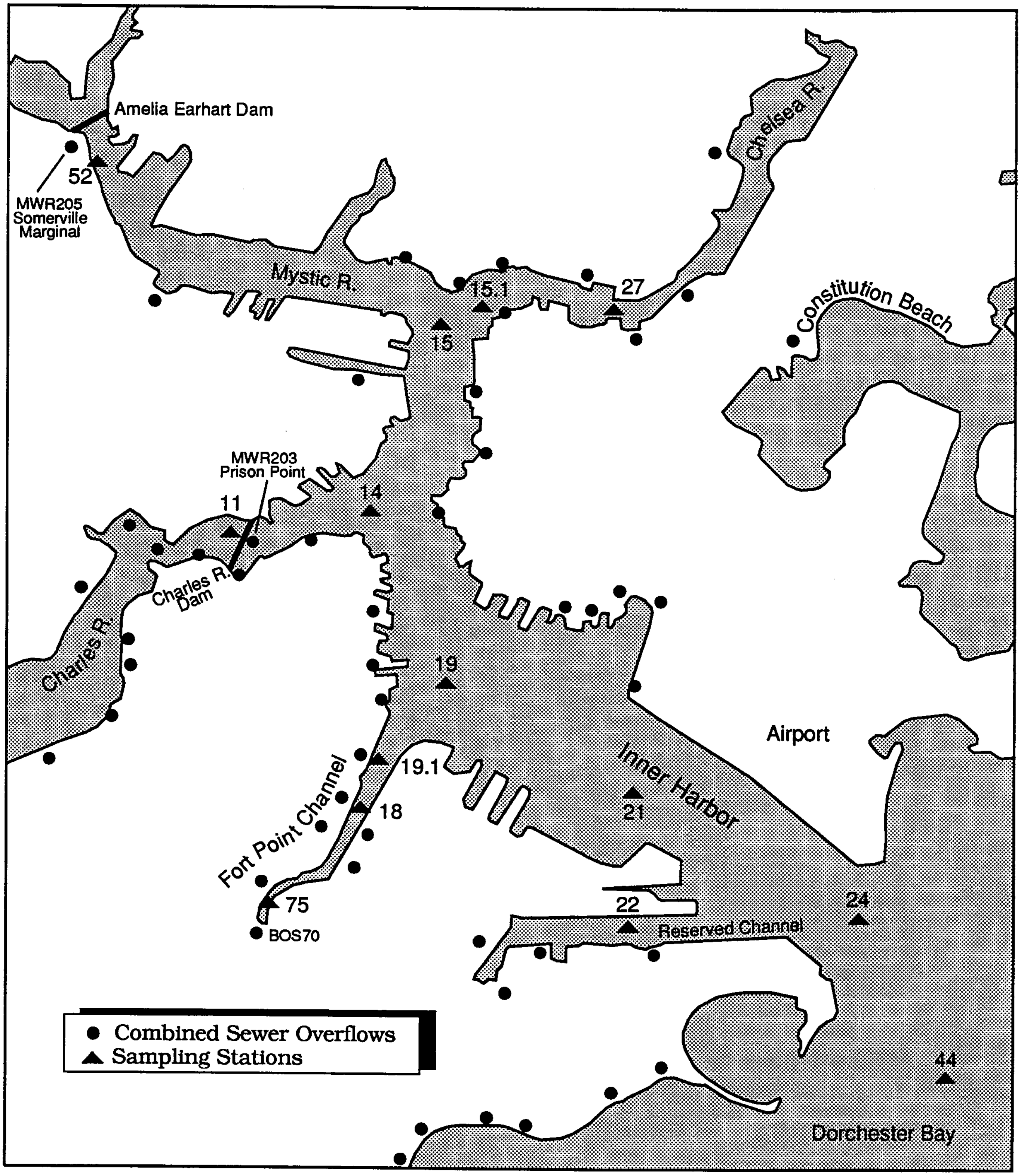


Figure 3.01. Stations sampled in the inner harbor.

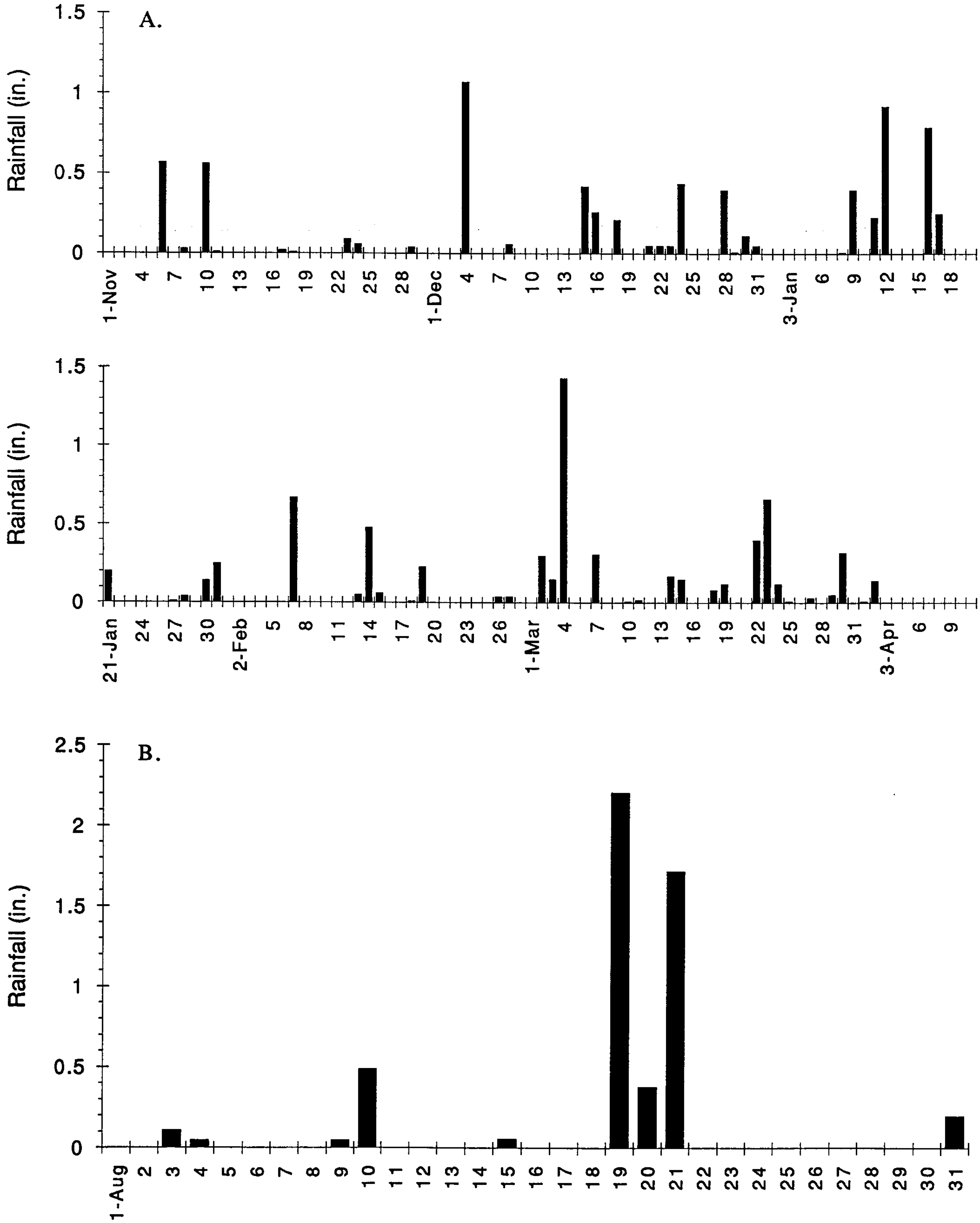


Figure 3.02. Rainfall during the inner harbor sampling periods. A. Fall, winter, and spring 1990-1991 and B. Summer 1991.

Table 3.01. Geometric means (col/100 ml) with 95% confidence intervals (CI) for fecal coliform and *Enterococcus* counts at inner harbor stations.

Station			Fall 1990-Spring 1991		Summer 1991	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Fecal coliform						
11	Charles River	S	21	332 (259-425)	15	181 (65-497)
14	Charles River/Coast Guard	S	...	...	15	104 (33-329)
		B	...	...	15	12 (6-22)
15	Mystic/Chelsea	S	...	...	15	153 (48-479)
15.1	McArdle Bridge	S	6	73 (31-172)	...	...
		B	5	32 (13-76)	...	...
18	Fort Pt. Chan/Summer St.	S	27	249 (132-466)	15	639 (156-2611)
		B	28	31 (18-51)	15	128 (63-261)
19	Fort Pt. Chan/Mouth	S	...	...	15	87 (34-218)
		B	...	...	15	7 (2-21)
19.1	Fort Pt. Chan/Northern Ave.	S	25	139 (74-258)	...	...
		B	25	11 (6-17)	...	...
21	Main Ship Chan/Airport	S	...	...	14	57 (17-186)
		B	...	...	15	22 (8-56)
22	Reserved Channel	S	...	...	15	9 (1-44)
		B	...	...	15	12 (4-35)
24	Inner Harbor/Mouth	S	...	...	15	18 (4-71)
		B	...	...	15	6 (1-25)
27	Chelsea River	S	...	...	15	76 (18-310)
44	Spectacle Is./Airport	S	...	...	15	10 (2-40)
		B	...	...	15	15 (4-55)
52	MWR-205/Mystic R.	S	13	351 (123-993)	16	1861 (729-4752)
		B	12	131 (70-245)	14	1028 (592-1783)
75	Fort Pt. Chan/Head	S	27	435 (261-725)	15	3071 (967-9753)
		B	2	62 (33-115)	...	...

*S = Surface sample; B = Bottom sample

Table 3.01, continued.

Station			Fall 1990-Spring1991		Summer 1991	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Enterococcus						
11	Charles River	S	21	318 (225-450)	15	29 (8-102)
14	Charles River/Coast Guard	S	...	...	15	68 (22-205)
		B	...	...	15	28 (7-106)
15	Mystic/Chelsea	S	...	...	15	21 (7-58)
15.1	Mc Ardle Bridge	S	6	41 (16-103)	...	...
		B	5	26 (11-60)	...	...
18	Fort Pt. Chan/Summer St.	S	27	182 (94-350)	15	102 (23-449)
		B	28	24 (12-48)	15	64 (20-196)
19	Fort Pt. Chan/Mouth	S	...	...	15	53 (20-137)
		B	...	...	15	15 (4-48)
19.1	Fort Pt. Chan/Northern Ave.	S	25	98 (50-192)	...	...
		B	26	11(6-21)	...	...
21	Main Ship Chan/Airport	S	...	...	15	45 (14-142)
		B	...	...	15	22 (7-69)
22	Reserved Channel	S	...	...	15	44 (15-127)
		B	...	...	15	28 (8-87)
24	Inner Harbor/Mouth	S	...	...	15	28 (8-89)
		B	...	...	15	47 (13-164)
27	Chelsea River	S	...	...	15	29 (8-96)
44	Spectacle Is./Airport	S	...	...	15	8 (2-27)
		B	...	...	15	24 (7-72)
52	MWR-205/Mystic R.	S	13	157 (48-512)	16	277 (90-854)
		B	12	51 (24-107)	14	261 (133-514)
75	Fort Pt. Chan/Head	S	27	468 (252-871)	15	690 (150-3163)
		B	2	46 (17-120)	...	...

*S = Surface sample; B = Bottom sample

3. The Inner Harbor

Surface Samples

Fecal Coliform

Figure 3.03 shows percentile box plots for fecal coliform in the inner harbor surface samples collected in the fall-spring period. The samples were collected during a variety of weather conditions. Counts at each site typically varied over three or more orders of magnitude. The geometric means of counts from surface samples during this time period (Table 3.01) exceeded the Massachusetts SB standard at two stations in Fort Point Channel: at Station 75 near BOS-070 (a large combined sewer outfall located at the head of the channel) (geometric mean = 435 col/100 ml) and at Station 18 (geometric mean = 249 col/100 ml). Station 52, located near the Somerville Marginal CSO Facility Outfall (MWR-205) in the Mystic River, also had a geometric mean count (351 col/100 ml) exceeding the SB standard.

It is interesting that Station 11 (not shown on Figure 3.03), on the upstream side of the Charles River Dam (Table 3.01), had a geometric mean (332 col/100 ml) comparable to Fort Point Channel (249 col/100 ml).

Despite these sources of fecal coliform (the Charles River and Fort Point Channel) the geometric means of samples collected near or in the main ship channel, Stations 19.1 and 15.1, either met or came very close to meeting the SB receiving water standard.

Enterococcus

Figure 3.04 shows the percentile box plots for *Enterococcus* collected from surface samples in the fall-spring period. The overall pattern is similar to that for fecal coliform, with the highest median counts at the head of Fort Point Channel and in the Charles River (not shown on Figure 3.04). None of the stations met EPA suggested criteria for bathing beach water quality (a steady-state geometric mean of 35 col/100 ml), although at station 15.1, the geometric mean was only 41 col/100 ml with 90% of the samples under 500 col/100 ml.

Bottom Samples

Depths of bottom stations sampled in the inner harbor varied from 2 ft to 50 ft.

Fecal Coliform

Bottom samples yielded geometric mean counts significantly lower than the surface counts, except at Stations 15.1 and 52 (no bottom samples were collected at the Charles River station). Geometric mean counts from bottom samples were below 200 col/100 ml at all five stations, and the percentile box plot

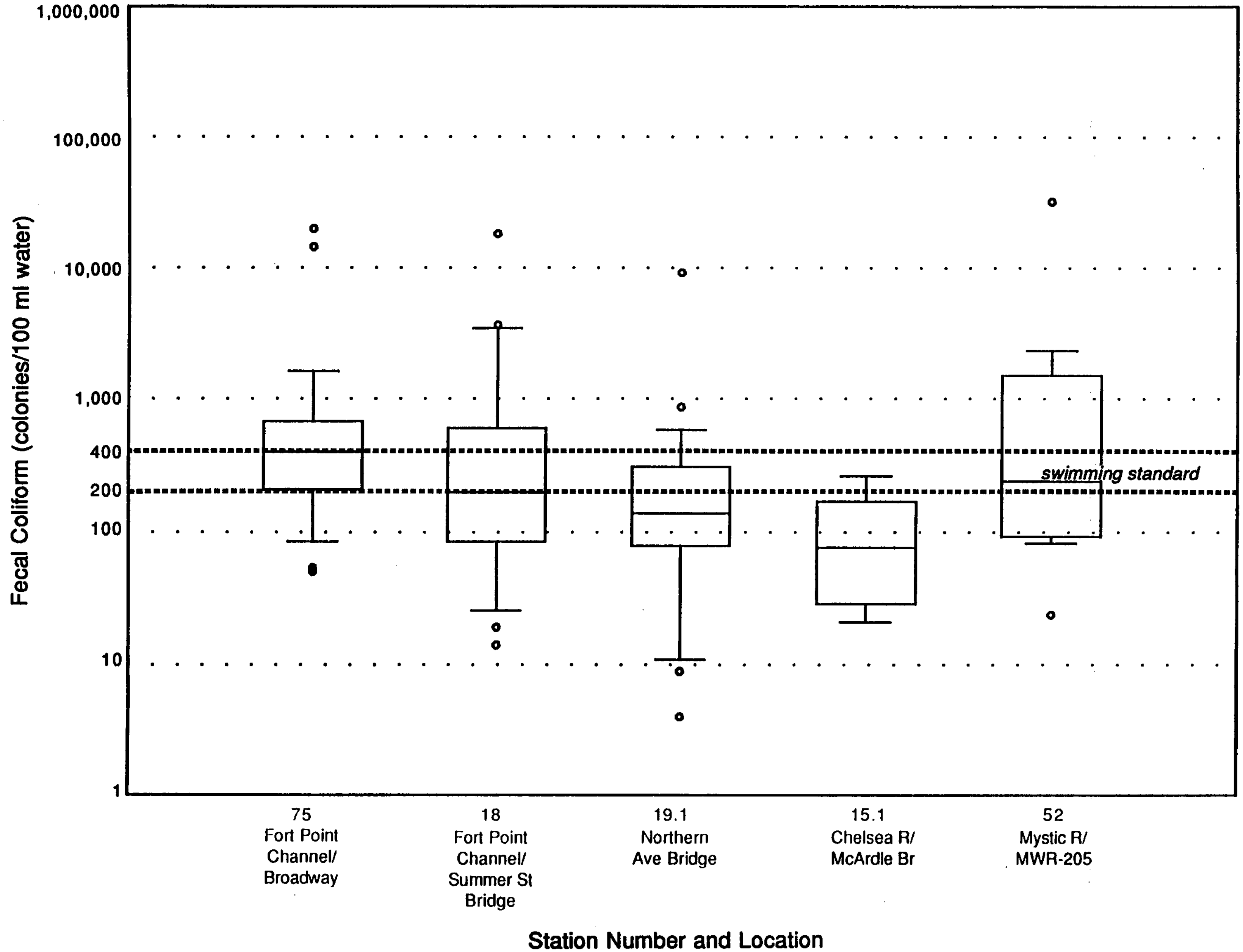


Figure 3.03. Percentile box plots of fecal coliform counts from surface samples in the inner harbor, fall 1990-spring 1991.

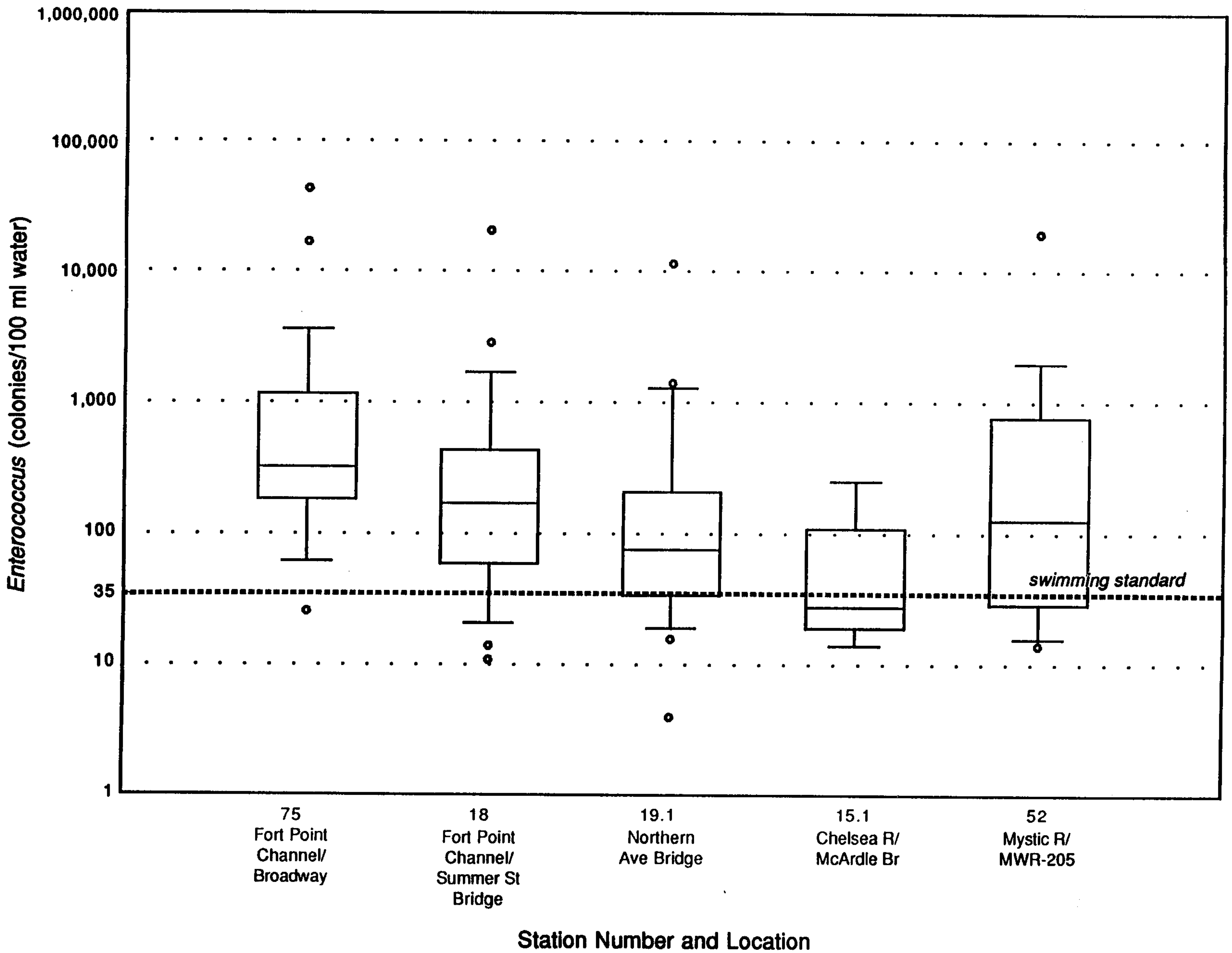


Figure 3.04. Percentile box plots of *Enterococcus* counts from surface samples in the inner harbor, fall 1990-spring 1991.

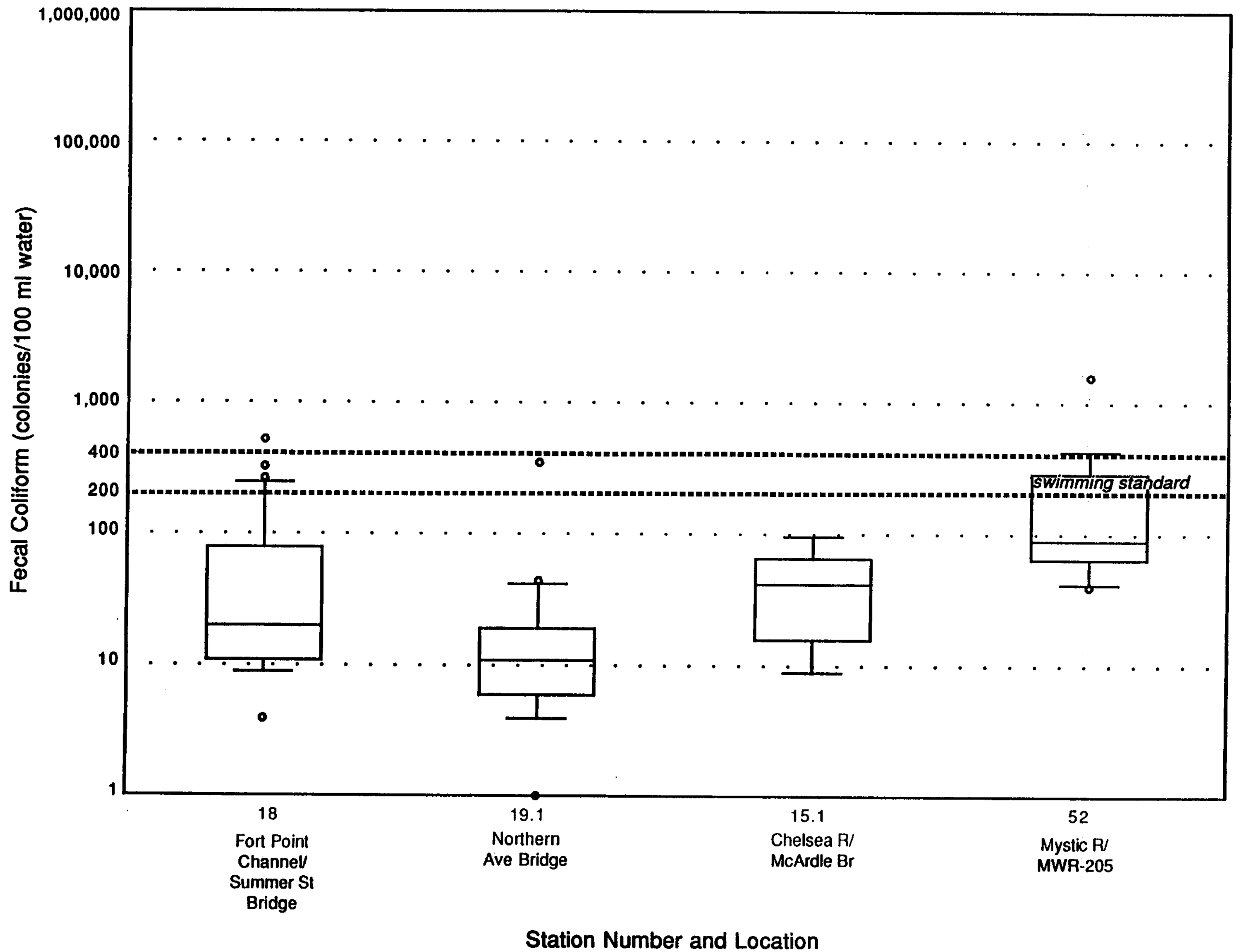


Figure 3.05. Percentile box plots of fecal coliform counts from bottom samples in the inner harbor, fall 1990-spring 1991.

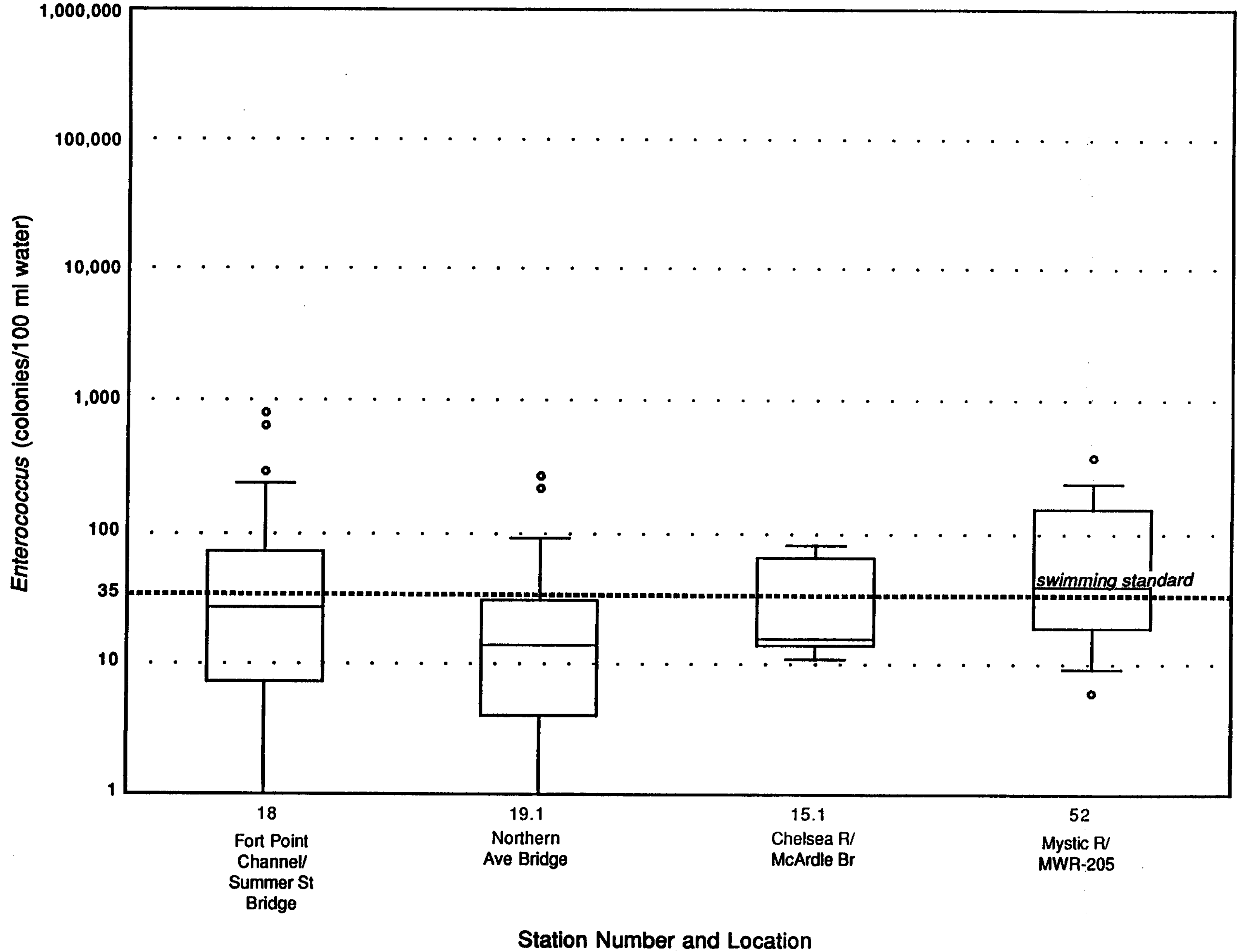


Figure 3.06. Percentile box plots of *Enterococcus* counts from bottom samples in the inner harbor, fall 1990-spring 1991.

(Figure 3.05) shows 90% of the samples had counts under 400 col/100 ml. (Only two samples were collected at Station 75, so this station is not shown on Figure 3.05.)

Enterococcus

Bottom samples for *Enterococcus* showed a pattern similar to that of fecal coliform: counts were significantly lower than at the surface except at Stations 15.1 and 52. At all stations, the geometric means were below or near the EPA recommended geometric mean for bathing beaches (Table 3.01). More than 90% of the bottom samples at each station were under 500 col/100 ml (Figure 3.06).

Summer 1991

The geometric means and corresponding 95% confidence intervals of fecal coliform and *Enterococcus* for the entire set of inner harbor samples are listed in Table 3.01.

We sampled the inner harbor area during August 1991. The distributions of fecal coliform and *Enterococcus* at stations in the inner harbor are shown in Figures 3.07-3.10. These percentile box plots show indicator bacteria densities in surface and bottom samples.

Surface Samples

Fecal Coliform

Geometric mean fecal coliform counts in the inner harbor varied among stations by more than three orders of magnitude (Table 3.01). The highest average counts were near two major CSOs: at Station 52 near MWR-205, and at Station 75 near BOS-070, while the lowest geometric mean counts were at the mouth of the inner harbor (Stations 22, 24, and 44). Percentile box plots (Figure 3.07) illustrate this spatial variation in fecal coliform counts. Not only was there variation over several orders of magnitude among stations, but the box plots show a similar amount of variation within stations. All the samples from Stations 52 and 75, both near major CSOs, exceeded water quality standards. At stations located in the main ship channel of the inner harbor, 50-75% of samples met the 200 col/100 ml bacterial water quality standards.

Enterococcus

Enterococcus counts (Figure 3.08) showed a pattern of variation similar to fecal coliform: the highest average counts were near the two large CSOs, BOS-070 (Fort Point Channel Station 75) and MWR-205 (Mystic River Station 52), while the lowest average counts were in the main ship channel, especially at the mouth of the inner harbor.

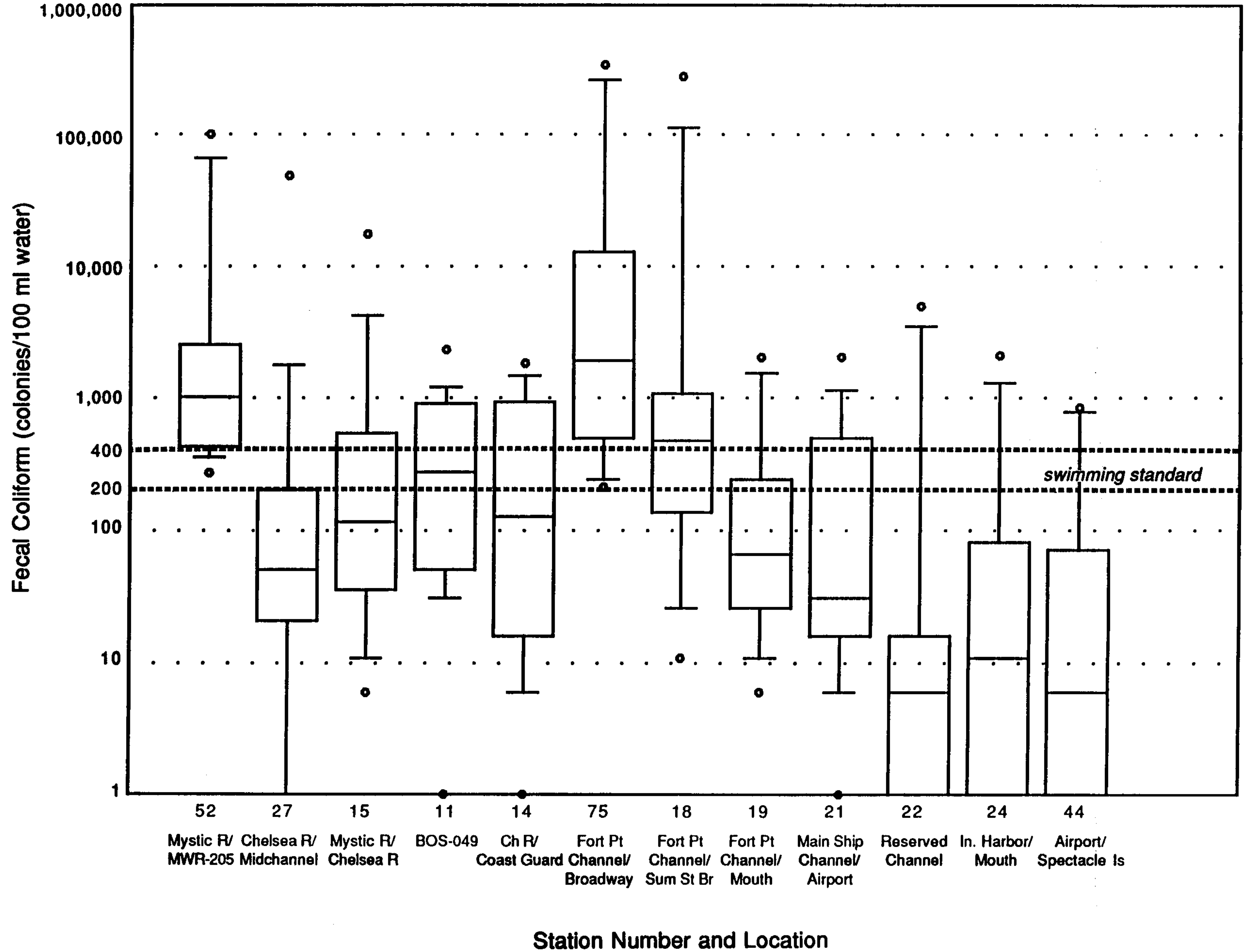


Figure 3.07. Percentile box plots of fecal coliform counts from surface samples in the inner harbor, August 1991.

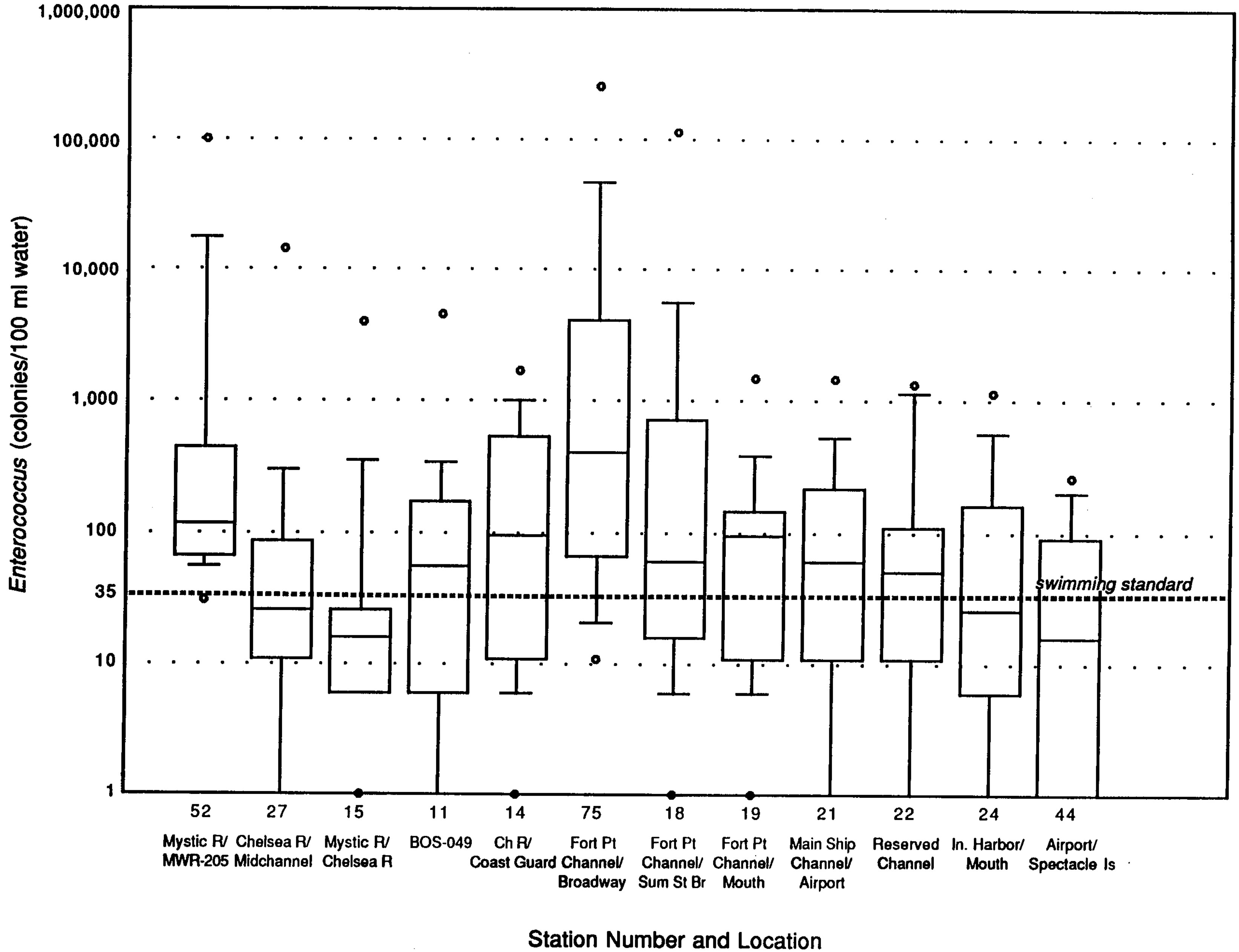


Figure 3.08. Percentile box plots of *Enterococcus* counts from surface samples in the inner harbor, August 1991.

3. The Inner Harbor

Bottom Samples

Percentile box plots (Figures 3.09 and 3.10) show the patterns of indicator bacteria densities in the inner harbor bottom waters.

Fecal Coliform

Bottom counts were significantly lower than surface counts at Stations 14 and 19, near the Charles River and Fort Point Channel (Table 3.01). At stations close to the mouth of the inner harbor, geometric mean bottom counts were higher at the bottom than at the surface, but the difference was not significant at the 5% level.

Enterococcus

Counts for *Enterococcus* from bottom samples were not significantly different from surface counts at any stations (Table 3.01). However at stations 24 and 44, at the mouth of the inner harbor, *Enterococcus* bottom counts were greater than the surface counts. Bottom *Enterococcus* counts were very similar among all stations sampled except for Station 52 near MWR-205, where counts were significantly higher than all other stations except 24 and 18.

3.1.c Relationship between Indicator Bacteria and Rainfall

Fall 1990-Spring 1991

Bacteria counts from surface samples at inner harbor stations were significantly correlated with the amount of rain that fell over three days (LORNP3): the amount of rain that fell on the day of sampling plus the amount of rain that fell the previous two days ($r = 0.58, p < 0.001$).

Summer 1991

The summer sampling period for the inner harbor included periods of dry weather as well as heavy rainfall during Hurricane Bob (Figure 3.02B).

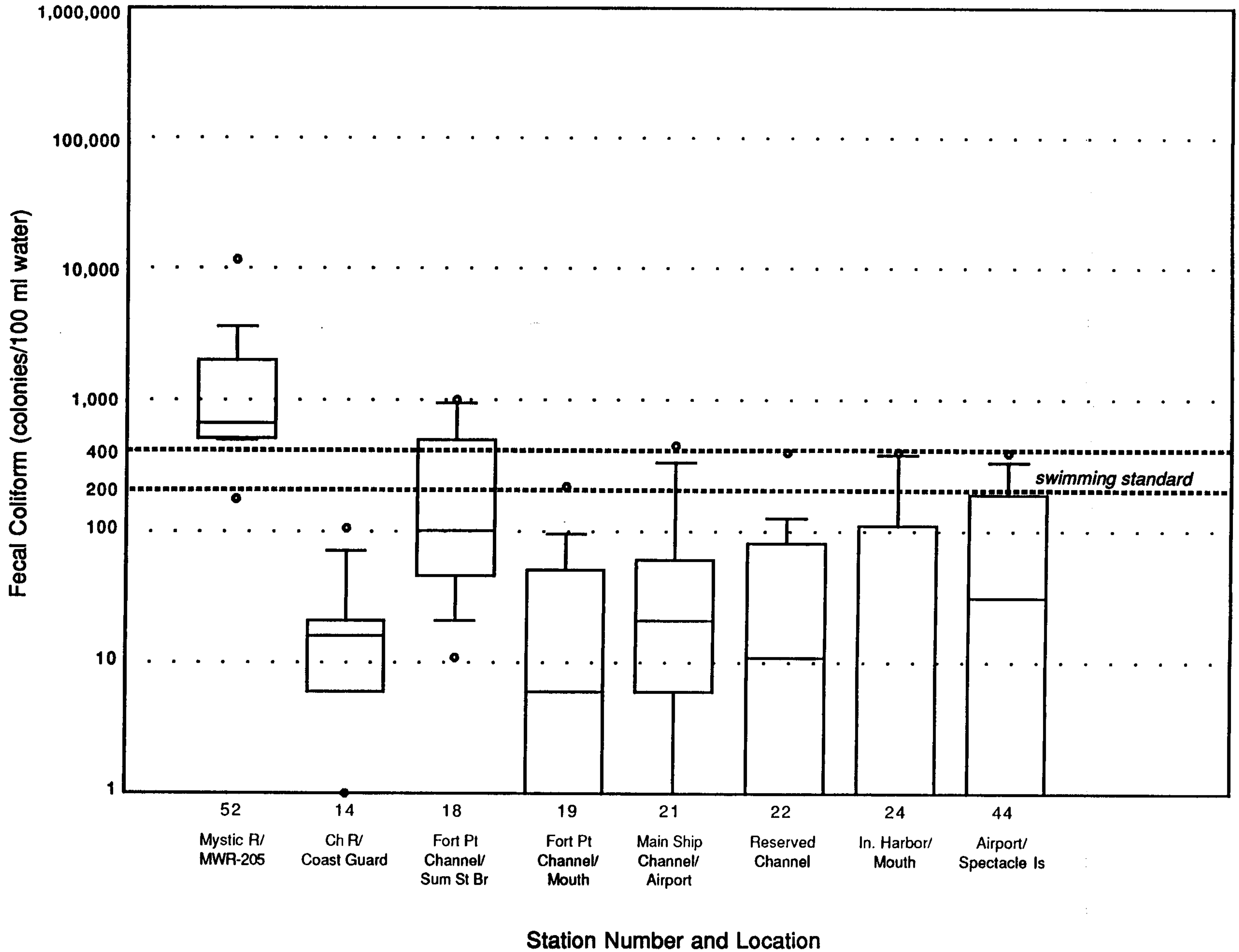


Figure 3.09. Percentile box plots of fecal coliform counts from bottom samples in the inner harbor, August 1991.

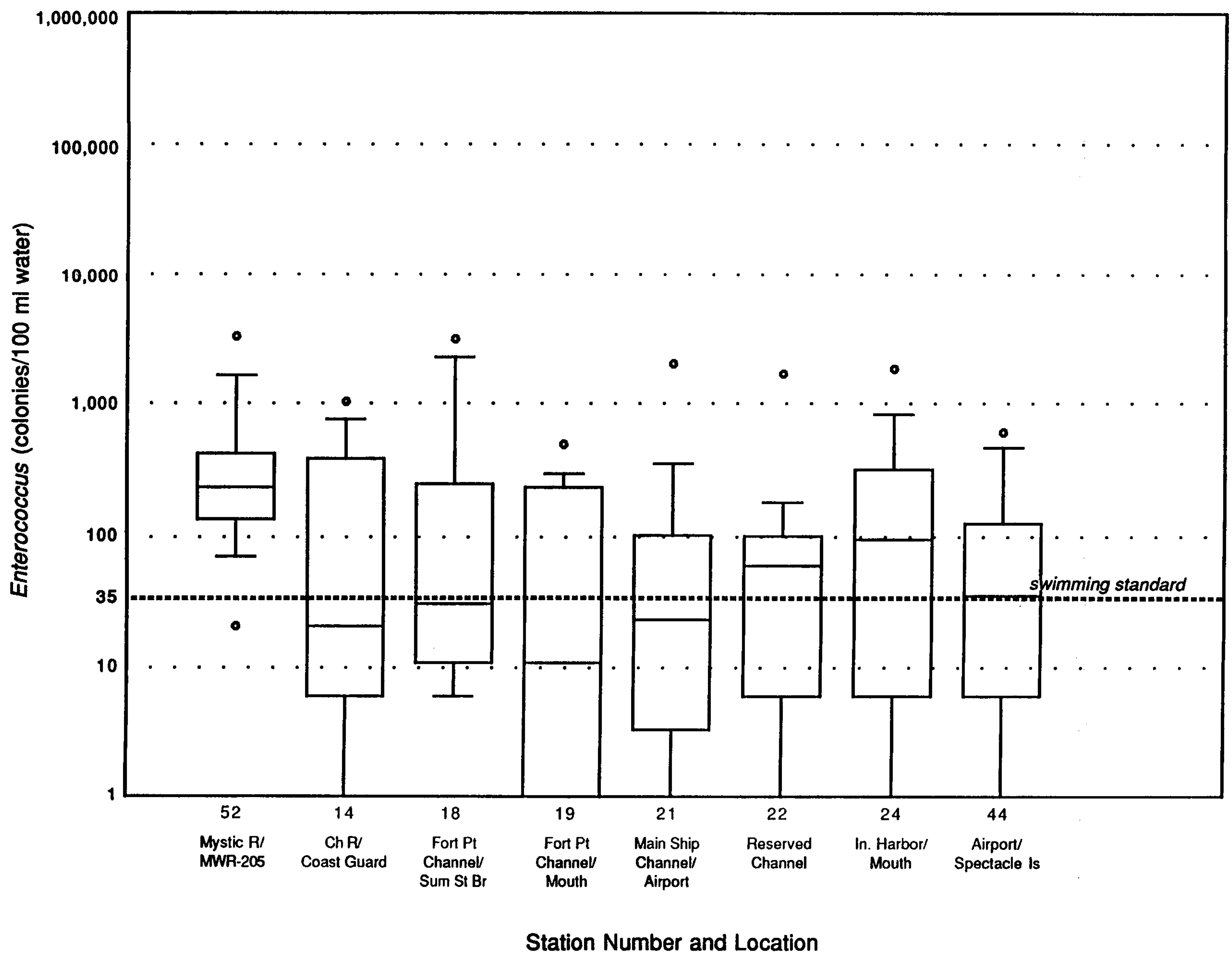


Figure 3.10. Percentile box plots of *Enterococcus* counts from bottom samples in the inner harbor, August 1991.

3. The Inner Harbor

The rainfall variable with the highest correlation with log-transformed fecal coliform densities for the inner harbor as a whole (surface samples, all 11 stations) was 3-day summed rainfall (LORNP3): $r = 0.60, p < 0.001$. (See page 2-16 for description of calculated rainfall variables.) Most individual stations in the inner harbor also showed strong correlations between rainfall and fecal coliform counts. However, there was only a weak relationship between rainfall and counts at the station nearest the Somerville Marginal CSO (for fecal coliform with rain the same day, LORN, $r = 0.46, p = 0.036$).

Regression Analyses of Indicator Bacteria Counts against Rainfall at Selected Inner Harbor Stations

Fort Point Channel, Station 18

Data collected at Station 18 provide a useful case to further analyze the relationship between rainfall and counts because this location is clearly affected by the large CSO at the head of Fort Point Channel, BOS-070. The regression equations for the relationship of indicator bacteria densities against 3-day summed rainfall for Station 18 for data collected from November 1990 through August 1991 are as follow. These data are all plotted on Figure 3.11.

Surface Samples

$$\text{Log(fecal coliform/100 ml)} = 2.1 + 0.82[\text{LORNP3}]$$

$$R^2 = 0.53,\ p < 0.001$$

$$\text{Log}(\textit{Enterococcus}\text{/100 ml}) = 1.8 + 0.70[\text{LORNP3}]$$

$$R^2 = 0.39,\ p < 0.001$$

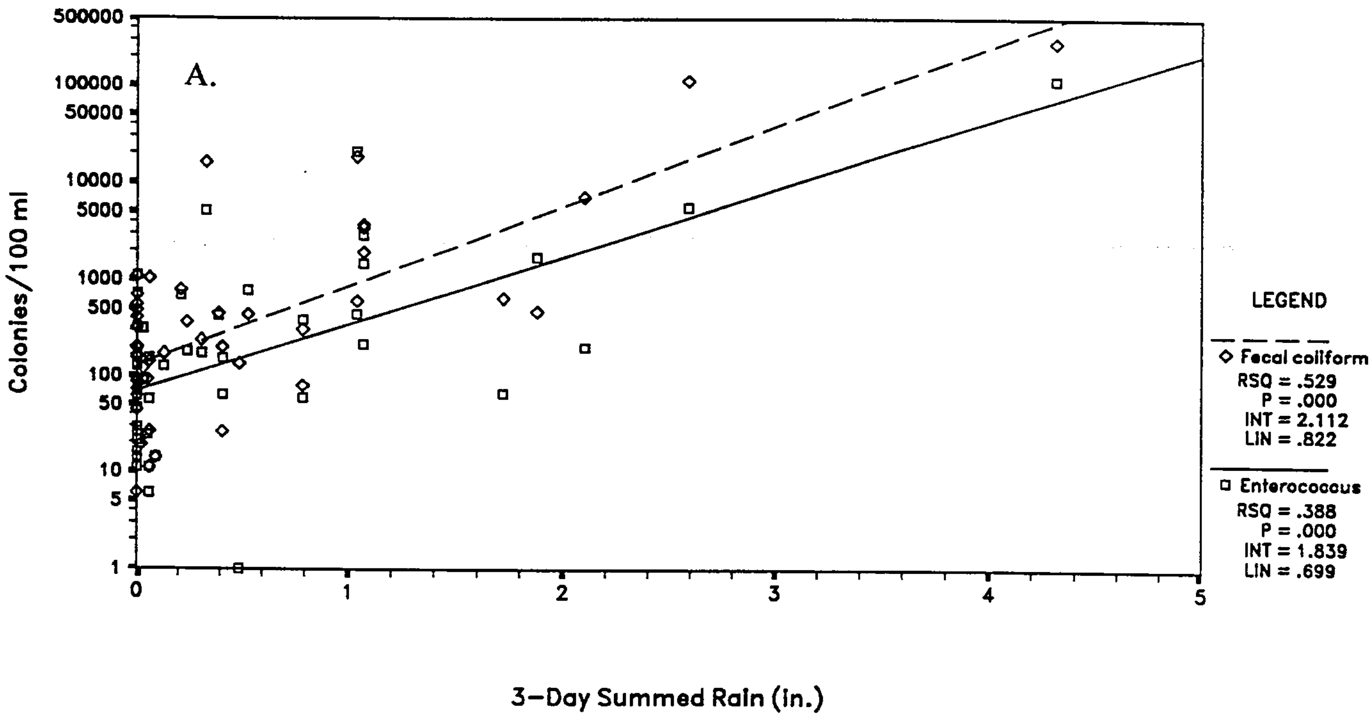
Bottom Samples

$$\text{Log(fecal coliform/100 ml)} = 1.5 + 0.38[\text{LORNP3}]$$

$$R^2 = 0.28,\ p < 0.001$$

$$\text{Log}(\textit{Enterococcus}\text{/100 ml}) = 1.3 + 0.50[\text{LORNP3}]$$

$$R^2 = 0.25,\ p < 0.001$$



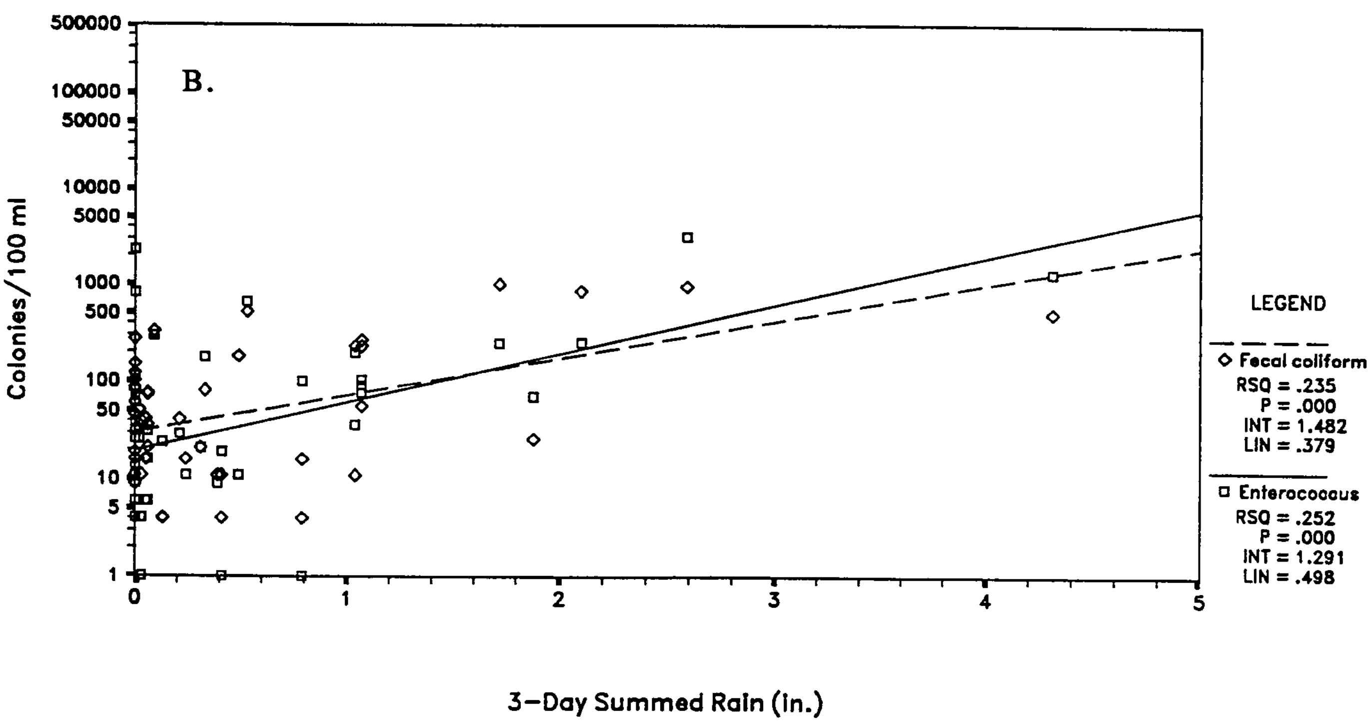


Figure 3.11. Fecal coliform counts and *Enterococcus* counts regressed against three-day summed rainfall (LORNP3) at Station 18 in Fort Point Channel. A. Surface data and B. Bottom data.

Mouth of Inner Harbor, Station 24

In contrast to Station 18, which is directly affected by overflows from a large CSO, Station 24, located at the mouth of the inner harbor, is relatively remote from major CSO sources. The regressions of coliform counts against rain explain a smaller percent of the variation in the data and are less statistically significant than at Station 18, reflecting dilution and die-off of indicator bacteria over time and space in the inner harbor. These data are plotted on Figure 3.12.

Surface Samples

$$\text{Log(fecal coliform/100 ml)} = 0.80 + 0.75[\text{LORNP3}]$$
$$R^2 = 0.46,\ p < 0.001$$

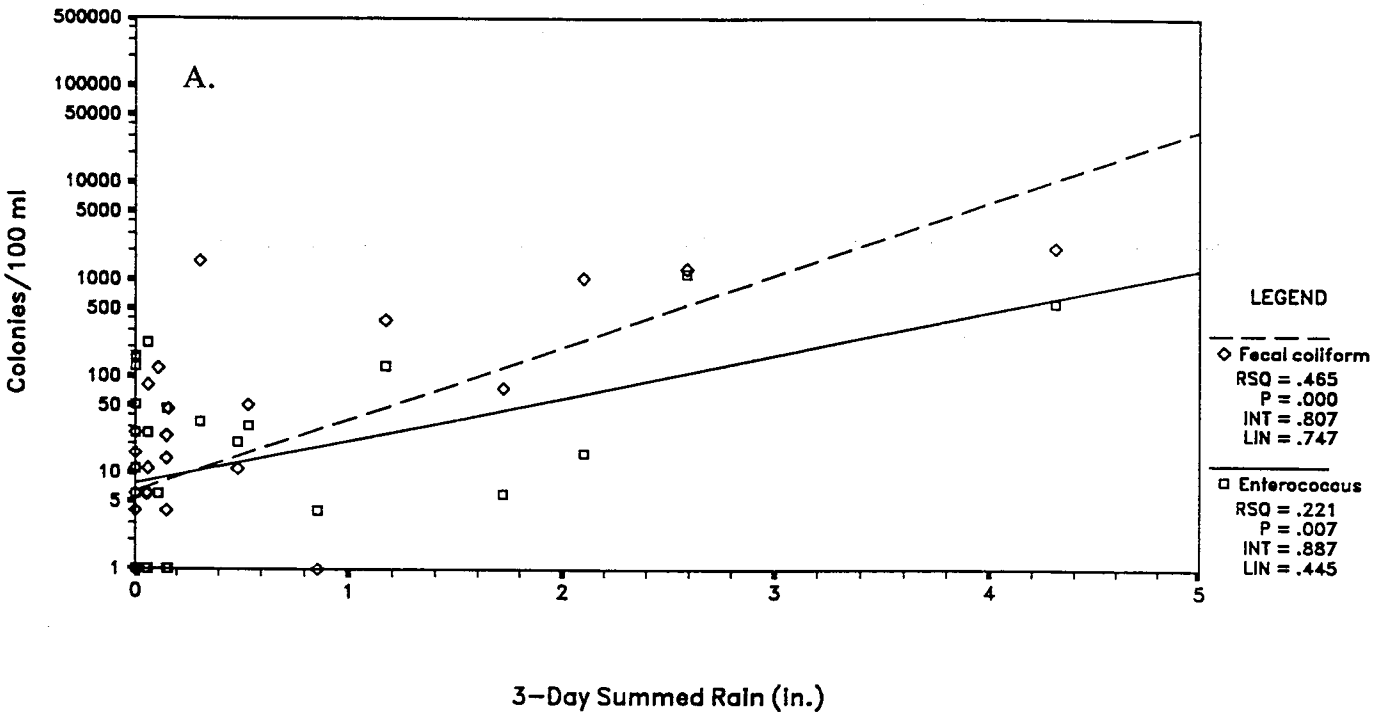
$$\text{Log(}\textit{Enterococcus}\text{/100 ml)} = 0.89 + 0.44[\text{LORNP3}]$$
$$R^2 = 0.22,\ p = 0.007$$

Bottom Samples
For samples taken from the bottom at this location, neither fecal coliform nor *Enterococcus* had a significant relationship with rainfall at $p < 0.01$.

Effect of One Storm Event on Fecal Coliform Counts at Three Inner Harbor Stations

The occurrence of Hurricane Bob (August 19) during the inner harbor monitoring period provided an opportunity to observe the effects of a major storm on water quality at different locations in the inner harbor. Figure 3.13 shows the effect of the rainfall at two stations near major combined sewer overflows and at one station relatively distant from major overflows in the main ship channel. Because of the severe weather conditions, we were not able to sample on the first day of the storm and therefore do not know whether the fecal coliform counts on August 20 represent an increase or decrease from what occurred on the 19th.

Station 52 is located near the outfall for the Somerville Marginal CSO Facility (MWR-205), which discharges screened and chlorinated combined sewage. This station had the highest dry-weather levels of fecal coliform in the receiving water (1950 col/100 ml, on August 17). One day after the hurricane (August



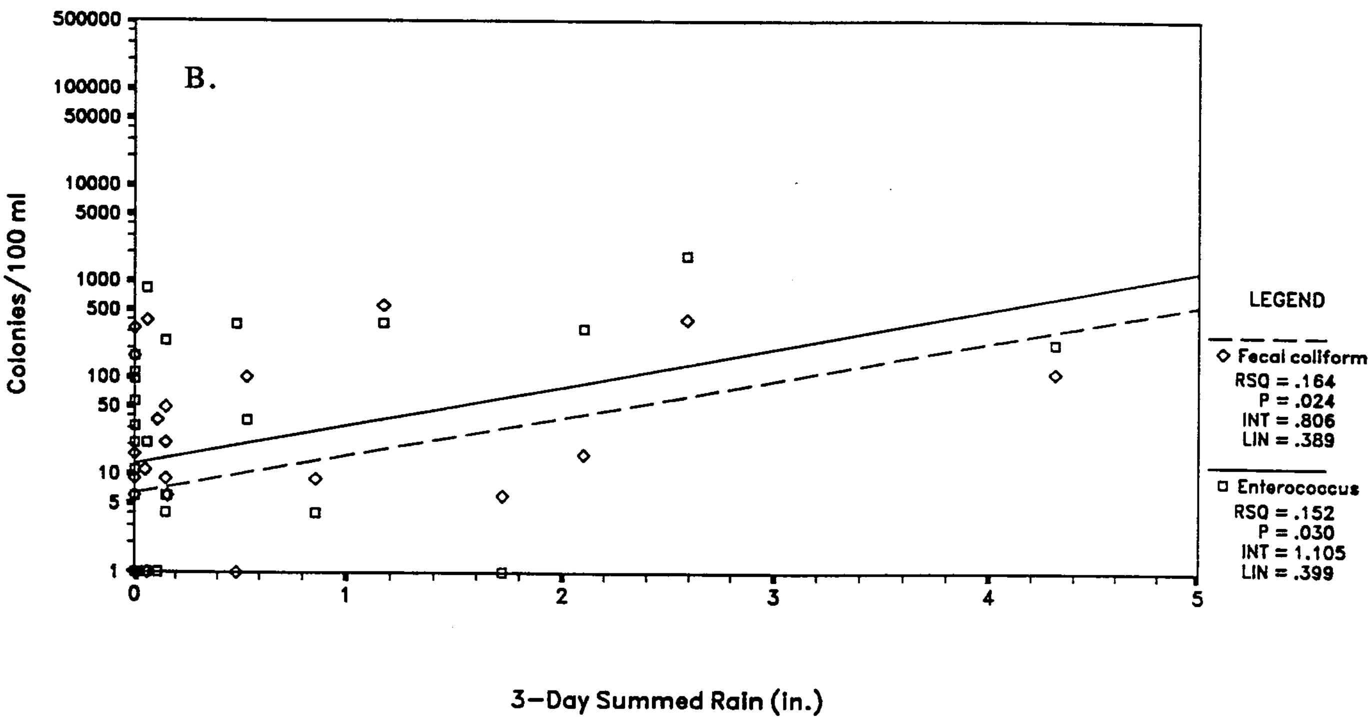
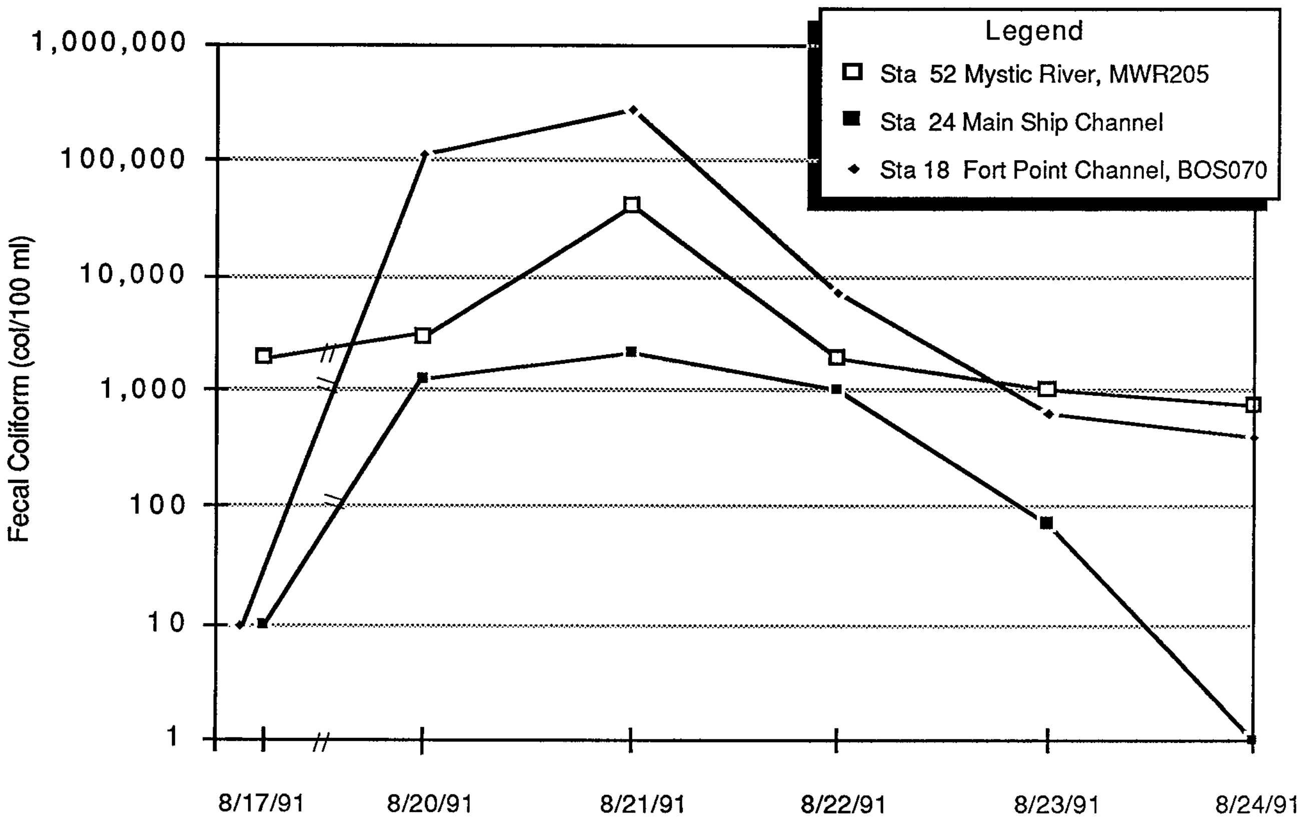


Figure 3.12. Fecal coliform counts and *Enterococcus* counts regressed against three-day summed rainfall (LORNP3) at Station 24 at the mouth of the inner harbor. A. Surface data and B. Bottom data.



Rainfall								
Date	8/17	8/18	8/19	8/20	8/21	8/22	8/23	8/24
Inches	0.0	0.0	2.21	0.38	1.72	0.0	0.0	0.0

Figure 3.13. The effect of the heavy rain during Hurricane Bob on water quality at three sites in Boston's inner harbor. The locations of the sampling stations are shown in Figure 3.01. No samples were collected August 18 or 19.

20) counts at this location were somewhat elevated (2950 col/100 ml). A second day of substantial rain (August 21) further raised the fecal coliform count by approximately an order of magnitude to 42,000 col/100 ml. The next day, counts fell back to the previous "dry-weather" level. The pattern of fecal coliform counts at Station 18, located in Fort Point Channel 1.25 km from a large CSO (BOS-070) that discharges untreated combined sewage, differed from that found near the Somerville Marginal Treatment Facility outfall. At Station 18, the dry-weather fecal coliform count (August 17) was only 10 col/100 ml. After the heavy rainstorm, counts rose dramatically, by more than four orders of magnitude, to 112,500 col/100 ml. Additional rain the next day was associated with a further increase to 281,000 col/100 ml. Over the next three days, counts dropped to 405 col/100 ml, not yet at "background" levels.

The third station shown in Figure 3.13, Station 24, is at the mouth of the inner harbor, relatively distant from CSO discharges. Counts here rose from a background level of 10 col/100 ml to 2130 col/100 ml by August 21. After the rain stopped, it took only two days for counts to fall within Class SB standards, and by three days after the rain, counts had returned to the background level.

3.1.d Relationship between Indicator Bacteria and Salinity

In the inner harbor, samples were collected from waters with a broad salinity range. During the summer, the inner harbor is stratified, with a lighter, fresher layer of water flowing from the Charles and Mystic Rivers overlaying more saline bottom water. This stratification is lessened in the winter.

Surface Samples

For all inner harbor stations analyzed as a group (excluding Station 11 in the Charles River), indicator bacteria counts were significantly and negatively correlated with salinity (for fecal coliform, $r = -0.57$, $p < 0.001$; and for *Enterococcus*, $r = -0.50$, $p < 0.001$).

At three individual stations chosen to reflect different geographic areas of the inner harbor, there was no consistent pattern of correlations of indicator bacteria densities with salinity. At Station 18 (Fort Point Channel), *Enterococcus* was significantly correlated with salinity ($r = -0.54$, $p = 0.002$), but fecal coliform counts were not. At Station 24 (mouth of inner harbor), fecal coliform counts were significantly correlated with salinity ($r = -0.66$, $p = 0.004$), but *Enterococcus* counts were not. Near the Somerville Marginal CSO (Station 52), there was no significant relationship of either fecal coliform or *Enterococcus* with salinity.

Bottom Samples

For bottom samples from the inner harbor, with all stations considered as a group, there was no significant correlation for fecal coliform counts with salinity or *Enterococcus* counts with salinity.

At Stations 18 and 24, there were no significant correlations of either fecal coliform or *Enterococcus* with salinity. At Station 52 (Somerville Marginal), *Enterococcus* counts were significantly correlated with salinity (r = -0.55, p = 0.02) but fecal coliform counts were not significantly correlated with salinity.

3.1.e Dissolved Oxygen

All dissolved oxygen (DO) measurements were made during daylight hours.

Fall 1990-Spring 1991

Dissolved oxygen data for this time period are presented in Table 3.02. As would be expected during the colder winter months, when oxygen is chemically more soluble than in warmer water and respiration in the water and sediment is lower, DO levels were relatively high--ranging from a low of 2.5 mg/l near BOS-070 at the head of Fort Point Channel (Station 75) to a high of 12.4 mg/l at the mouth of the channel.

Table 3.02. Means and ranges of dissolved oxygen measurements, from fall 1990-spring 1991.

	DO (mg/l)	
Location (Station no.)	Surface mean (range)	Bottom mean (range)
Chelsea River (15.1)	10.1 (9.0-11.2)	9.1 (8.1-10.4)
Fort Point Chan., Broadway St. (75)	8.6 (2.8-11.2)	8.0 (7.8-8.1)
Fort Point Chan., Summer St. (18)	9.3 (5.6-12.4)	9.4 (5.3-13.1)
Fort Point Chan., Northern Ave. (19.1)	9.8 (7.6-12.1)	9.4 (7.1-11.9)

3. The Inner Harbor

Summer 1991

Surface

Figure 3.14 shows the percentile box plots for surface DO levels in the inner harbor during the summer sampling period. The lowest mean DO levels were at the two Fort Point Channel stations, presumably affected by BOS-070, and near MWR-205 in the Mystic River. The highest average DO levels were at Stations 24 and 21, near the relatively open water at the mouth of Fort Point Channel. Most of the lowest DO measurements occurred after Hurricane Bob (August 19-21).

Bottom

Figure 3.15 shows percentile box plots for bottom water samples. Not all locations had water deep enough to require collecting bottom samples, but where both surface and bottom samples were collected, average DO measurements were lower at the bottom than at the surface. The geographic pattern for bottom samples was similar to that for the surface, with the lowest DO levels found near MWR-205 and in Fort Point Channel

3.2 Discussion

3.2.a Indicator Bacteria Counts Compared to Water Quality Standards and Relationship with Rainfall

Water quality at different locations in Boston's inner harbor varies depending upon proximity to rivers and CSOs. Not surprisingly, the locations most affected by bacterial contamination are adjacent to large CSOs--sites in Fort Point Channel and in the Mystic River near the Somerville Marginal CSO. The next most impacted area is the mouth of the Charles River, affected by both river water quality and the Prison Point CSO treatment facility. The mouth of the inner harbor was the least impacted area.

In 1991, none of the inner harbor stations met class SB water quality standards during both wet and dry weather. How the water quality was affected by rainfall varied among stations, and depended on the dry-weather water quality and the distance from major CSOs. At Station 18 in Fort Point Channel, the dry weather count predicted by regression analysis was 126 col/100 ml; and 0.24 in. or more rain over three

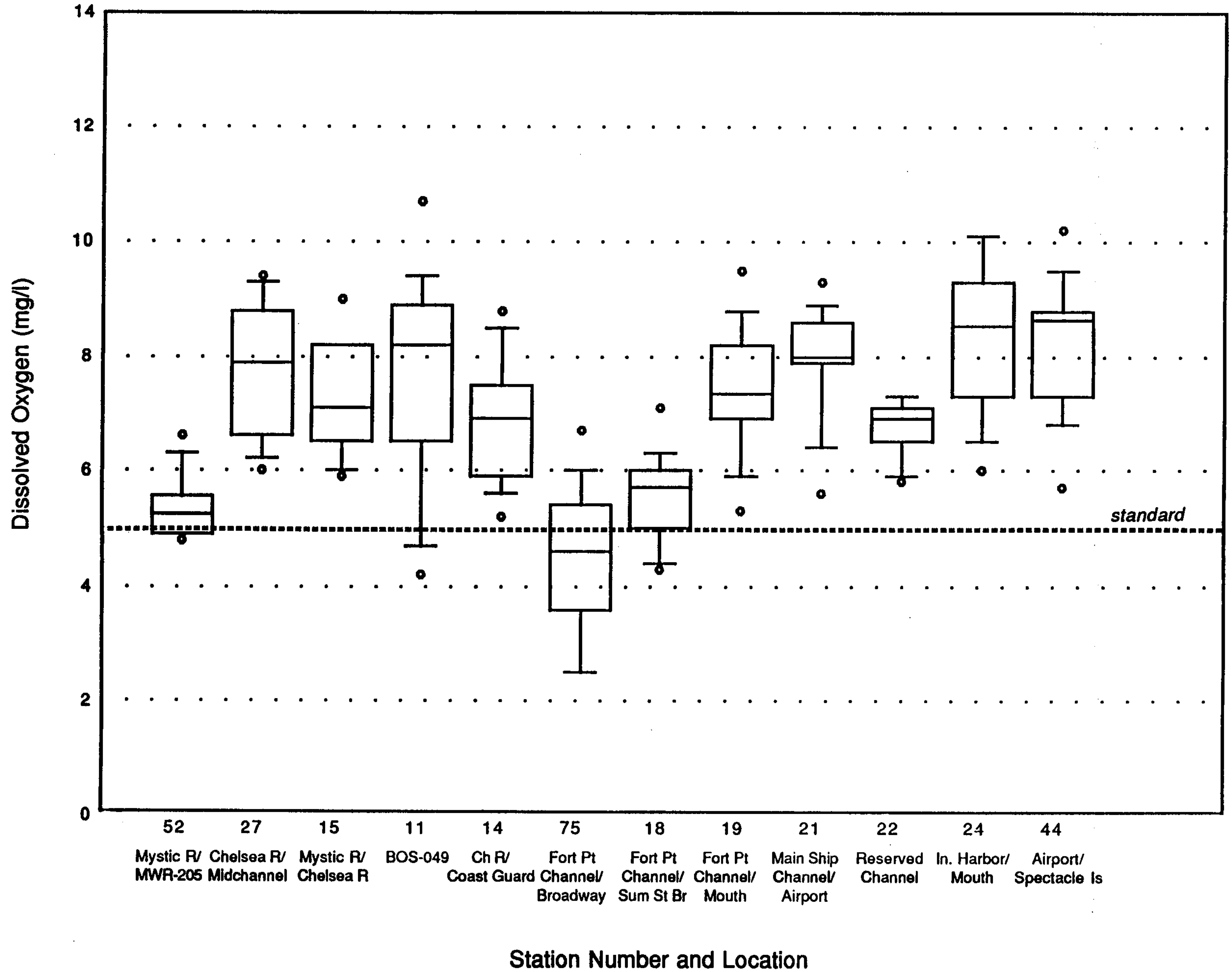


Figure 3.14. Percentile box plots of surface water dissolved oxygen levels in the inner harbor, August 1991.

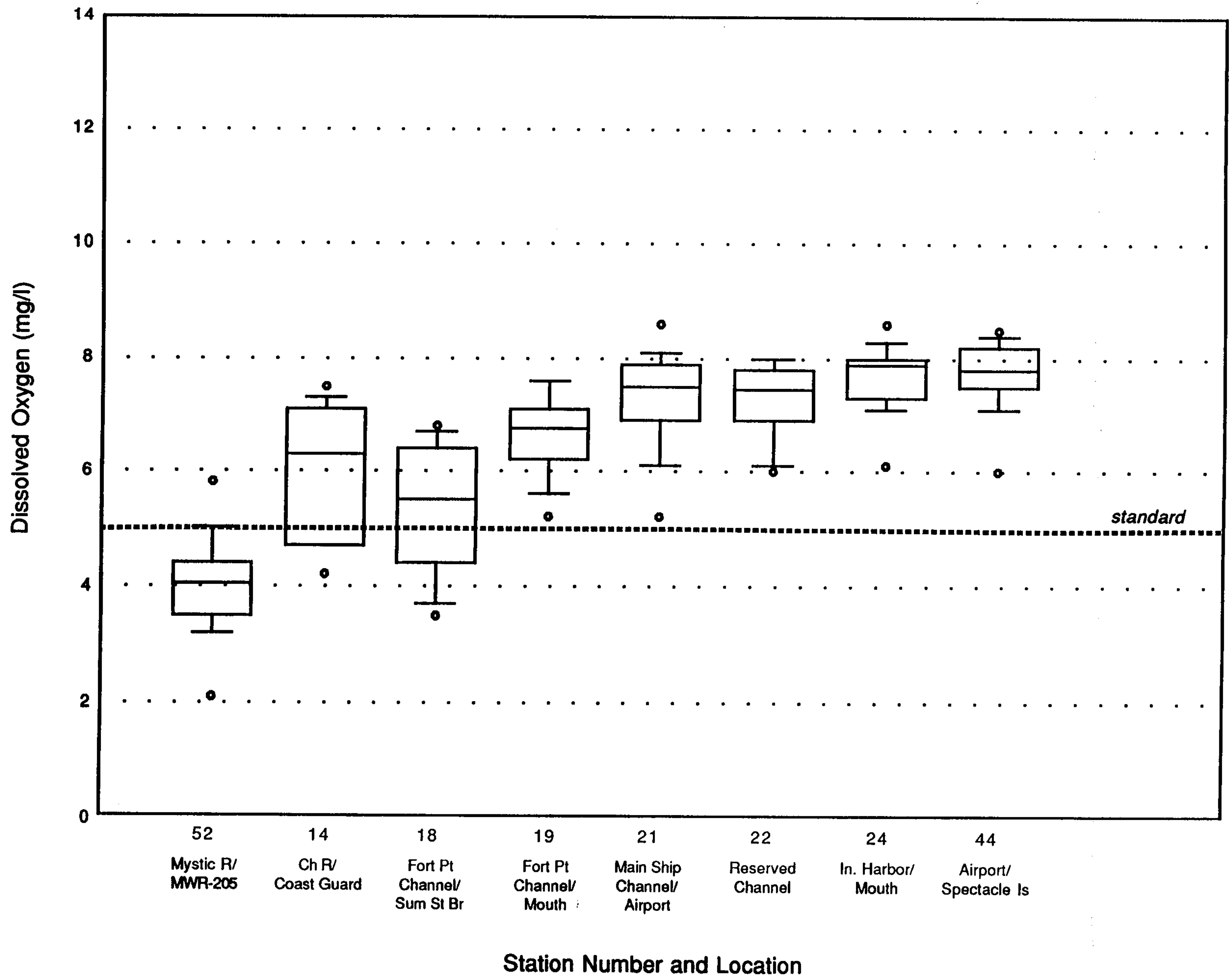


Figure 3.15. Percentile box plots of bottom water dissolved oxygen levels in the inner harbor, August 1991.

days would raise the count to over 200 col/100 ml. In contrast, at Station 24 near the mouth of the inner harbor, the dry-weather count predicted by regression analysis was 6 col/100 ml, with 2 in. of rain over three days causing fecal coliform counts to exceed 200 col/100 ml. The lower dry-weather counts at Station 24, and the fact that a relatively heavy rainfall is required to raise the counts above swimming standards, reflect the effects of dilution and "die-off" at locations relatively distant from CSOs.

Any effects of the inner harbor on Dorchester Bay can be estimated by data gathered at Station 44, in Dorchester Bay (see map, Figure 3.01). Here, the regression of fecal coliform on three-day rain was:

$$\text{Log(fecal coliform/100 ml)} = 0.54 + 0.64[\text{LORNP3}]$$
$$R^2 = 0.50,\ p = 0.002$$

Counts in Dorchester Bay, on average, exceeded 200 col/100 ml when rain summed over three days was ≥ 2.75 in. The observation that surface fecal coliform counts are significantly related to rainfall, but that the indicator bacteria densities diminish with distance from CSOs, is consistent with CSOs as the major source of sewage indicator bacteria to the inner harbor.

3.2.b Multi-year Analyses (1989, 1990, and 1991)

Depth Distribution of Indicator Bacteria in the Inner Harbor

One trend that previous years' data (MWRA 1991e) suggested was that while most of the inner harbor stations had surface bacteria counts higher than bottom counts, stations located at the mouth of the inner harbor had higher counts in the bottom waters than at the surface. The number of samples available previously was too few to confirm whether this pattern was statistically significant or not. Now, with three years of data, we repeated the analyses (t-tests), comparing surface bacteria counts to bottom bacteria counts. For fecal coliform, surface counts were significantly higher at Stations 14, 15, and 19 ($p < 0.001$). Fecal coliform counts were not statistically different between surface and bottom at Stations 21 and 24. At Station 44, just outside the mouth of the inner harbor, fecal coliform counts were higher in the bottom waters than at the surface ($p = 0.008$). For *Enterococcus,* surface counts were significantly higher at Station 14 ($p = 0.003$). At Stations 15, 19, and 21 there were no significant differences between surface and bottom *Enterococcus* counts. At Stations 24 and 44, bottom *Enterococcus* counts were significantly higher than surface *Enterococcus* counts ($p < 0.001$).

3. The Inner Harbor

As suggested in previous work (MWRA 1991e), sewage indicator bacteria at the surface in the inner harbor are associated with fresher water, and their source is probably CSOs and rivers. Indicator bacteria at the bottom are likely to have a source more remote in space and time. Possible sources include bottom sediment, settling from the surface, or sludge. Now that sludge is no longer being discharged into Boston Harbor, future monitoring may show a decrease in counts from bottom waters in the inner harbor.

Effect of Tidal Current on Bacterial Water Quality

Data over three years were combined, and bacteria counts were analyzed (t-tests) with respect to tidal current at four stations in the inner harbor (18, 19, 24, and 44). Surface counts for fecal coliform were significantly higher on the ebb tide than on the flood tide at Stations 19 ($p = 0.003$), 24 ($p = 0.003$), and 44 ($p = 0.016$). At Station 18, $p = 0.06$. CSOs tend to activate on the outgoing tide, so this observation is consistent with CSOs as a source of fecal coliform to the surface waters. Although counts of *Enterococcus* tended to be higher on the ebb tide, the differences between ebb and flood values for this indicator were not statistically significant.

Changes in Counts of Indicator Bacteria over Time: Hypotheses

As data are collected over a period of several years, it will be possible to make interannual comparisons to determine if water quality in the harbor is changing. Because samples in different years are inevitably collected under varying environmental conditions, especially differing rainfall conditions, it will be impossible to make meaningful inferences about changes in water quality (changes in bacteria counts) without accounting for differing environmental conditions. Although the statistical analyses necessary to evaluate interannual changes are not within the scope of this report, it is appropriate to present some hypotheses about how changes in pollution levels would be reflected in the data and analyzed in future reports.

In order to measure the effects of CSOs on sewage indicator bacteria counts in the receiving water, we need to know both the baseline "dry-weather" counts of bacteria, which presumably are affected by sources other than combined sewers, as well as the counts influenced by wet weather. Regression analyses, described in Section 3.1.c and shown in Figures 3.11 and 3.12, are ways of measuring both of these effects. When bacteria counts are regressed against rainfall, the intercept (0 in. of rain) represents a measure of the dry-weather level of bacteria, and the slope of the regression line reflects how the counts are affected by rain. The greater the slope of the regression line, the lesser the amount of rain necessary to increase bacteria counts. Thus we can hypothesize that if the amount of fecal indicator bacteria from wet-weather CSOs decreases over time because of improvements to the sewerage system, the slope of the regression line at a sampling location will also decrease. If the sources of dry-weather contamination are decreasing, the intercept will decrease (given the same slope). A statistical technique, analysis of covariance, can determine if the regression lines for different data sets are different. For the next CSO monitoring report, it may be appropriate to perform some analyses of covariance at different locations in the harbor for data collected during different years as a measure of water quality changes.

3.3 Conclusions

Boston's inner harbor is a physically complex marine environment. Within a relatively small area which can be characterized as an arrangement of artificially dredged channels, this urban estuary receives fresh water from two rivers, and is the only area of Boston Harbor where there is significant stratification, with a relatively fresh layer of water overlying a more saline bottom layer. The relationships among rainfall, CSOs, and water quality in the inner harbor vary greatly within this geographic area, and are affected by both anthropogenic factors (such as the structure and functioning of the sewer system) and natural factors (such as wind, tide, salinity, water temperature, and exposure to daylight).

The results of any attempt to measure water quality and relate it to environmental parameters inevitably rest on the study sampling design: where samples are taken, frequency of sampling, and number of samples. In this study, we measured water quality at stations both near CSOs and distant from CSOs, and sampled during wet and dry weather, at surface and bottom, and during all phases of the tidal cycle. The high frequency of sampling has enabled us to create a data set that permits statistical analysis relating both natural and anthropogenic variables and allows us to draw some conclusions.

- **Indicator Density Variation within Stations**

  Indicator bacteria counts exhibited high variability, sometimes over three orders of magnitude within stations--in both dry and rainy weather. This implies that it will be necessary to continue to collect relatively large numbers of samples (e.g., at least 20) at each station to detect significant differences among stations and to detect change over time within stations.

3. The Inner Harbor

- **Spatial Variation in Indicator Bacteria Densities**

Indicator counts varied considerably among stations in the inner harbor, as well as with depth sampled. Variation in indicator bacteria densities reflects the heterogeneous environment of the inner harbor. During 1990 and 1991, stations with the lowest measures of central tendency (geometric mean, median) for surface samples were at the mouth of the inner harbor, most distant from CSOs and rivers. Not surprisingly, Fort Point Channel stations and the Somerville Marginal station had the highest sewage indicator bacteria counts.

- **Correlation with Rainfall**

Sewage indicator bacteria densities in the receiving water were best correlated with cumulative rainfall over three antecedent days. Although there was a large amount of variation in dry weather bacteria counts, on average dry weather counts in the inner harbor met the fecal coliform standard except in close proximity to large CSO pipes. The effect of rainfall on indicator bacteria densities in the water diminished at stations furthest from the rivers and CSOs.

- **Dissolved Oxygen**

The lowest levels of dissolved oxygen were found adjacent to the two largest CSOs--in Fort Point Channel and near the Somerville Marginal CSO. Hurricane Bob was also followed by depressed DO levels, which may have caused additional oxygen demand to the water column by stirring up sediments.

- **Variation with Environmental Parameters**

Patterns of variation of fecal coliform and *Enterococcus* counts with rainfall, tide, salinity, and depth were all consistent with a CSO-associated source of sewage in the surface layer in the inner harbor. However, indicator bacteria densities in the bottom waters of the inner harbor did not appear to be strongly coupled with these environmental variables and probably have a source more remote in time and space. Sludge is one possible source. Future monitoring will show if, with the cessation of sludge discharges in December 1991, bottom water quality in the inner harbor improves.

4. Neponset River and Dorchester Bay

Monitoring in the Neponset River estuary was conducted throughout the fall and winter of 1990-1991 and the spring of 1991. Intensive sampling in the Neponset River estuary and Dorchester Bay was performed July 22 through September 5, 1991. In addition, quarterly monitoring of the entire length of the Neponset River was done in cooperation with the Neponset River Watershed Association. Monitoring results from the fall of 1990, spring of 1991 and summer of 1991 are presented in Section 4.1. Results from the upstream monitoring of the Neponset River are presented in Section 4.2. Discussion is in Section 4.3, and Conclusions in 4.4.

4.1 Results: Neponset River and Dorchester Bay, Fall and Winter 1990, Spring 1991, and Summer 1991

4.1.a Sampling Locations and Rainfall

Figure 4.01 shows the location of all the stations sampled in the Neponset River/Dorchester Bay area.

During the fall and winter of 1990, we sampled Stations 54 and 55 in the Neponset River and Station 89 adjacent to the Commercial Point overflow pipe (Table 4.01). During the following spring, we continued sampling at Station 89, and also sampled at Stations 41 and 39 near the Fox Point CSO Facility (Table 4.02). Three stations in northern Dorchester Bay (36, 38, and 44) were sampled several times during the spring period.

The Neponset River estuary and Dorchester Bay were monitored intensively between July 23 and September 5, 1991. Fifteen stations, listed in Table 4.02 and shown on Figure 4.01 were sampled during the summer 1991 monitoring period. Station 24 in the inner harbor was included to assess the effect of the inner harbor on Dorchester Bay (or vice versa). Surface samples were collected at all fifteen stations. Bottom samples were collected at stations 24, 38, 42, 44, and 84, where the water was more than 10 ft deep.

Figure 4.02 shows the amount of rain that fell each day during the fall and winter, spring, and summer sampling periods.

During the fall and winter (Figure 4.02A), there were eight days when rainfall (or snow equivalent to rainfall) was greater than 0.5 in. During the spring (Figure 4.02B), three rainfall events exceeded 0.5 in.,

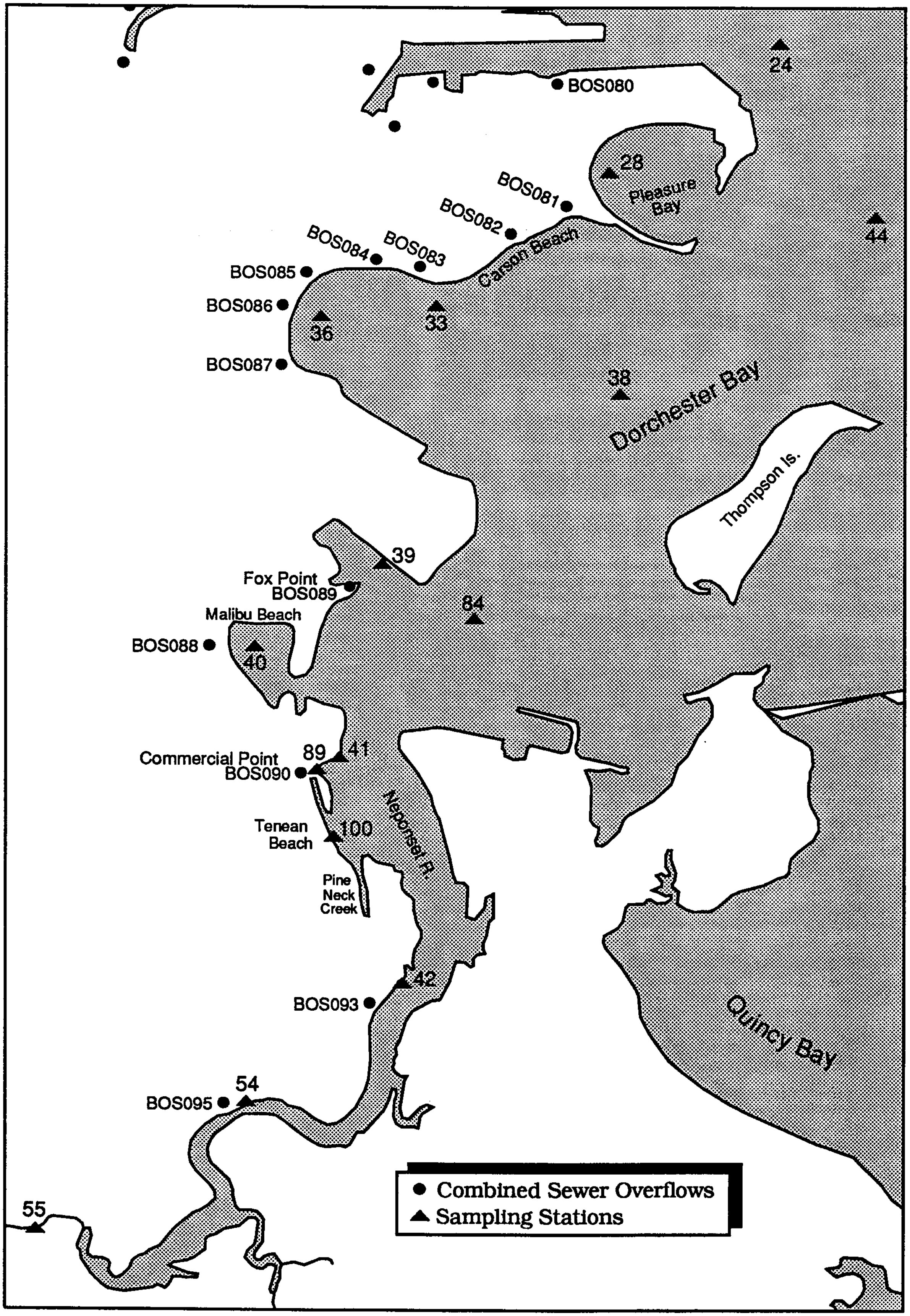


Figure 4.01. Stations sampled in the Neponset River and Dorchester Bay.

including a rainfall of 3.32 in. on April 21. The summer monitoring period included Hurricane Bob and three moderate rainfall events.

4.1.b Indicator Bacteria Counts

Fall-Winter 1990-1991

Table 4.01 shows the geometric mean indicator bacteria counts with 95% confidence intervals for November 14 through March 13. Counts for both fecal coliform and *Enterococcus* from Stations 55 and 54 (in the Neponset River) were higher than counts near the Commercial Point CSO. Geometric mean fecal coliform counts exceeded 1000 col/100 ml in the river, while the geometric mean count near the CSO was only 180 col/100 ml.

Spring 1991

From March 25 through June 5, intensive monitoring at the two stations (Stations 41 and 89) near the Commercial Point CSO and one station near the Fox Point CSO (Station 39) continued. In addition, several samples were collected in northern Dorchester Bay (Stations 36, 38, and 44). Table 4.02 shows that the geometric mean fecal coliform count at Station 89, at the Commercial Point CSO pipe, was higher than water quality standards (723 col/100 ml). A short distance (approximately 50 m) away, at Station 41, the geometric mean fecal coliform count (83 col/100 ml) was well within water quality standards.

Near the Fox Point CSO, geometric mean fecal coliform counts (105 col/100 ml) were within water quality standards.

Samples from northern Dorchester Bay were well within water quality standards for fecal coliform and *Enterococcus*.

Summer 1991

Surface Samples

Percentile box plots (Figures 4.03 and 4.04) show the counts of fecal coliform and *Enterococcus* from surface samples at these stations. On the figures, the stations are arranged in geographic order, with the most upstream station in the Neponset River on the left and the mouth of the inner harbor on the right. The

Table 4.01. Geometric means (col/100 ml) with 95% confidence intervals (CI) for fecal coliform and *Enterococcus* counts at Neponset River and Dorchester Bay stations in the fall-winter sampling period.

Station			Fall-Winter 1990-1991	
No.	Location	Depth*	n	mean (CI)
Fecal coliform				
54	Neponset R. Granite Ave (BOS-095)	S	4	1364 (896-2076)
55	Neponset R., Lower Mills, above dam	S	22	1080 (829-1406)
89	Victory Park; Commercial Pt (BOS-090)	S	29	180 (90-358)
Enterococcus				
54	Neponset R. Granite Ave (BOS-095)	S	4	945 (351-2539)
55	Neponset R., Lower Mills, above dam	S	22	595 (414-856)
89	Victory Park; Commercial Pt (BOS-090)	S	29	175 (81-375)

* S= Surface sample

Table 4.02. Geometric means (col/100 ml) with 95% confidence intervals (CI) for fecal coliform and *Enterococcus* counts at Neponset River and Dorchester Bay stations spring and summer, 1991.

Station			Spring 1991		Summer 1991	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Fecal coliform						
24	Inner Harbor/Mouth	S	...	...	17	10 (3-32)
		B	...	...	16	12 (4-31)
28	Pleasure Bay	S	...	...	14	11 (2-43)
33	L-Street	S	...	...	17	16 (6-44)
36	BOS-086	S	7	9 (2-38)	17	11 (3-34)
38	Mid-Old Harbor	S	8	20 (5-72)	17	3 (1-8)
		B	...	...	16	6 (1-17)
39	Fox Point (BOS-089)	S	14	105 (37-297)	17	52 (16-162)
40	Malibu Bay (BOS-088)	S	...	...	17	39 (17-89)
41	Commercial Point	S	18	83 (36-190)	16	41 (10-160)
42	Neponset River (BOS-093)	S	...	...	19	277 (110-697)
		B	...	...	14	70 (36-136)
44	Airport/Spectacle Is.	S	3	1 (0-3)	17	3 (1-7)
		B	...	...	16	8 (2-25)
54	Neponset R. Granite Ave (BOS-095)	S	...	...	18	720 (401-1291)
55	Neponset R., Lower Mills, above dam	S	...	...	18	2816 (1685-4707)
84	Columbia Point	S	...	...	17	6 (2-17)
		B	...	...	16	10 (4-23)
89	Victory Park (Comm. Pt. BOS-090)	S	15	723(216-2411)	17	422 (98-1810)
100	Tenean Beach	S	...	...	16	266 (130-543)

Table 4.02, continued.

Station			Spring 1991		Summer 1991	
No.	Location	Depth	n	mean (CI)	n	mean (CI)
Enterococcus						
24	Inner Harbor/Mouth	S	...	...	17	5 (2-12)
		B	...	...	16	8 (3-20)
28	Pleasure Bay	S	...	...	14	34 (11-103)
33	L-Street	S	...	...	17	8 (2-24)
36	BOS-086	S	7	7 (2-25)	17	6 (1-18)
38	Mid-Old Harbor	S	8	20 (3-119)	17	5 (1-13)
		B	...	...	16	10 (3-31)
39	Fox Point (BOS-089)	S	13	19 (5-64)	17	5 (1-20)
40	Malibu Bay (BOS-088)	S	...	...	17	9 (3-27)
41	Commercial Point	S	18	29 (14-60)	16	12 (3-49)
42	Neponset River (BOS-093)	S	...	...	19	53 (16-168)
		B	...	...	14	54 (18-162)
44	Airport/Spectacle	S	3	0 (0-0)	17	5 (2-13)
		B	...	...	16	11(2-44)
54	Neponset R. Granite Ave (BOS-095)	S	...	...	18	210 (83-527)
55	Neponset R., Lower Mills, above dam	S	...	...	18	1400 (654-2997)
84	Columbia Point	S	...	...	17	5 (2-12)
		B	...	...	16	6 (2-18)
89	Victory Park (Comm. Pt. BOS-090)	S	15	425 (104-1723)	17	201 (51-784)
100	Tenean Beach	S	...	...	16	50 (20-126)

* S= Surface; B= Bottom

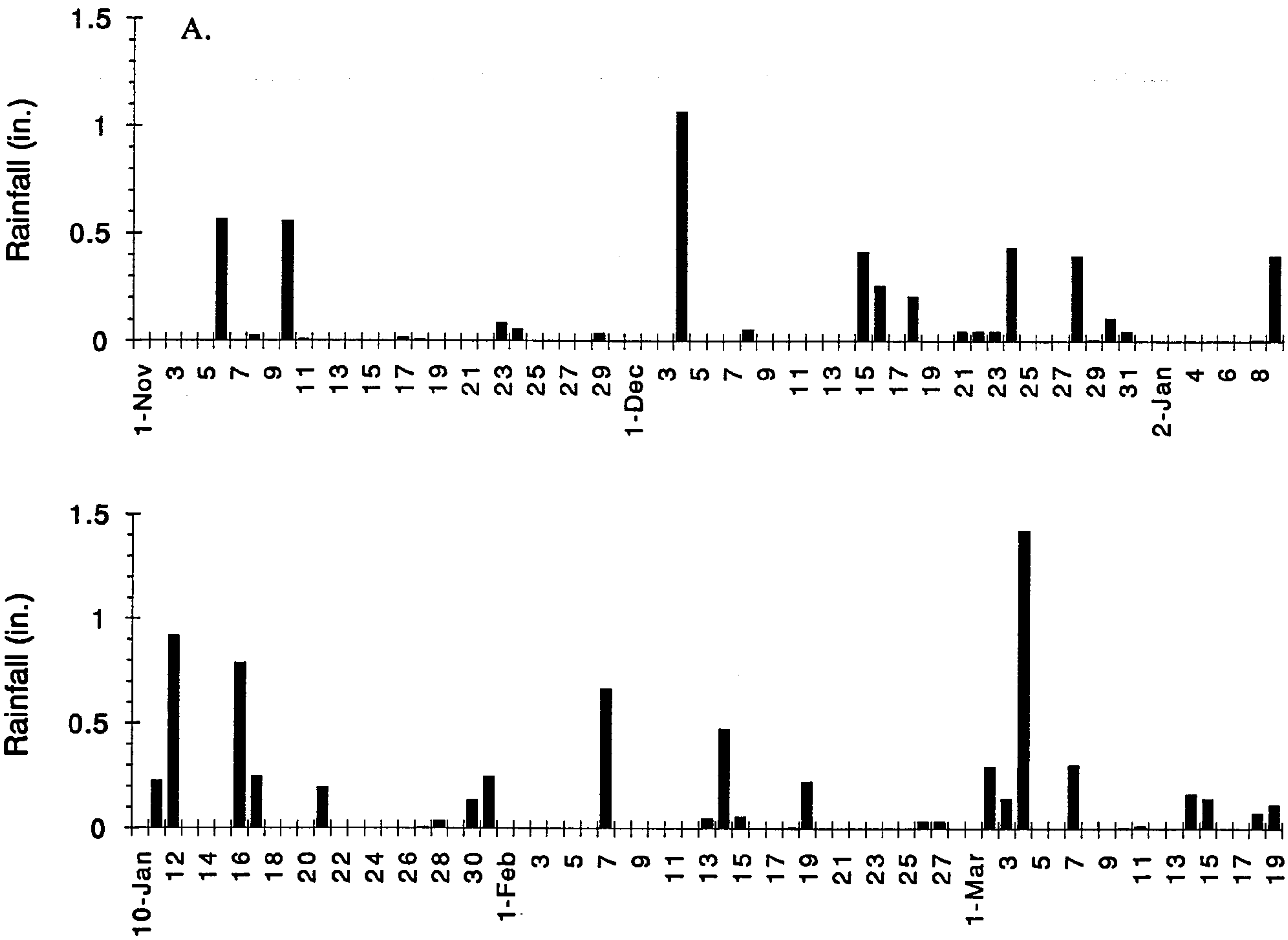


Figure 4.02. Rainfall during the Neponset River and Dorchester Bay sampling periods. A. Fall-winter 1990-1991.

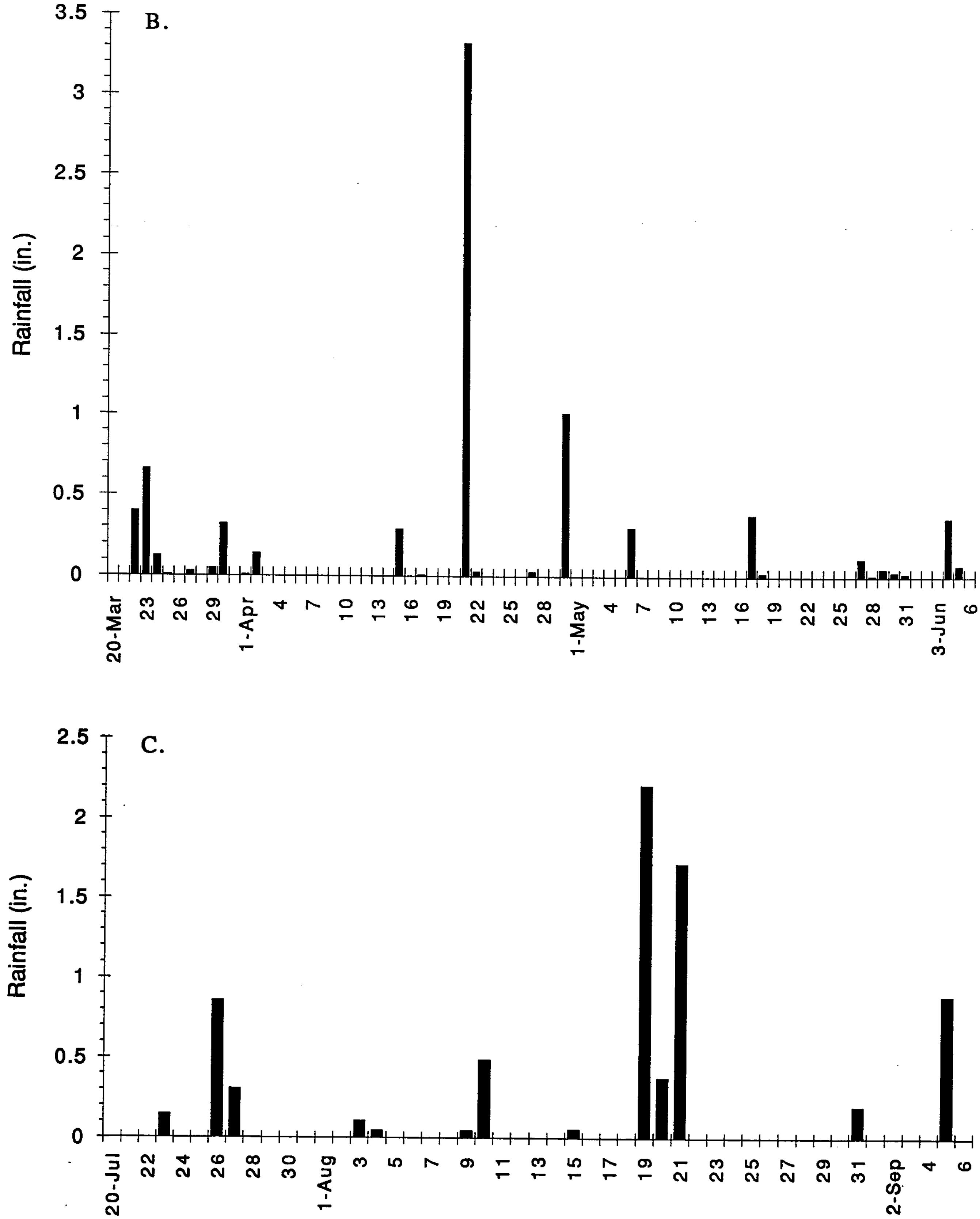


Figure 4.02, continued. Rainfall during the Neponset River and Dorchester Bay sampling periods.
B. Spring 1991 and C. Summer 1991.

4. Neponset River and Dorchester Bay

general pattern for fecal coliform was higher counts in the Neponset River, upstream of Station 41 at Stations 55, 54, 42, and 100. Geometric mean counts were higher than 200 col/100 ml upstream of Station 41 (and also at Station 89, adjacent to the Commercial Point outfall pipe). Geometric mean counts were lower than the 200 col/100 ml standard at stations in Dorchester Bay and at the mouth of the inner harbor. *Enterococcus* showed a geographic pattern similar to fecal coliform. Again, the highest geometric mean (1400 col/100 ml) was at Station 55, the most upstream location. The lowest counts were in Dorchester Bay and Station 24 at the mouth of the inner harbor.

Bottom Samples

Samples of bottom water were collected at Stations 24, 38, 42, 44, and 84, where the water was deeper than 10 ft. None of the bottom stations had geometric mean fecal coliform counts significantly different from the surface geometric mean counts (Table 4.02).

4.1.c Relationship between Indicator Bacteria and Rainfall

Fall and Winter 1990-1991

At Stations 55, 54, and 89, sampled during this time period, the rainfall variable with the best correlation with indicator bacteria density was rain summed over four days (for fecal coliform, $r = 0.39$, $p = 0.002$; for *Enterococcus*, $r = 0.57$, $p < 0.001$).

Spring 1991

Indicator bacteria counts for both fecal coliform and *Enterococcus* at Stations 41, 39, 36, 38, 44, and 89 during the spring sampling period correlated best with rainfall summed over two days.

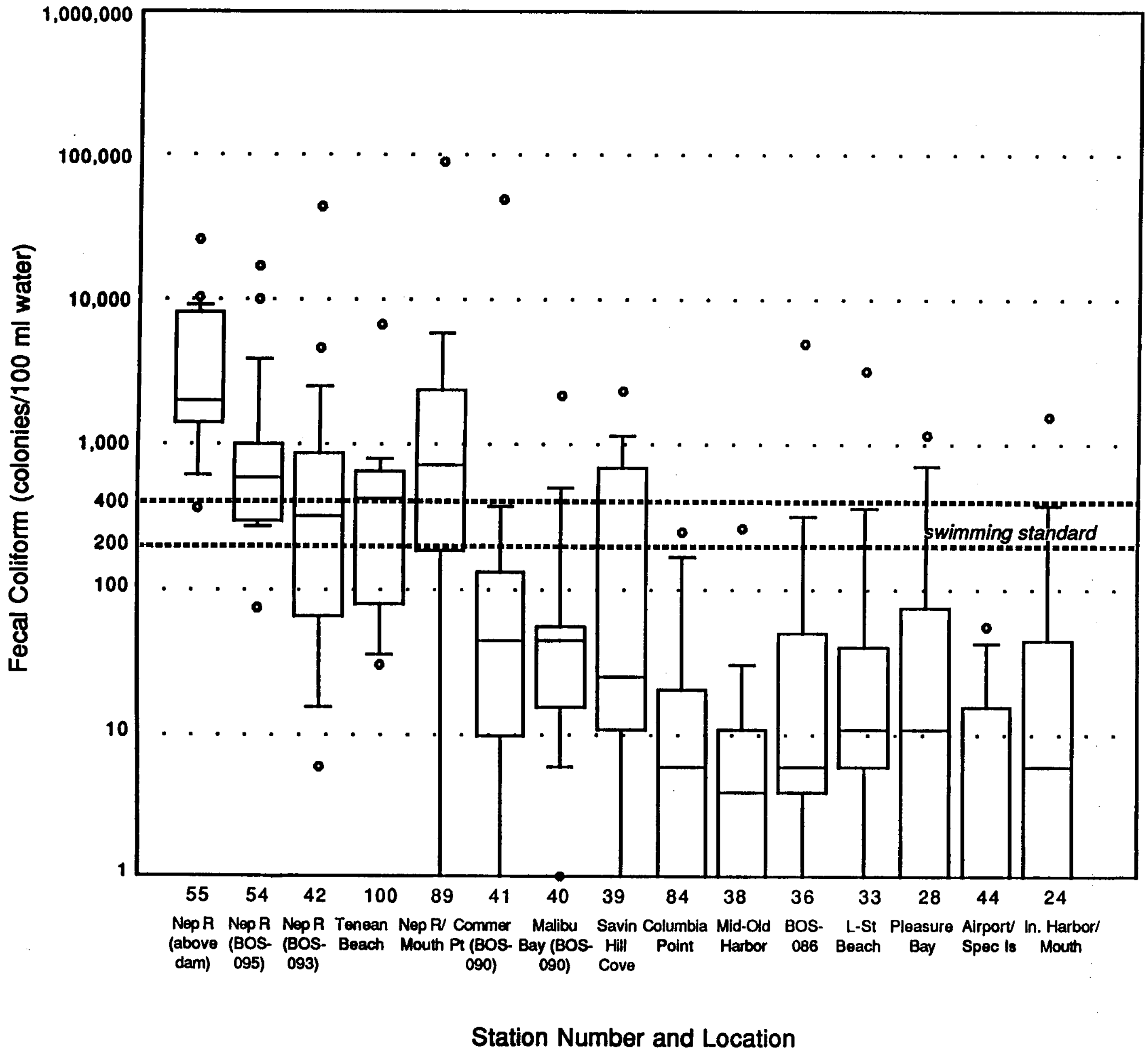


Figure 4.03. Percentile box plots of fecal coliform counts from surface samples in the Neponset River and Dorchester Bay, summer 1991.

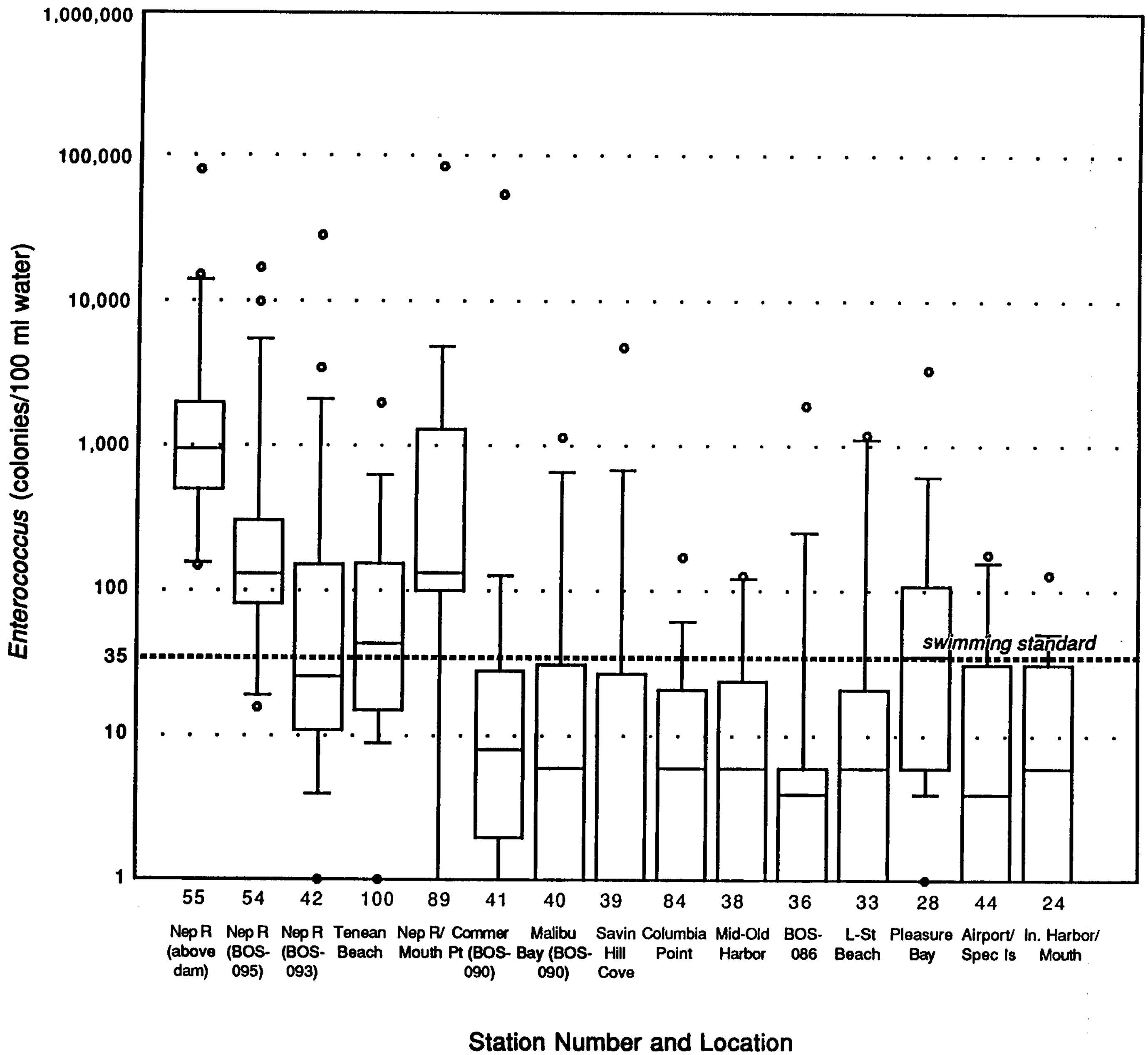


Figure 4.04. Percentile box plots of *Enterococcus* counts from surface samples in the Neponset River and Dorchester Bay, summer 1991.

4. Neponset River and Dorchester Bay

Summer 1991

The Neponset River and Dorchester Bay showed significant correlations between indicator bacteria density and rainfall during the summer 1991 sampling period. Overall, rain summed over three days was significantly related to fecal coliform density ($r = 0.44$, $p < 0.001$) and to *Enterococcus* density ($r = 0.53$, $p < 0.001$). The strength of the relationship between rain summed over two or three days and indicator bacteria densities varied among stations, and was weakest at Stations 41, 39, and 44. Two of these stations (41 and 39) are near CSO screening and chlorination facilities. Station 44 is located in the outer harbor, distant from nearshore sources of sewage.

Effect of a Rainstorm on Dorchester Bay

A storm that deposited 1.17 in. of rain over a period of two days (July 26 and 27) occurred during the summer monitoring period. To show the spatial pattern of indicator bacteria after a rain in Dorchester Bay, the fecal coliform counts from surface water samples collected July 27 are plotted on a map (Figure 4.05). Counts were similar within an order of magnitude at sites in northern Dorchester Bay--Stations 36, 33, 28, and 38 were all approximately 10^2 col/100 ml, as were the outermost inner harbor site (Station 24) and Station 84 in southern Dorchester Bay. Lower counts (10^1 col/100 ml) were found at the most offshore site in northern Dorchester Bay (Station 44), and at the two sites adjacent to the Commercial Point outfall (Stations 89 and 41). Higher counts (10^3 col/100 ml) were found in the Neponset River (Station 42), at Malibu Bay (Station 40), at Tenean Beach (Station 100), and near the Fox Point outfall (Station 39).

Table 4.03 shows the fecal coliform counts before and after the July 26-27 rainstorm at sites near the two major Dorchester Bay CSOs (BOS-089 and 090), at Tenean Beach, and in the Neponset River. Elevated fecal coliform counts were found at Tenean Beach on July 27, even when fecal coliform counts near the Commercial Point CSO were below the detection limit. Fecal coliform counts near the Fox Point CSO were elevated on July 27, when a discharge was recorded. However, the Fox Point discharge was probably not a significant source of fecal coliform contamination at Tenean Beach because counts at the stations located between Fox Point and the beach (Stations 84 and 41) were lower than at the beach.

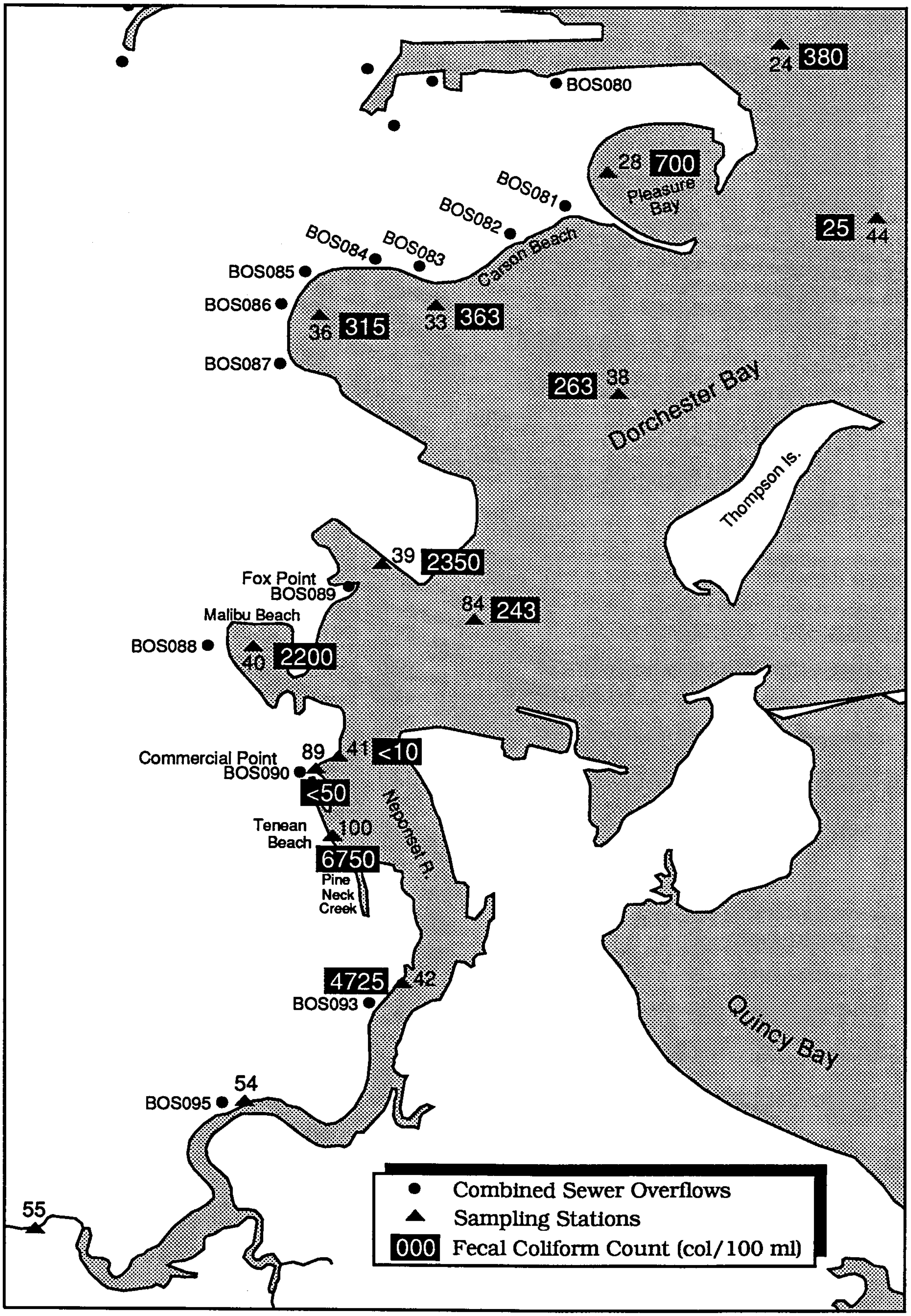


Figure 4.05. Fecal coliform counts in the Neponset River and Dorchester Bay on July 27, 1991, after 1.17 in. of rain.

4. Neponset River and Dorchester Bay

Table 4.03. Fecal coliform counts at stations near the Fox Point and Commercial Point CSOs and at Tenean Beach before and after a rainfall.

		Fecal coliform counts (colonies/100 ml) from samples collected July 1991 Date (in. of rain)					
Station		25th (0.0)	26th (0.86)	27th (0.31)	29th (0.0)	30th (0.0)	31st (0.0)
39	Fox Point	1150	5	2350	<5	60	70
84	Columbia Point	<5	5	243	10	<5	5
41	Commercial Point	10	370	<50	313	115	45
89	Commercial Point	1550	5575	<50	295	730	465
100	Tenean Beach	800	118	6750	400	555	35
42	Neponset River	65	80	4725	478	315	105

Lower Neponset River: Comparison of Wet and Dry Weather Fecal Coliform Counts

Geometric mean fecal coliform counts at three stations in the Neponset River were higher in wet weather than in dry weather (Table 4.04).

Table 4.04. Geometric mean fecal coliform counts (colonies/100 ml) at stations in the lower Neponset River, summer 1991.

	Station 55	Station 54	Station 42
Wet weather	6072	3031	1531
Dry weather	2013	471	117

4. Neponset River and Dorchester Bay

Regression Analyses of Indicator Bacteria Counts and Rain at Dorchester Bay Beaches

Northern and southern Dorchester Bay beaches had differing relationships of fecal coliform counts to rainfall. At Tenean Beach in southern Dorchester Bay (Figure 4.06A), the regression of fecal coliform against rainfall was not statistically significant. Counts at Tenean Beach were not a significant function of counts at the Commercial Point CSO (Stations 89 and 41) or in the lower Neponset River (Station 42).

In contrast to Tenean Beach, two beach areas in northern Dorchester Bay had significant relationships between fecal coliform counts and three-day summed rainfall (Figure 4.07A and B). The equations for these regressions are:

Carson Beach (Station 33)

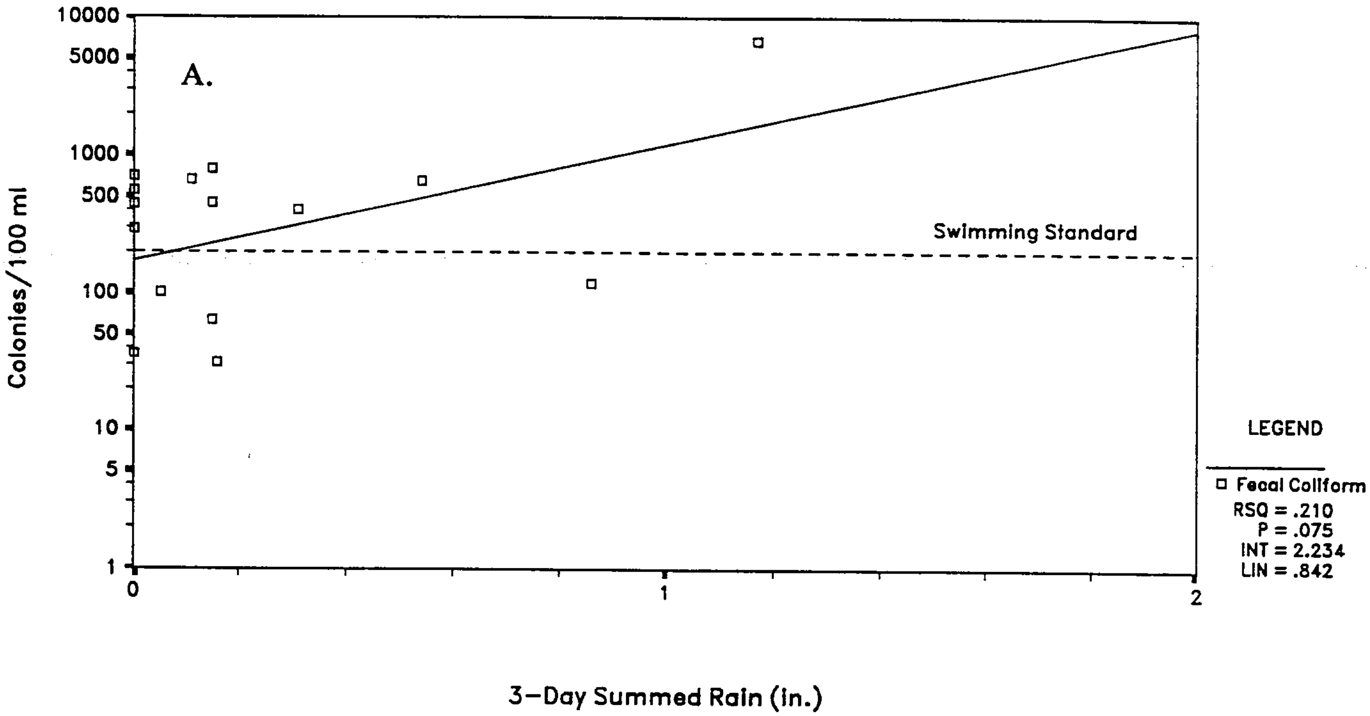
$$\text{Log(Fecal coliform/100 ml)} = 0.92 + 1.46[\text{LORNP3}]$$
$$R^2 = 0.31,\ p = 0.019$$

By this equation, fecal coliform counts exceed 200 col/100 ml when rainfall summed over three days exceeds 0.94 in., with rainfall explaining approximately 31% of the variation in counts.

Pleasure Bay (Station 28)

$$\text{Log(Fecal coliform/100 ml)} = 0.58 + 1.98[\text{LORNP3}]$$
$$R^2 = 0.42,\ p = 0.012$$

Fecal coliform counts exceed 200 col/100 ml when rainfall summed over three days exceeds 0.87 in., with rainfall explaining approximately 42% of the variation in counts.



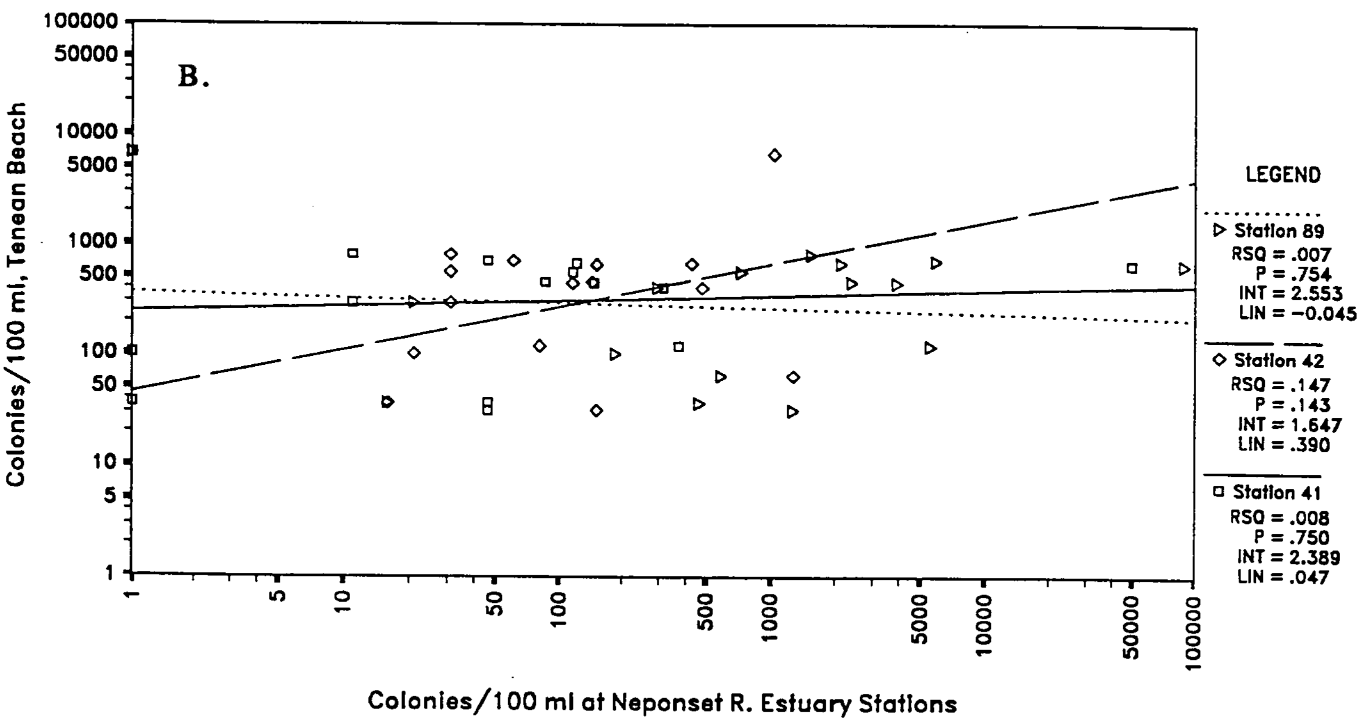
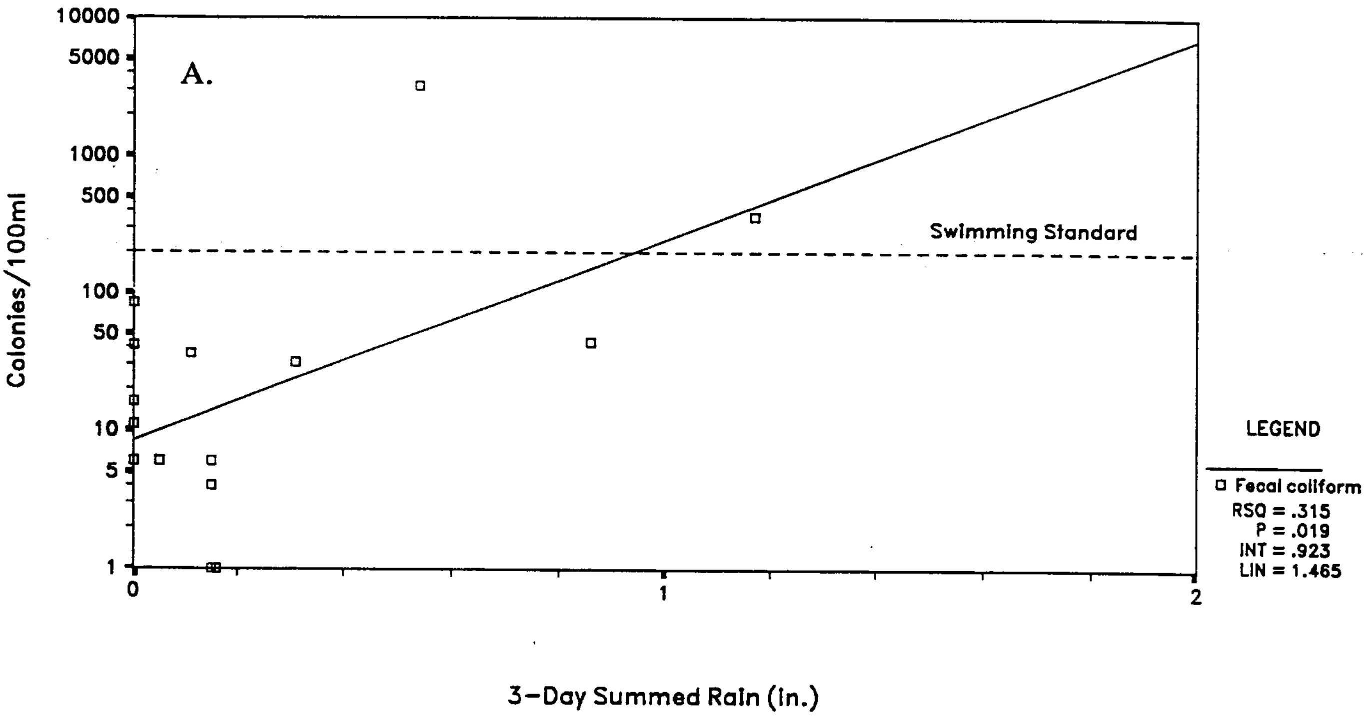


Figure 4.06. Fecal coliform counts at Tenean Beach in southern Dorchester Bay regressed against A. three-day summed rainfall (LORNP3) and B. counts in the Neponset River (Station 42) and at the Commercial Point outfall (Stations 41 and 89).



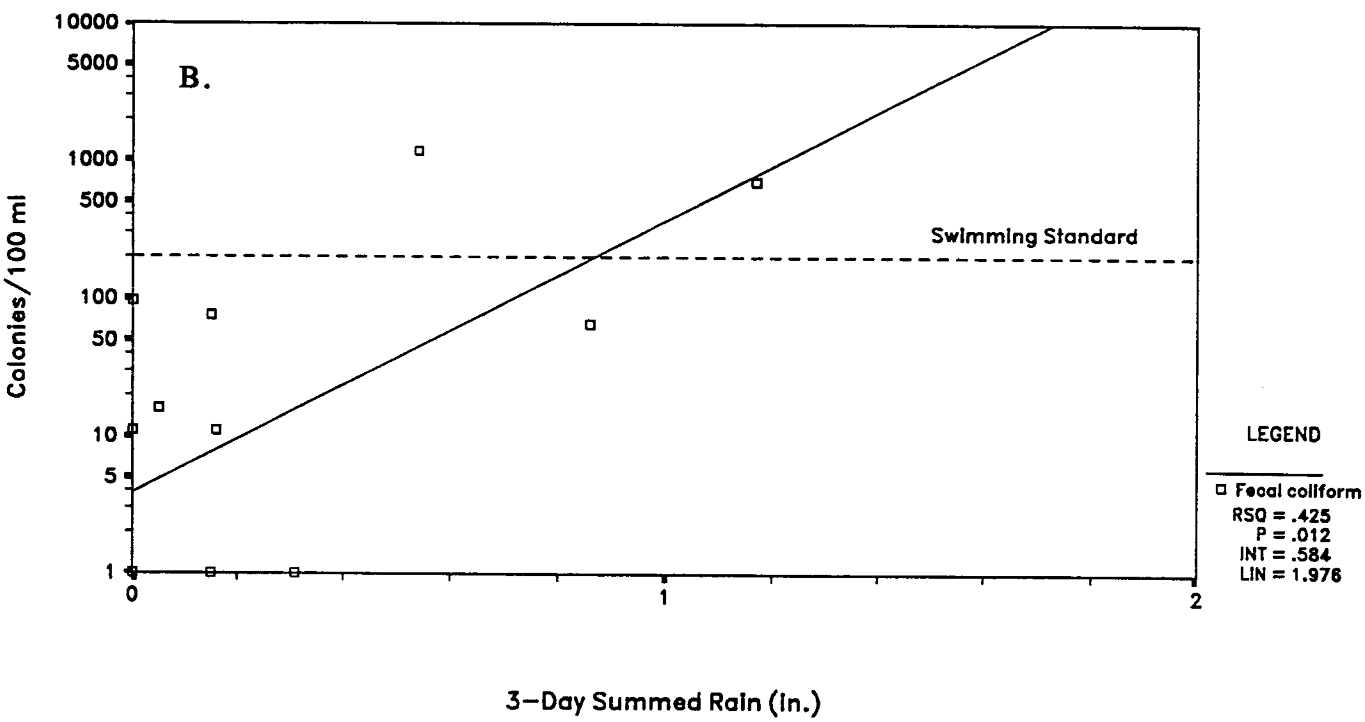


Figure 4.07. Fecal coliform counts in northern Dorchester Bay regressed against three-day summed rainfall (LORNP3) at A. Station 33, Carson Beach, and B. Station 28, Pleasure Bay.

4.1.d Relationship between Indicator Bacteria and Salinity

Fall-Winter, 1990-1991

There was a strong and significant negative correlation between indicator bacteria counts and salinity (for fecal coliform, $r = -0.65$, $p < 0.001$; for *Enterococcus,* $r = 0.47$, $p < 0.001$), reflecting the negative gradient in bacteria counts from riverine to estuarine stations.

Spring 1991

At the Dorchester Bay stations, the spring sampling period showed a strong negative correlation between indicator bacteria counts and salinity for fecal coliform ($r = 0.65$, $p < 0.001$) and for *Enterococcus* ($r = 0.47$, $p < 0.001$), but there was no significant relationship between salinity and counts at the stations in the Neponset River.

Summer 1991

Overall, there was a negative relationship between indicator bacteria counts in the Neponset River and salinity (for fecal coliform, $r = -0.39$, $p < 0.001$; for *Enterococcus,* $r = -0.44$, $p < 0.001$). In Dorchester Bay, the relationship was somewhat weaker (for fecal coliform, $r = -0.33$, $p < 0.001$; for *Enterococcus,* $r = -0.23$, $p = 0.001$).

4.1.e Dissolved Oxygen

Fall-Winter 1990-1991

Dissolved oxygen levels in the Neponset River were high, as would be expected in colder waters. The median DO concentration at stations 54 and 55 was 13 mg/l. At Station 89 near the Commercial Point outfall pipe, the median dissolved oxygen level was lower (10 mg/l).

4. Neponset River and Dorchester Bay

Spring 1991

During the spring sampling season, the median DO levels at Stations 89, 41, 39, and 36 were all between 8 mg/l and 10 mg/l (data not shown). There was only one measurement, 2.4 mg/l at Station 89, lower than the minimum state standard of 5 mg/l.

Summer 1991

Figure 4.08 shows percentile box plots for surface dissolved oxygen in the Neponset River and Dorchester Bay. While the median DO measurements for each station were above 5.0 mg/l, many of the stations had single outlying points well below the 5 mg/l level. These points are measurements made on July 27, during the second day of a rainstorm.

At Stations 55, 54, 42, 89, and 41, 10-25% of the measurements were below 5 mg/l, indicating DO problems in the river and near the Commercial Point CSO Treatment Facility.

Levels of dissolved oxygen at the bottom showed a pattern similar to surface measurements (Figure 4.09). There was an outlying low point at each site measured during the July 27 rainstorm. Median values at all sites were 6 mg/l or higher. Except for the outliers, all the measurements at stations 84, 38, 44, and 24 were higher than 6 mg/l.

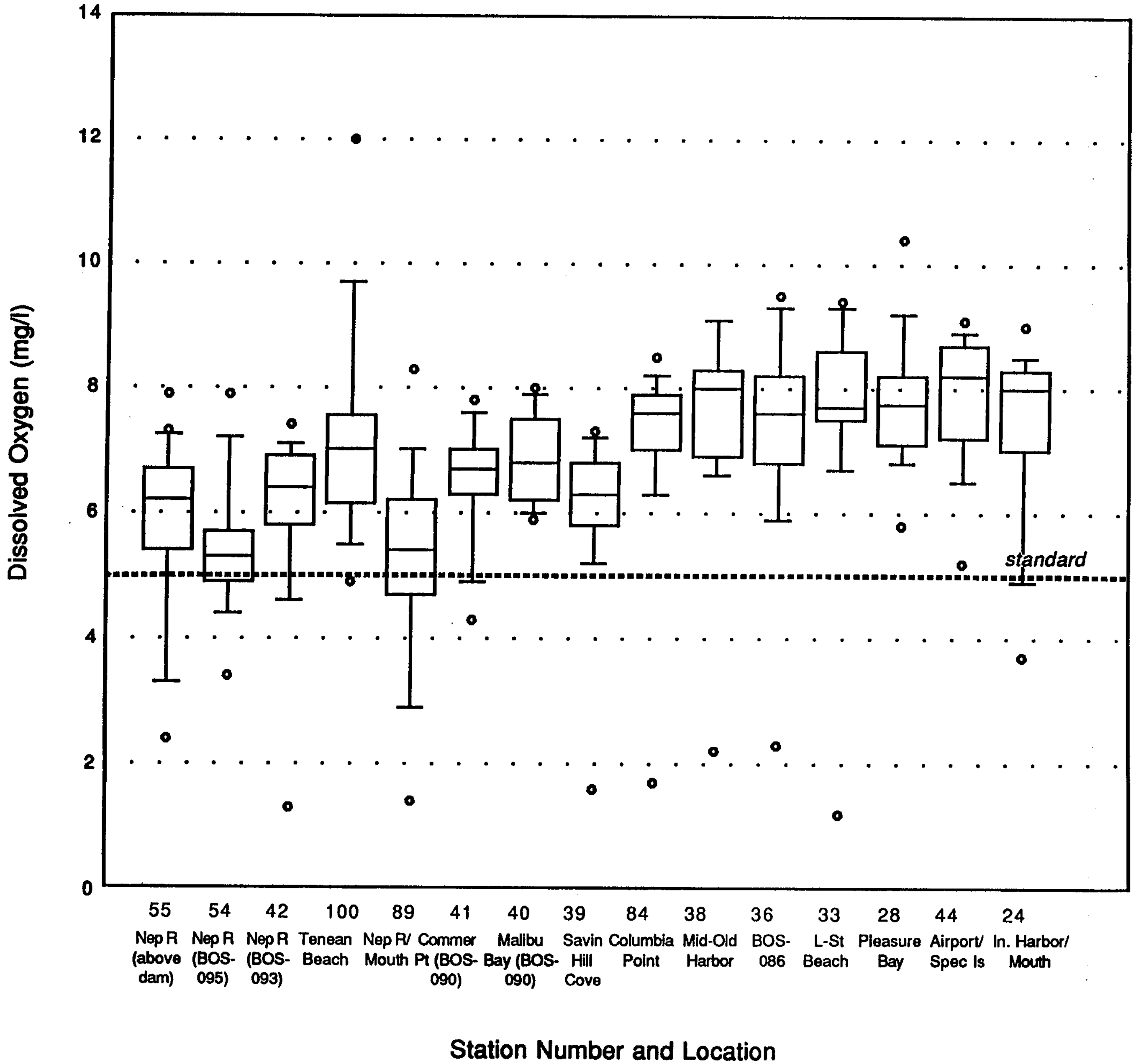


Figure 4.08. Percentile box plots of surface water dissolved oxygen levels in the Neponset River and Dorchester Bay, summer 1991.

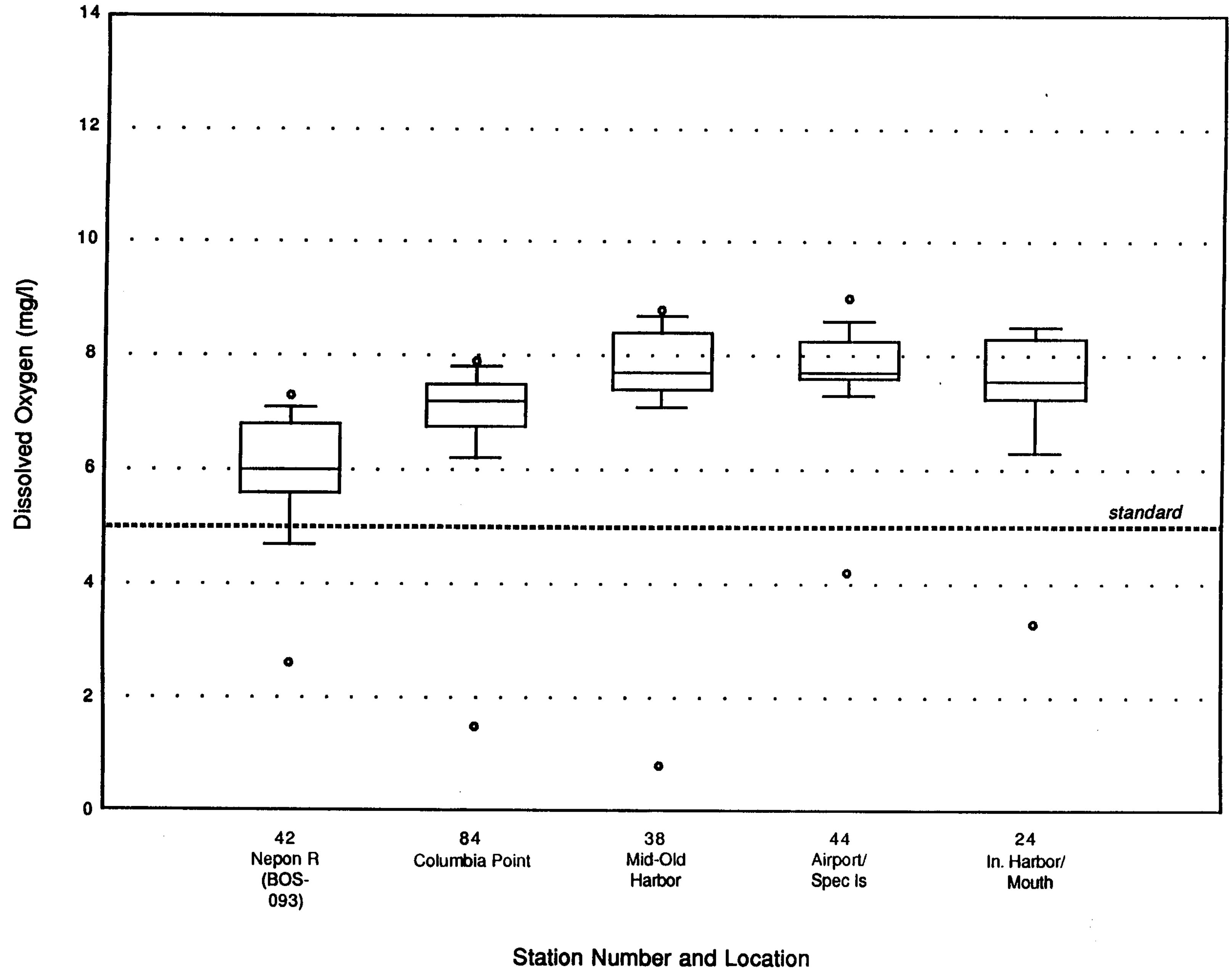


Figure 4.09. Percentile box plots of bottom water dissolved oxygen levels in the Neponset River and Dorchester Bay, summer 1991.

4.1.f Multiple Regression Analyses of Water Quality Data from Northern Dorchester Bay (Old Harbor)

As exploratory analyses, multiple regressions were performed on samples collected in northern Dorchester Bay. Data from stations 28, 33, 36, and 38 were included together in the analyses. The purpose of the multiple regression analysis was to apportion the variance among a group of predictive variables (listed in Tables 2.02 and 2.03) to see which variables were most important in explaining the variance in fecal coliform and *Enterococcus* counts. As shown in Table 4.05, the only variable explaining a significant amount of variance in bacteria counts for this geographic area was LORNP3 (rainfall summed over three days). Tidal phase, salinity, temperature, and treatment plant variables did not explain a significant amount of the variance in bacteria counts.

Table 4.05. Multiple regression analyses of 1991 data (summer sampling period) of samples collected in northern Dorchester Bay. Surface samples collected from Stations 28, 33, 36, and 38 were analyzed as a group.

Log(fecal coliform/100 ml) = 0.630098 + 1.658546[LORNP3]

Multiple R = 0.59

$R^2 = 0.35$

$F_{(1,63)} = 34.51, p < 0.0001$

Log(*Enterococcus*/100 ml) = 0.649705 + 1.519489[LORNP3]

Multiple R = 0.54

$R^2 = 0.29$

$F_{(1,63)} = 25.69, p < 0.0001$

4.2 Results: Upstream Monitoring of Neponset River during 1990 and 1991

Because previous monitoring in the Neponset River (MWRA 1990, 1991e) suggested that most of the bacteria contamination in the Neponset River came from upstream sources, MWRA carried out a cooperative study with the Neponset River Watershed Association to begin to determine the major sources of sewage indicator bacteria to upstream parts of the river.

4.2.a Sampling Locations and Dates

The Neponset River was sampled quarterly by the Neponset River Watershed Association at 15 sites, previously established by DEP. The sites are located along the entire length of the river, from Foxborough, near the source of the river, to the river's mouth (Figure 4.10). Two of these sites were identical with MWRA sampling sites: Station N16 located upstream of all CSOs is the same as MWRA Station 55, and Station N17 is the same as MWRA Station 54 (downstream of BOS-095). Seven surveys were carried out by the Neponset River Watershed Association: three surveys (7/25/90, 10/13/90, and 10/19/91) were wet weather (rain fell either on the day of sampling or the day before) and four surveys were during dry weather (6/2/90, 1/19/91, 4/19/91, and 7/20/91).

4.2.b Dry Weather Fecal Coliform Counts

Table 4.06 shows the fecal coliform counts obtained during four dry weather surveys and three wet weather surveys. There was considerable variation in fecal coliform counts at individual stations during both wet and dry weather conditions. For example, dry weather counts at Station N2 ranged from <10 to 400 col/100 ml; and wet-weather counts at Station N2 ranged from <10 to 1600 col/100 ml. Figure 4.11 is a plot of the geometric means for dry-weather fecal coliform counts at each station. The graph is arranged so that the most upstream station is on the left, with stations arranged in geographic order progressing in a downstream direction. Stations N1, N2, N4, N5, N7, and N8 had geometric mean fecal coliform counts less than 200 col/100 ml during dry weather, while all the other stations had geometric mean counts exceeding the class B standard during dry weather. The most upstream stations had the lowest geometric mean counts, except for Station N3, while stations further downstream typically had higher counts. The station with the highest geometric mean count (approximately 1,000 col/100 ml) was N16, immediately upstream of the dam.

STATION	LOCATION	RIVER MILE
N1	Outlet Neponset Reservoir, Foxborough	29.5
N2	Outlet Crackrock Pond, Foxborough	28.9
N3	Summer Street Dam, Walpole	27.2
N4	Pond off South Street, Walpole	24.7
N5	West Street Bridge at Kendall Company, Walpole	23.5
N7	Outlet Bird Pond, East Walpole	20.8
N8	Hollingsworth and Vose Dam, East Walpole	20.4
N10	Pleasant Street Bridge, Norwood	19.1
N11	Neponset Street Bridge, Norwood	15.8
N12	East Branch, Neponset Street, Canton	15.8, 1.7
N13	Freeman Highway Bridge, Milton	8.9
N13A	Mother Brook at Hyde Park Avenue Bridge, Hyde Park	7.9, 0.2
N14	Dana Avenue, confluence with Mother Brook, Hyde Park	7.9
N16	Adams Street Bridge, Milton	4.2
N17	Granite Avenue Bridge, Boston-Milton	2.5

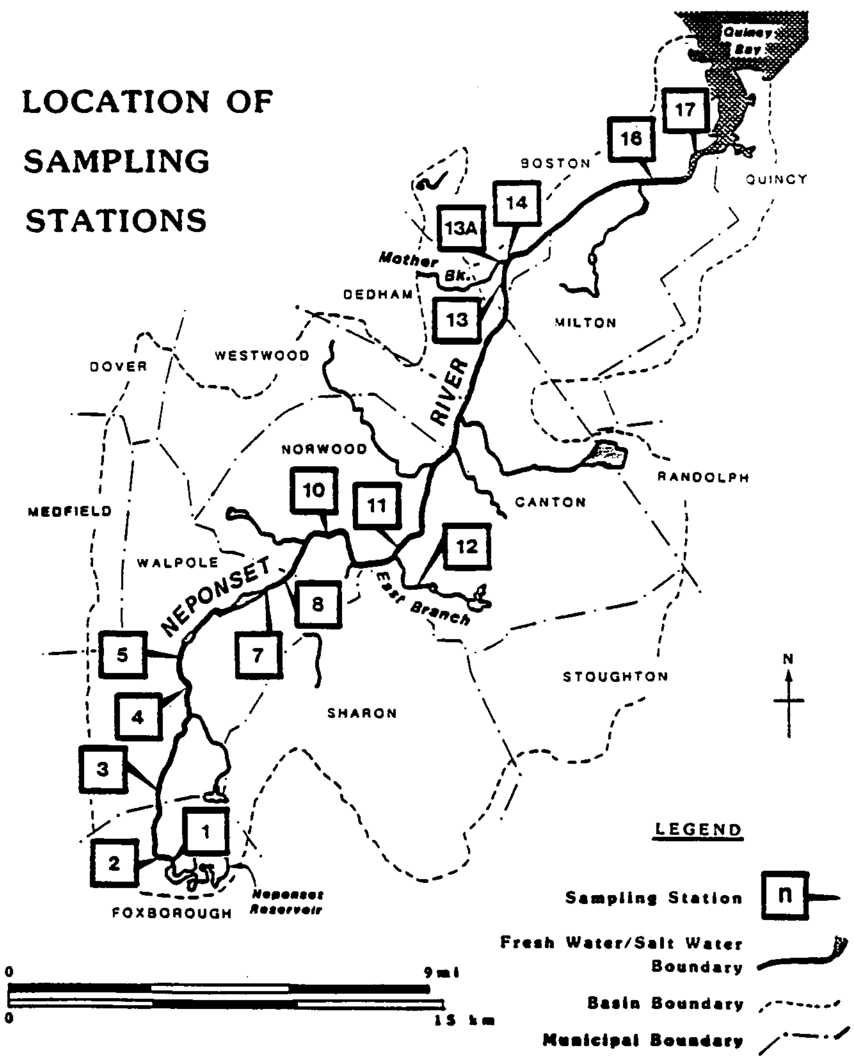


Figure 4.10. Neponset River Watershed Association monitoring stations. Figure from Massachusetts Department of Environmental Protection.

Table 4.06. Neponset River fecal coliform counts (col/100 ml) and geometric means at each station for three wet-weather sampling periods and four dry-weather sampling periods, 1990-1991.

Wet weather

Station	7/25/90	10/13/90	10/19/91	Geometric mean
N1	100	390	<10	31
N2	1,600	330	<10	81
N3	245,000	19,900	480	13,276
N4	<10	3,470	130	77
N5	21,400	9,000	100	2,680
N7	800	1,670	160	598
N8	900	2,840	90	613
N10	4,600	13,300	290	2,608
N11	10,800	5,100	250	2,397
N12	3,100	5,700	480	2,039
N13	3,600	370	ND	1,154
N13A	6,600	44,000	ND	17,041
N14	ND	9,200	ND	9,200
N16	6,800	ND	ND	6,800
N17	8,400	ND	ND	8,400

Dry weather

	6/2/90	1/19/91	4/19/91	7/20/91	Geometric mean
N1	<10	<10	20	15	4
N2	400	10	<10	3,350	60
N3	360	160	260	1,350	377
N4	90	<10	<10	25	7
N5	40	50	10	770	63
N7	40	320	10	15	37
N8	20	130	<10	<10	7
N10	310	320	60	585	243
N11	330	280	160	295	257
N12	680	240	260	1,525	504
N13	470	740	40	193	228
N13A	600	1,100	190	470	493
N14	400	870	1,185	550	690
N16	702	1,750	700	1,140	995
N17	889	630	260	340	492

ND = No Data.

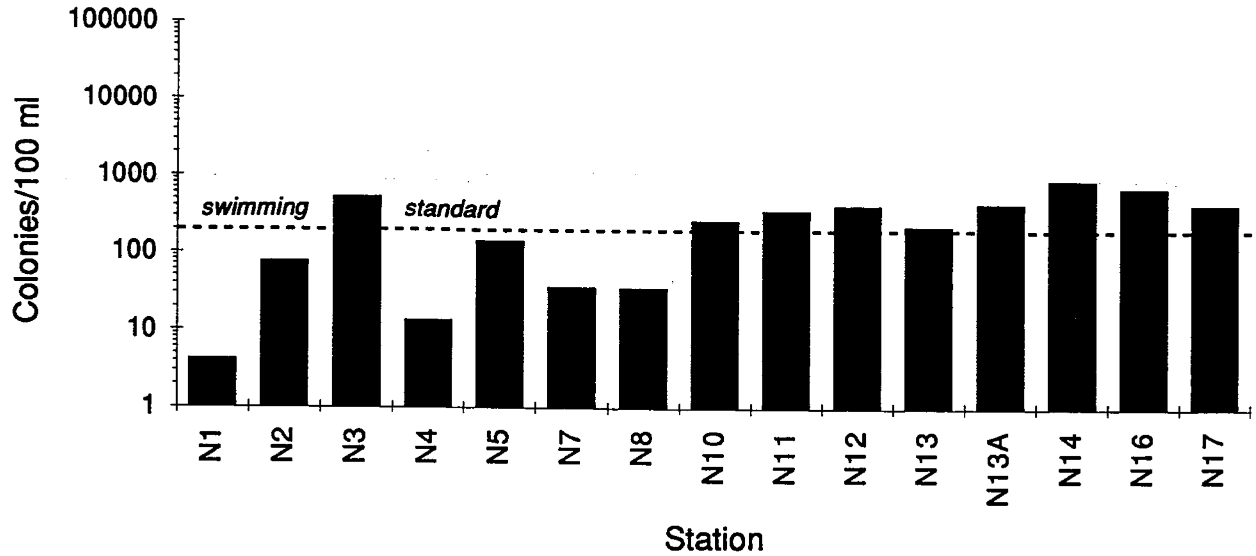


Figure 4.11. Geometric mean fecal coliform counts in the Neponset River from four dry-weather surveys, 1990-1991.

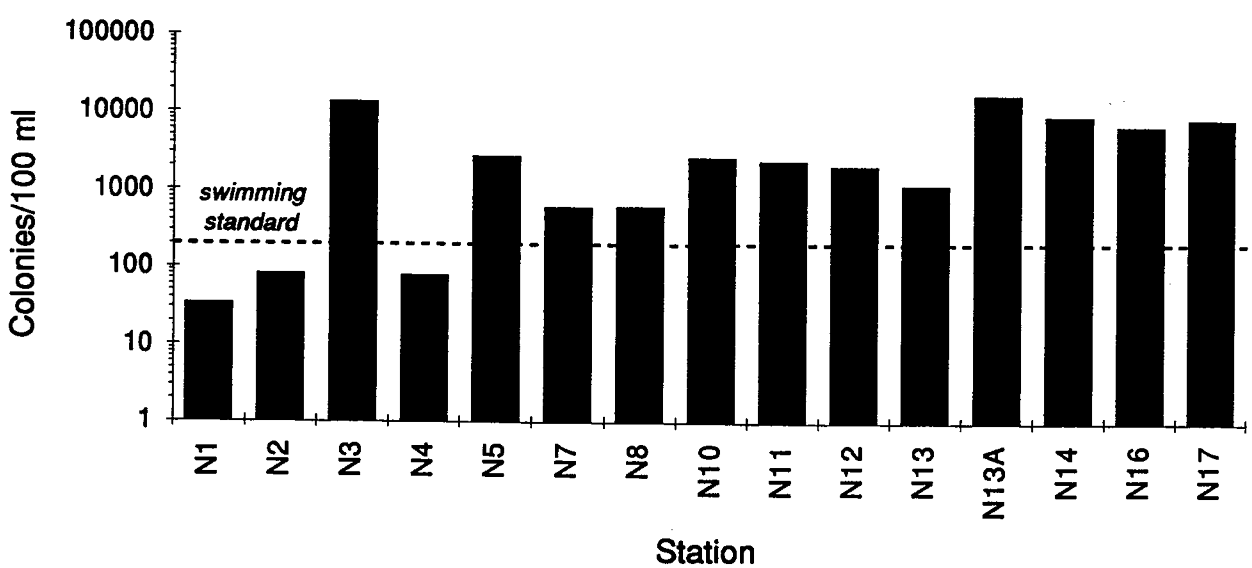


Figure 4.12. Geometric mean fecal coliform counts in the Neponset River from three wet-weather surveys, 1990-1991.

4.2.c Wet Weather Fecal Coliform Counts

Figure 4.12 shows geometric means for fecal coliform levels during the three wet-weather surveys. Rainfall was associated with increased fecal coliform counts of approximately one order of magnitude at all stations except N2, where geometric mean counts were approximately the same for wet and dry weather.

4.3 Discussion

4.3.a Geographic Variation in Water Quality in the Neponset River/Dorchester Bay Area

As was observed in the first CSO monitoring report (MWRA 1991e) there was significant variation in levels of bacterial pollution among different areas of Dorchester Bay. On average, samples from southern Dorchester Bay showed worse water quality than samples from northern Dorchester Bay. When counts are elevated in northern Dorchester Bay, the geographic pattern of pollution is consistent with local CSOs and street runoff as the major source. The inner harbor does not appear to significantly affect water quality at northern Dorchester Bay beaches.

In both the northern and southern parts of Dorchester Bay, sites near the shoreline had poorer water quality than more offshore areas. Thus, nearshore sources of sewage like CSOs and storm drains are the most important factors affecting bacterial water quality, rather than more distant sources like sewage treatment plants.

4.3.b Changes in Water Quality and Beach Postings in Dorchester Bay over Three Years

Water Quality near the Fox Point and Commercial Point Treatment Facilities

Although bacterial water quality in southern Dorchester Bay is poorer than in northern Dorchester Bay, conditions have been improving over the past three years. One important factor has been the construction of two new facilities to screen and chlorinate combined sewage from the two largest combined sewer outfalls in the area, at Fox Point and Commercial Point. Table 4.07 shows bacterial water quality near the outfall pipes.

4. Neponset River and Dorchester Bay

Bacterial water quality near the outfall pipes has been monitored since 1989, including periods before and after the screening and chlorination began.

Table 4.07. Fecal coliform counts in the water near new CSO treatment facilities in southern Dorchester Bay before and after the facilities became operational.

Area	Facility status (dates)	Geometric mean fecal coliform col/100 ml (95% confidence intervals)
Savin Hill Cove (near Fox Point CSO: Station 39)	Preoperational (1989)	749 (403-1392)
	Operational (1990 and 1991)	79 (42-150)
Commercial Point (Station 41)	Preoperational (1989 and 1990)	175 (93-327)
	Operational (1991)	49 (16-147)

Water Quality at Dorchester Bay Beaches

Southern Dorchester Bay: Tenean and Malibu Beaches

Figure 4.13 summarizes water quality sampling data collected by MDC over the past three bathing beach seasons at Tenean and Malibu beaches. There has been a trend at both beaches of decreasing numbers of samples exceeding water quality standards, e.g., at Tenean Beach samples exceeding standards decreased from more than 45% in 1989 to less than 15% in 1991. This trend coincides with the decreasing fecal coliform counts found near the new CSO treatment facilities (Table 4.07). The CSO treatment facilities at Fox Point and Commercial Point have been effective at reducing bacterial contamination in the southern Dorchester Bay area.

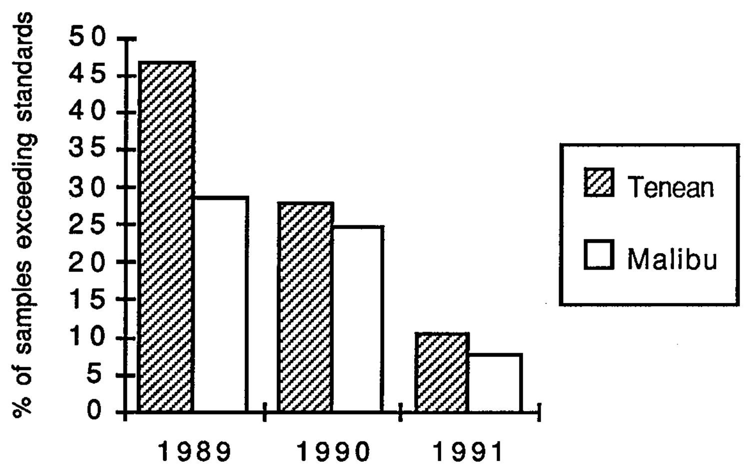


Figure 4.13. Percent of water samples at Tenean and Malibu beaches that exceeded the water quality standard for swimming over a three-year period. Based on data collected by MDC (1989-1991).

The analysis of a single storm event showed that elevated fecal coliform counts at Tenean Beach occurred even when counts of fecal coliform at Station 41, near the Commercial Point CSO, were below detection limits (Table 4.03, see July 27). Although on July 27 fecal coliform levels near the Fox Point CSO were elevated, lower counts at Stations 41 and 89, between Tenean Beach and Fox Point, indicate that the Fox Point CSO was not a significant source of contamination to Tenean Beach. Another possible source of contamination to Tenean Beach is the Neponset River. Because fecal coliform counts at Station 42, the Neponset River, were slightly lower than at the beach, contamination from the river alone does not completely explain the beach contamination, and there may be other source(s).

The analysis of this rain event is consistent with the regression analyses of all samples collected during the summer monitoring period (Figure 4.06A and B): bacterial water quality problems at Tenean Beach are not completely explained by rainfall or by high counts at the CSOs, or by contamination from the Neponset River. MWRA and BWSC are investigating other potential sources, including possible illegal cross-connections to a large storm drain in Pine Neck Creek, adjacent to the beach.

4. Neponset River and Dorchester Bay

Northern Dorchester Bay: Carson and Pleasure Bay Beaches

The percentages of samples collected by MDC which exceeded water quality standards at beaches in the northern part of Dorchester Bay for the past three years are shown in Figure 4.14. Carson Beach and Pleasure Bay have generally had better water quality with less variation over three years than Tenean and Malibu beaches. These MDC data are consistent with MWRA data, which showed that the geometric means of fecal coliform counts (Table 4.02) at northern Dorchester Bay beaches were lower than in southern Dorchester Bay. However, as shown in Figure 4.14, there has been no clear trend of either increase or decrease in the number of samples exceeding water quality standards over the past three years at these two beaches. Because only about 10 samples were collected per year at each site, the number of beach postings was very dependent upon rainfall patterns relative to the sampling schedule, which is always on the same day of the week. These data are very sensitive to varying rainfall patterns among different years.

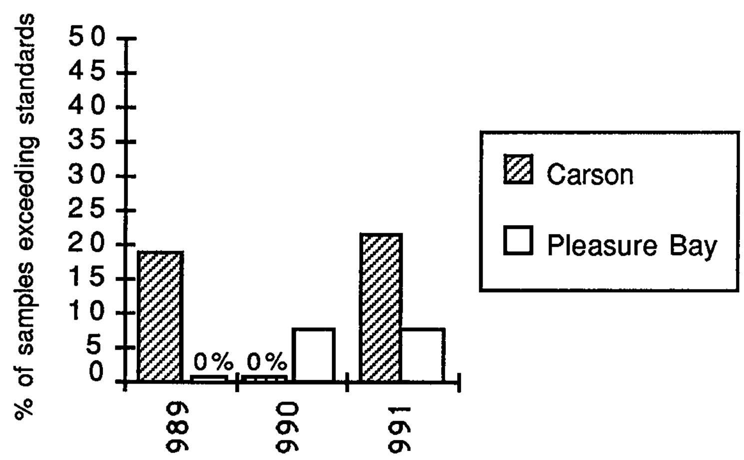


Figure 4.14. Percent of water samples at Carson Beach and Pleasure Bay that exceeded the water quality standard for swimming over a three-year period. Based on data collected by MDC (1989-1991).

4.3.c Relationship between Water Quality and Measured Flows from Two CSOs in the Lower Neponset River

MWRA water quality monitoring in the Neponset River area was coordinated with the flow monitoring study of two CSOs (BOS-093 and BOS-095) by Boston Water and Sewer Commission (BWSC 1991).

4. Neponset River and Dorchester Bay

Table 4.08 shows the relationship among measured flows from the CSOs and fecal coliform counts in the Neponset at stations near the two CSOs (Stations 54 and 42) and upstream of both CSOs (Station 55).

Table 4.08. Metered overflows compared to bacteria counts in the Neponset River, July-September, 1991. Station 55 is located upstream of both CSOs, above a dam; Station 54 is downstream of BOS-095; and Station 42 is downstream of BOS-093.

		Overflow (M.G.)		Fecal coliform (col/100 ml)		
Date	Rain (in.)	BOS-095	BOS-093	Station 55	Station 54	Station 42
Jul 23	0.15	0	0.029	363	270	1275
Jul 24	0	0	0	4975	1175	823
Jul 26	0.86	0	0.104	ND	ND	ND
Jul 27	0.31	0	0	10250	9975	4725
Aug 10	0.49	0.67	0.195	25500	1525	645
Aug 19	2.21	0.8	0.36	ND	ND	ND
Aug 20	0.38	ND	ND	ND	ND	ND
Aug 21	1.72	1.146	0.546	8300	16850	28400
Sept 5	0.89	0.311	0.77	12900	9750	150
Dry weather geometric mean				2013	471	117

ND = No data.

During both wet and dry weather, the overall pattern of fecal coliform counts in the lower Neponset River was decreasing densities in the downstream direction. There were two occasions during this metering period when overflows from these CSOs were associated with counts in the nearfield water higher than the upstream counts. These occasions were (1) On July 25 an overflow of 0.029 million gallons from BOS-093 coincided with a fecal coliform count at nearby Station 42 (1275 col/100 ml) that was 4-fold higher than upstream counts. Associated with only 0.15 in. of rain, this overflow was relatively small. (2) On August 19-21, a very different weather condition, Hurricane Bob, was also followed by increased levels of fecal coliform near these CSOs. Rain falling over the three-day period resulted in overflows of at least a half-million gallons from BOS-093, and over one million gallons from BOS-095. As shown in Table 4.08, counts on August 21 were two and three times higher near the CSOs than the upstream counts.

Although receiving-water impacts could be detected in these two cases, four other measured overflows occurred without increasing fecal coliform counts near the CSOs compared to upstream counts. High upstream wet-weather fecal coliform counts combined with tidal dilution near the CSOs can mask the impact of overflows from BOS-093 and BOS-095.

4.3.d Upstream Patterns of Sewage Indicators in the Neponset River

Data collected by MWRA and the Neponset River Watershed Association, as well as 1991monitoring by DEP, showed that by the time the Neponset River reached the area impacted by CSOs, bacteria counts in the water consistently exceeded state standards, in both dry and wet weather. Thus upstream sources of sewage have a significant role in the degradation of water quality in the river. The most severely affected portion of the river is the lower 20.4 miles, downstream of the Hollingworth and Vose Dam in East Walpole. One station upstream of the dam (N3, Summer St. Dam in Walpole) also showed extremely high fecal coliform counts during wet weather and counts higher than standards during dry weather. The pattern of fecal coliform counts, with high and low counts interspersed along the river, indicates that there are a number of sources of sewage along the length of the river, rather than a single upstream source.

4.3.e Dissolved Oxygen in Dorchester Bay

Most of the dissolved oxygen measurements made during this study indicate that during the day, Dorchester Bay is characteristically well-oxygenated. However, one set of measurements taken during the second day of a two-day rainstorm indicates that water column dissolved oxygen levels were severely depressed. In Dorchester Bay after a moderate rainstorm and two days of cloudy weather, DO readings were typically 3-4 mg/l lower than normal. We do not know what the source of oxygen demand was, but a simple calculation of the BOD from an estimate of the combined sewage discharged during the storm implies that oxygen demand from combined sewage in the water is approximately 1,000-fold too low to account for this amount of oxygen depletion.[1] Other factors that might significantly affect dissolved oxygen levels in the water

[1] Assume that 1M.G. of combined sewage is discharged into Dorchester Bay, with a BOD of 50 mg/l:

$$1 \text{ M.G.} \approx 4 \times 10^6 \text{ l}$$

$$4 \times 10^6 \text{ l} \times 50 \text{ mg BOD/l} = 2 \times 10^8 \text{ mg BOD from combined sewage from one storm.}$$

Assuming Dorchester Bay has a volume of 3.1 x 10^{10} l (R. Seignell, pers. comm) and is well mixed, then the BOD in Dorchester Bay from CSO is

$$\frac{2 \times 10^8 \text{ mg BOD}}{1/3 \times 10^{11} \text{ l}} = 6 \times 10^{-3} \text{ mg BOD/l}$$

column are the amount of water column respiration, decreased solar irradiance, resuspension of sediments and/or sludge, or treatment plant effluent.

4.4 Conclusions

- **Spatial Variation in Water Quality in Dorchester Bay**

  Within Dorchester Bay, there is a pattern of relatively high fecal indicator bacteria counts (averaging above water quality standards) in southern Dorchester Bay and the Neponset River, and low counts in northern Dorchester Bay.

  Pollution from the inner harbor does not appear to have a significant effect on indicator bacteria levels at beaches in northern Dorchester Bay.

- **Relationship between Sewage Indicator Bacteria and Rainfall**

  Indicator bacteria counts at Carson Beach and Pleasure Bay were significantly related to rainfall. Indicator bacteria counts at Tenean Beach, although highest after a heavy rain, were not significantly related to rainfall because high counts also occurred during dry weather. Potential dry-weather sources of contamination include the Neponset River and contamination in Pine Neck Creek.

  The operation of two CSO screening and chlorination plants in southern Dorchester Bay has significantly reduced wet-weather bacterial contamination in the water and decreased the number of postings at Tenean and Malibu beaches over the past three years.

- **Dissolved Oxygen**

  As a rule, daytime DO levels were within water quality standards. Following a heavy rainstorm, dissolved oxygen levels in Dorchester Bay were depressed 3-5 mg/l below normal levels, and were well below state standards. However, environmental factors other than combined sewage inputs, perhaps low light levels and respiration, sediment and/or sludge resuspension, and treatment plant effluent, could cause this oxygen depletion.

4. Neponset River and Dorchester Bay

• Aesthetics

Although the public health threat from CSOs in southern Dorchester Bay has been greatly reduced because of the operation of screening and chlorination facilities, significant aesthetic problems remain. Discharges from these facilities do produce slicks, sewage odors, and contain small sewage-related "floatables" (toilet paper, condoms, tampon applicators). Both discharge pipes are located at the shoreline in recreational areas--Fox Point discharges in a marina, and Commercial Point discharges under a footbridge in Victory Park.

5. The Charles River

There are a number of combined sewer overflows (CSOs) along the length of the Charles River downstream of the Watertown Dam. However, most of the combined sewage that is discharged into the river receives treatment (screening and disinfection) at the Cottage Farm CSO Treatment Facility. Combined sewage is also screened and chlorinated at the Prison Point CSO Treatment Facility before discharge into Boston's inner harbor at the mouth of the river downstream of the Charles River Dam.

Surface samples were collected at all the stations in the Charles River, with bottom samples collected only at sites where the water was more than 20 ft deep.

5.1 Results, Fall 1990 and Summer 1991

5.1.a Sampling Locations and Rainfall

Figure 5.01 shows the location of stations sampled in the Charles River. Daily rainfall during these sampling periods is shown in Figure 5.02. Stations 11 and 12 (Station 12 is upstream of Station 1, not shown on map) were sampled periodically from November 14, 1990, to April 11, 1991. Rainfall during this period is shown in Figure 5.02A. Most samples were collected between October 22 and November 8, 1990, and from September 3-20, 1991. Rainfall during these periods is shown in 5.02B and 5.02C. Between October 17 and November 8, 1990, there were six days of moderate rain (approximately 0.5 in.), and three days of light rainfall (Figure 5.02A). During the September 1991 sampling period, there were three storms depositing between 0.5 and 1.0 in. of rain, and two days of relatively light rain (<0.5 in.).

5.1.b Indicator Bacteria Counts

Table 5.01 shows geometric means with corresponding 95% confidence intervals for fecal coliform and *Enterococcus* during the fall of 1990 and the summer of 1991.

Fall 1990

Only surface samples were collected in the Charles River during the Fall 1990 sampling period.

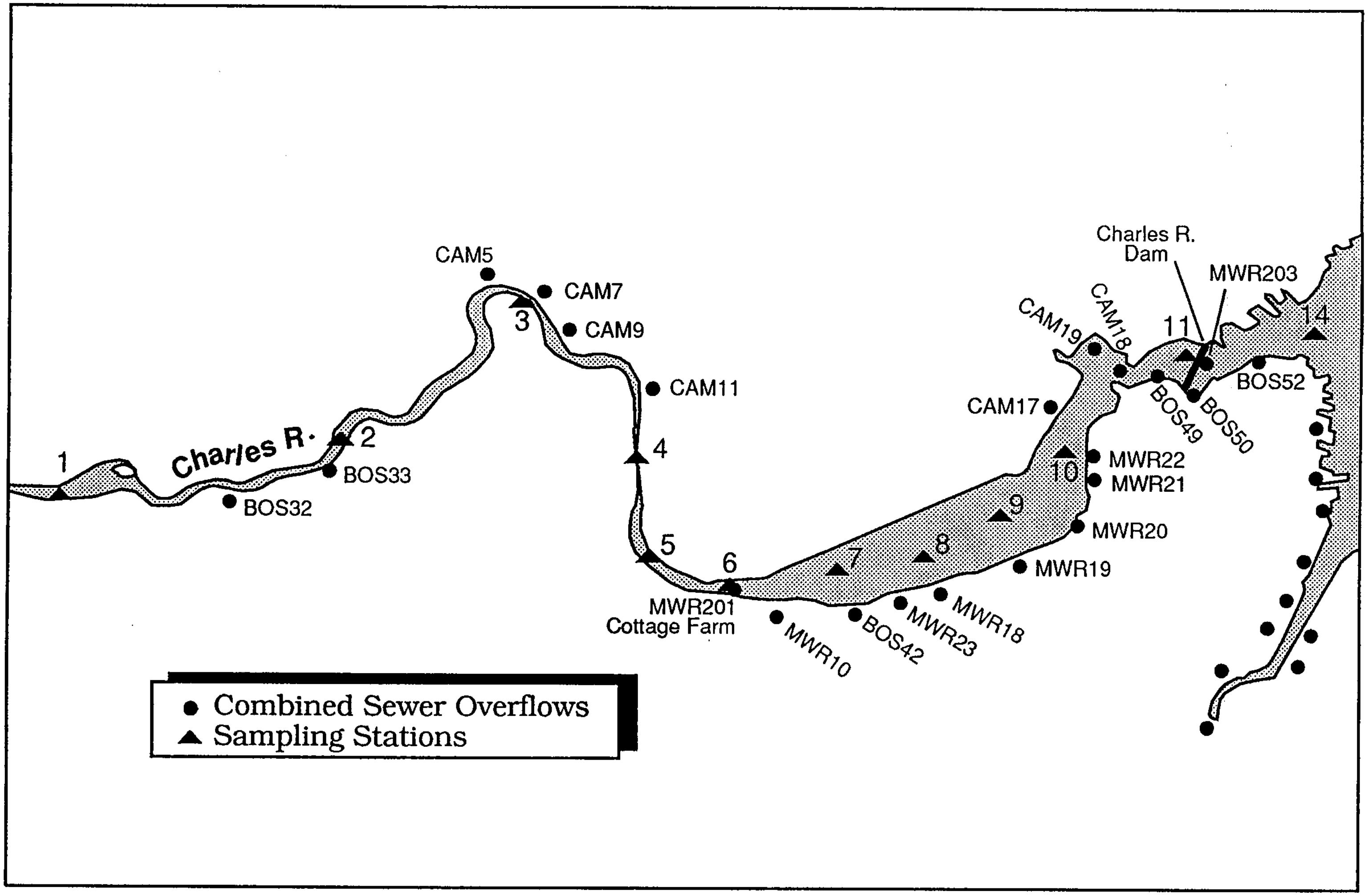


Figure 5.01. Stations sampled in the Charles River.

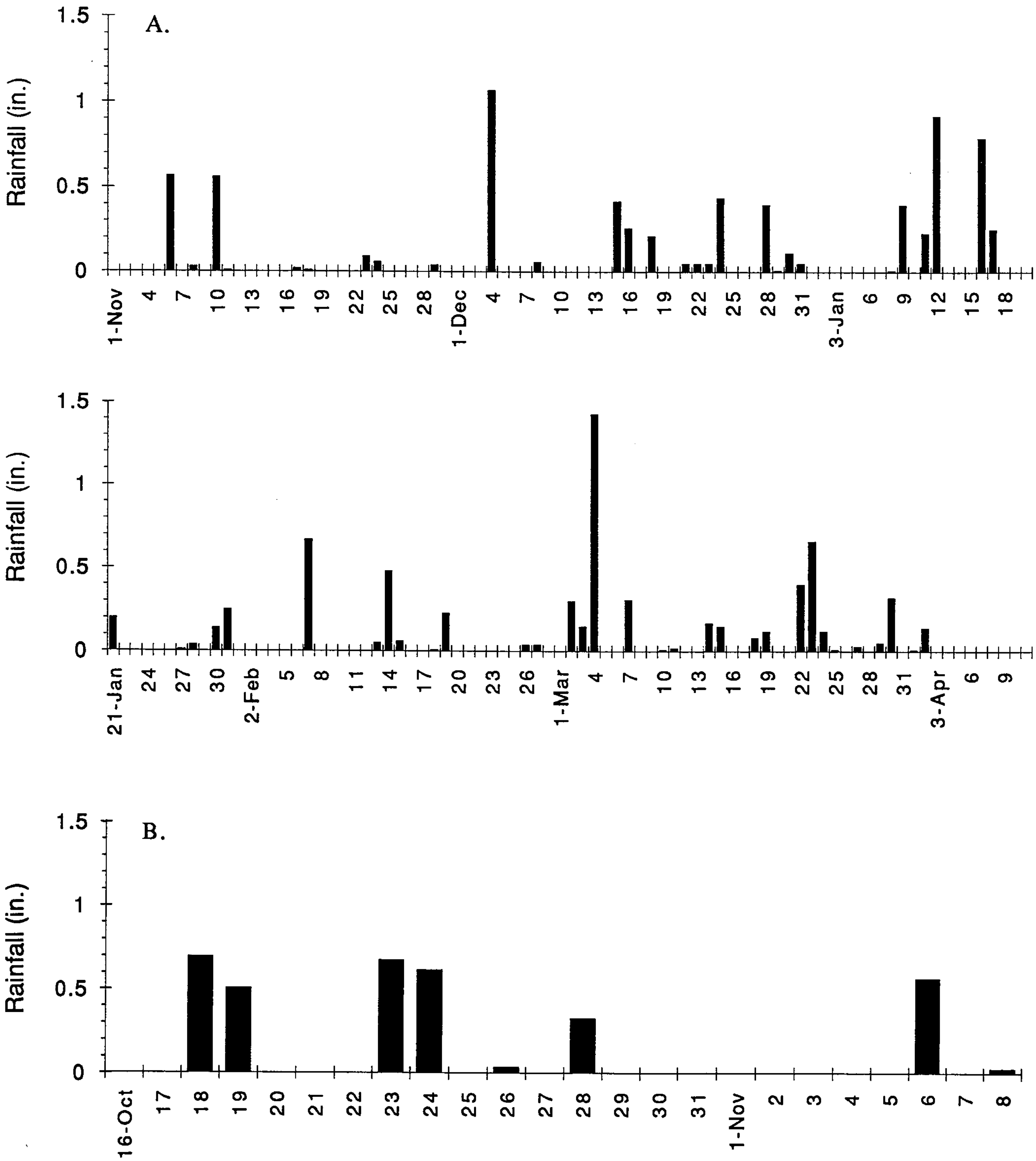


Figure 5.02. Rainfall during the Charles River sampling periods. A. Winter 1990-1991 and B. Fall 1990.

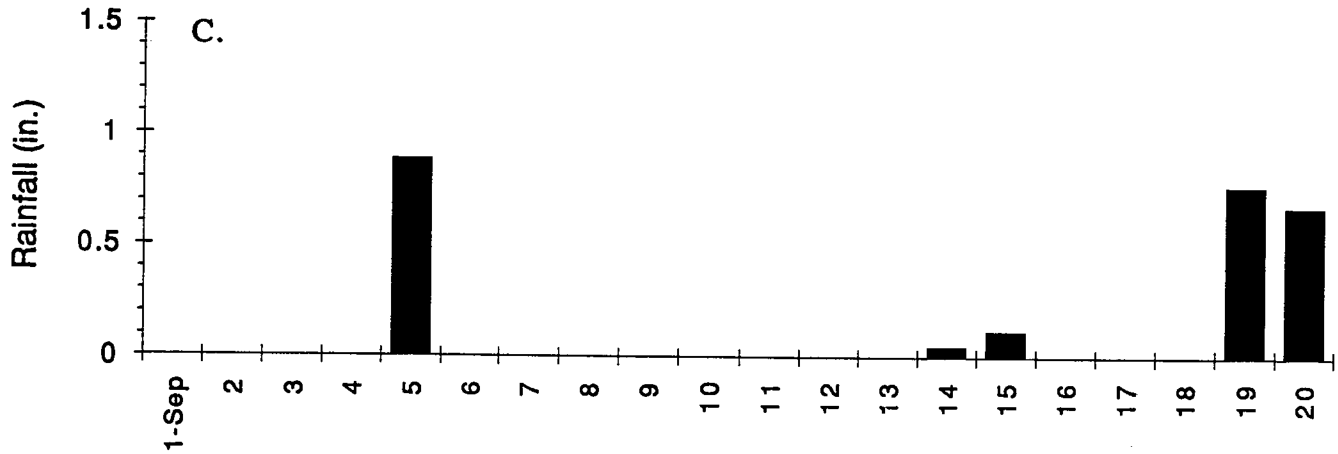


Figure 5.02, continued. Rainfall during the Charles River sampling periods. C. Summer 1991.

5. The Charles River

Table 5.01. Geometric means (col/100 ml) with 95% confidence intervals (CI) for fecal coliform and *Enterococcus* counts at stations in the Charles River.

Station			Fall 1990		Summer 1991	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Fecal Coliform						
1	Newton Yacht Club	S	11	783 (400-1531)	14	616 (318-1192)
2	BOS-033	S	11	914 (497-1682)	14	5113 (3584-7294)
3	Between CAM-005 and CAM-006	S	11	1425 (756-2683)	14	690 (357-1334)
4	Between River St. and Western Ave. Bridges	S	11	1641 (1154-2333)	14	585 (326-1048)
5	Bend near Cottage Farm	S	11	1738 (1204-2507)	14	481 (279-826)
6	BU Bridge (near MWR-201 outfall)	S	11	1416 (936-2141)	13	880 (441-1754)
		B	...	...	15	1336 (843-2118)
7	MIT Boathouse	S	11	1276 (671-2426)	15	1569 (1034-2380)
		B	...	...	13	1548 (961-2494)
8	Harvard Bridge	S	11	1686 (687-4135)	14	887 (495-1588)
		B	...	...	14	1175 (724-1906)
9	Between Harvard and Longfellow Bridges	S	11	1868 (1117-3124)	14	372 (233-594)
		B	...	...	14	188 (87-404)
10	MWR-022	S	11	968 (716-1309)	14	176 (99-311)
		B	...	...	14	18 (5-59)
11	BOS-049	S	12	1046 (660-1656)	14	108 (62-189)
		B	...	...	14	170 (97-297)
14	Charles River/Coast Guard	S	11	392 (207-741)	13	52 (17-153)
		B	...	...	13	24 (10-57)

*S = surface sample; B = bottom sample.

Table 5.01, continued.

Station			Fall 1990		Summer 1991	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Enterococcus						
1	Newton Yacht Club	S	11	592 (257-1361)	14	641 (301-1360)
2	BOS-033	S	11	840 (470-1500)	14	892 (432-1844)
3	Between CAM-005 and CAM-006	S	11	940 (523-1686)	14	239 (125-459)
4	Between River St and Western Ave Bridges	S	11	1349 (888-2048)	14	197 (88-439)
5	Bend near Cottage Farm	S	11	1239 (772-1989)	14	85 (32-227)
6	BU Bridge (near MWR-201)	S	11	993 (604-1632)	13	367 (206-653)
		B	...	...	15	688 (370-1278)
7	MIT Boathouse	S	11	831 (501-1378)	15	427 (209-869)
		B	...	...	13	414 (175-983)
8	Harvard Bridge	S	11	953 (466-1950)	14	149 (50-438)
		B	...	...	14	279 (93-839)
9	Between Harvard and Longfellow Bridges	S	11	882 (592-1313)	13	47 (15-144)
		B	...	...	14	35 (12-99)
10	MWR-022	S	11	422 (242-735)	13	32 (11-92)
		B	...	...	14	4 (1-13)
11	BOS-049	S	12	427 (312-584)	14	65 (24-175)
		B	...	...	14	346 (136-880)
14	Charles River/Coast Guard	S	11	378 (176-811)	14	59 (18-191)
		B	...	...	14	112 (39-322)

*S = surface sample; B = bottom sample.

5. The Charles River

Fecal coliform

Figure 5.03 is a percentile box plot of fecal coliform counts in samples. The boxes are arranged with the most upstream station (Station 1) on the left and the most downstream station (Station 14) on the right. Station 1 is upstream of all CSOs, and Station 14 is downstream of the Charles River Dam. The median counts shown in Figure 5.03, as well as the geometric mean counts (Table 5.01), at all stations were all above 200 col/100 ml, exceeding standards for class B waters. There was no clear spatial trend of increasing or decreasing fecal coliform densities along the length of the river. The 95% confidence intervals overlapped at all stations, except that geometric means of coliform counts at Stations 3, 4, 5, 6, and 9 were significantly higher than at Station 14 (downstream of the Charles River Dam).

Enterococcus

Enterococcus counts from the fall 1990 monitoring are shown as percentile box plots in Figure 5.04 and the geometric means with 95% confidence limits are in Table 5.01. Average counts at all stations were well above EPA-recommended geometric mean swimming standards. There was no significant pattern of increasing or decreasing bacteria counts along the length of the river, although average *Enterococcus* counts near the mouth of the river were slightly lower than at more upstream stations. For example, geometric mean counts at Station 11 were significantly lower than the geometric means at Stations 4, 5, 6, and 9.

Summer 1991

Measurements made during the summer 1991 sampling period included surface counts at all stations in the Charles River, and bottom measurements at locations downstream of Station 5.

Surface Samples

Fecal coliform

Figure 5.05 shows percentile box plots of fecal coliform measurements from surface samples in the Charles River. At most locations, most of the samples exceeded the 200 col/100 ml standard. There was some spatial heterogeneity of fecal coliform counts during this time period. Counts at Stations 1, 3, 4, 5, and 6 were similar. Station 2, near BOS-033, had the highest average counts. Locations downstream of Station 7 showed a pattern of decreasing counts in the downstream direction.

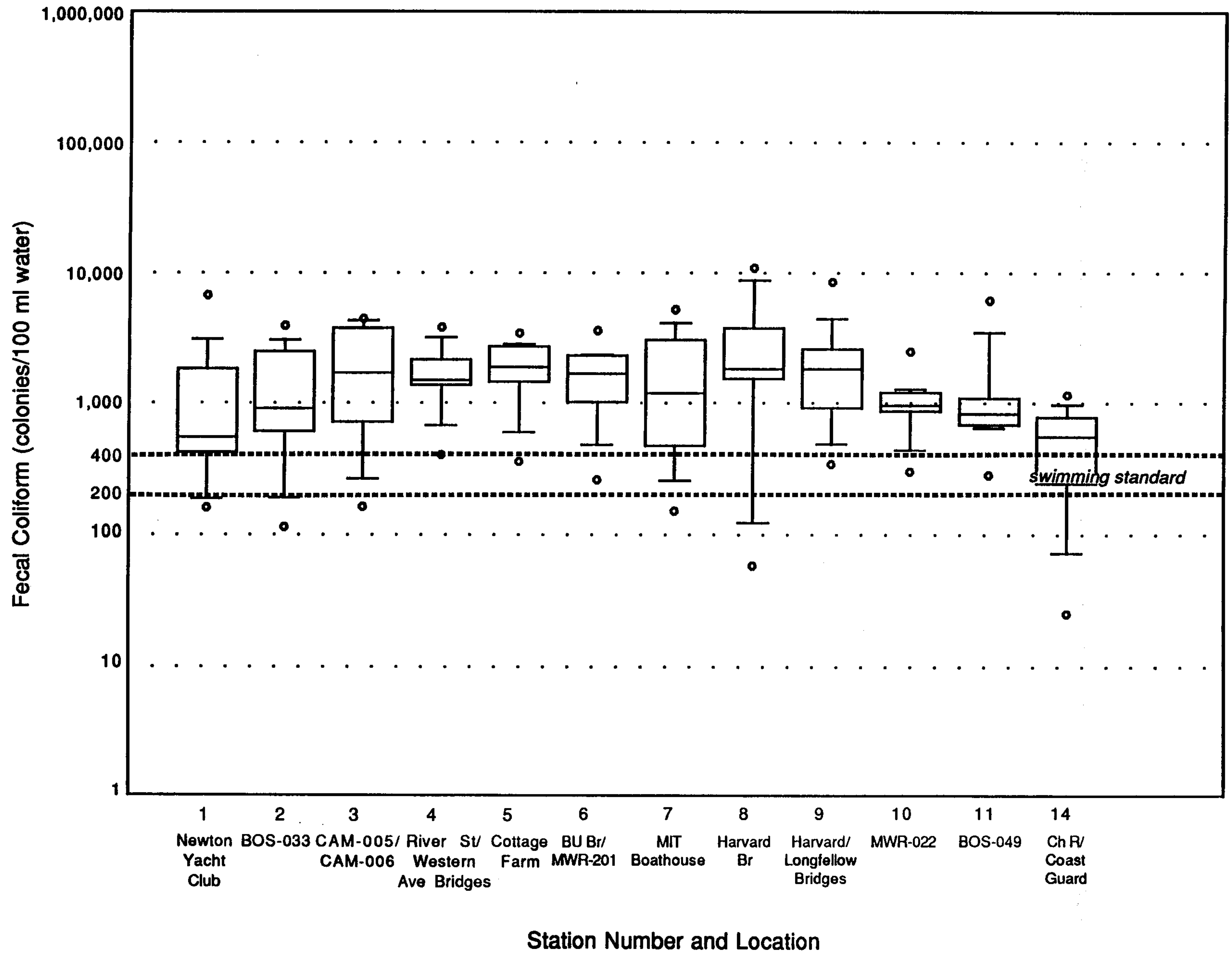


Figure 5.03. Percentile box plots of fecal coliform counts from surface samples in the Charles River, fall 1990.

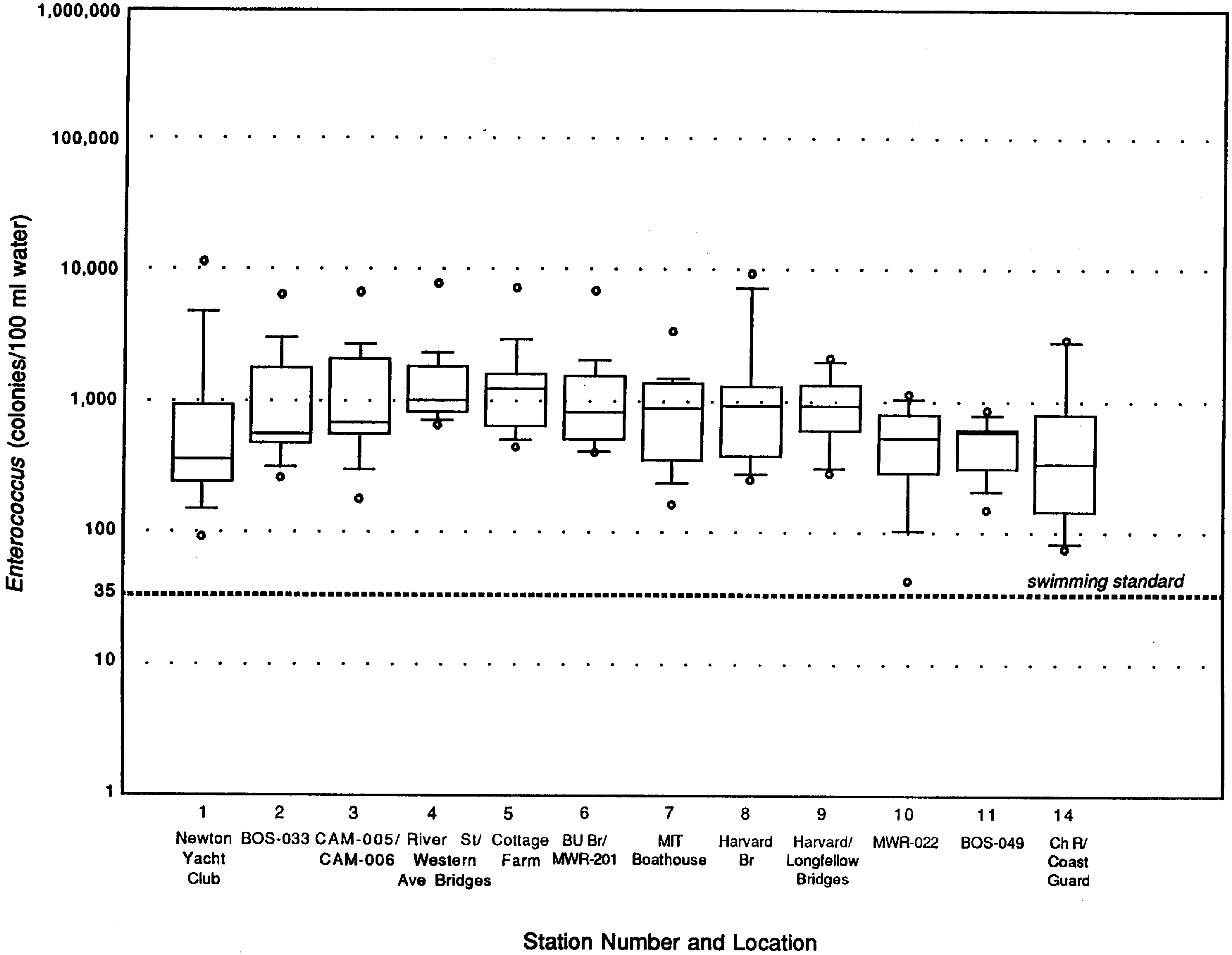


Figure 5.04. Percentile box plots of *Enterococcus* counts from surface samples in the Charles River, fall 1990.

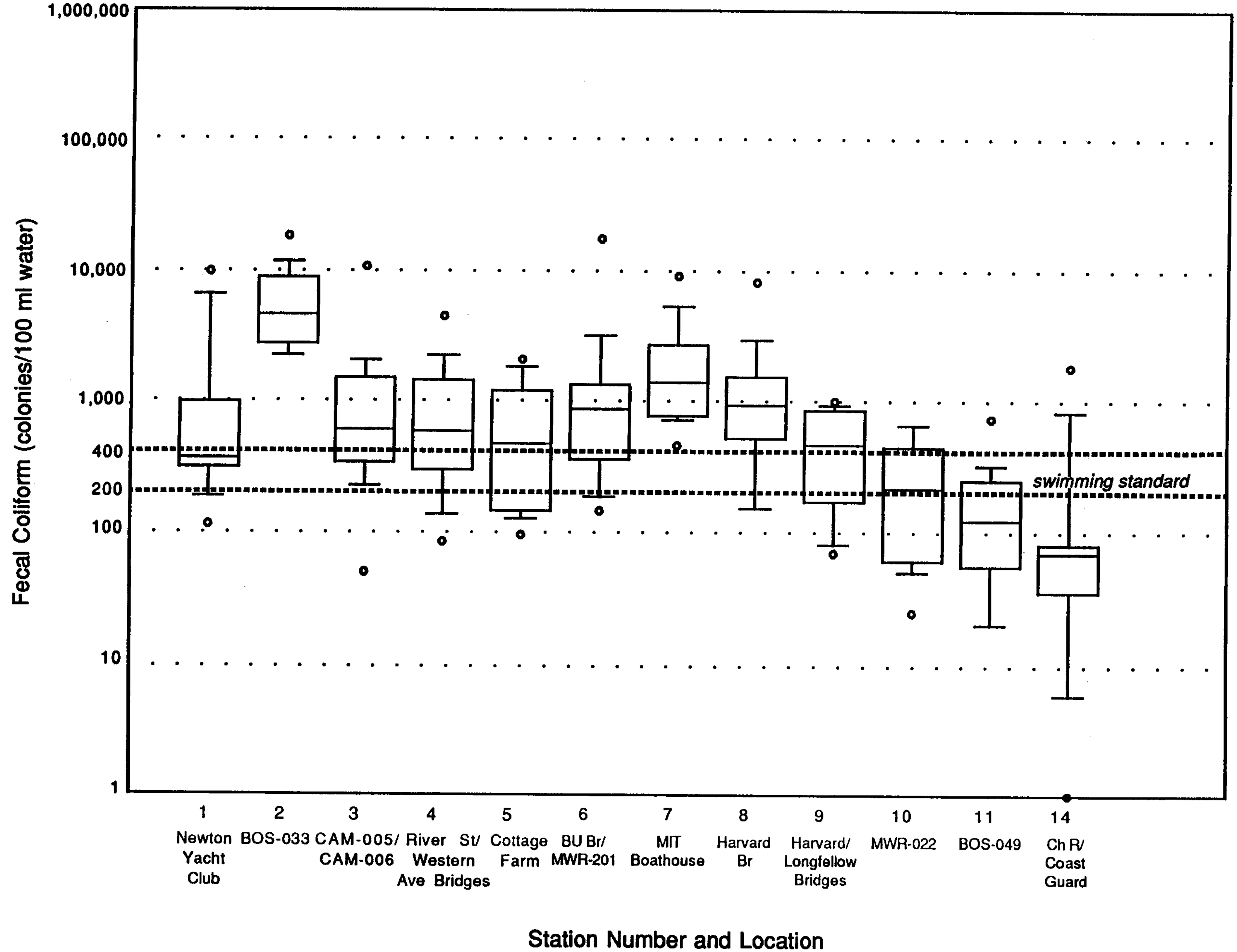


Figure 5.05. Percentile box plots of fecal coliform counts from surface samples in the Charles River, summer 1991.

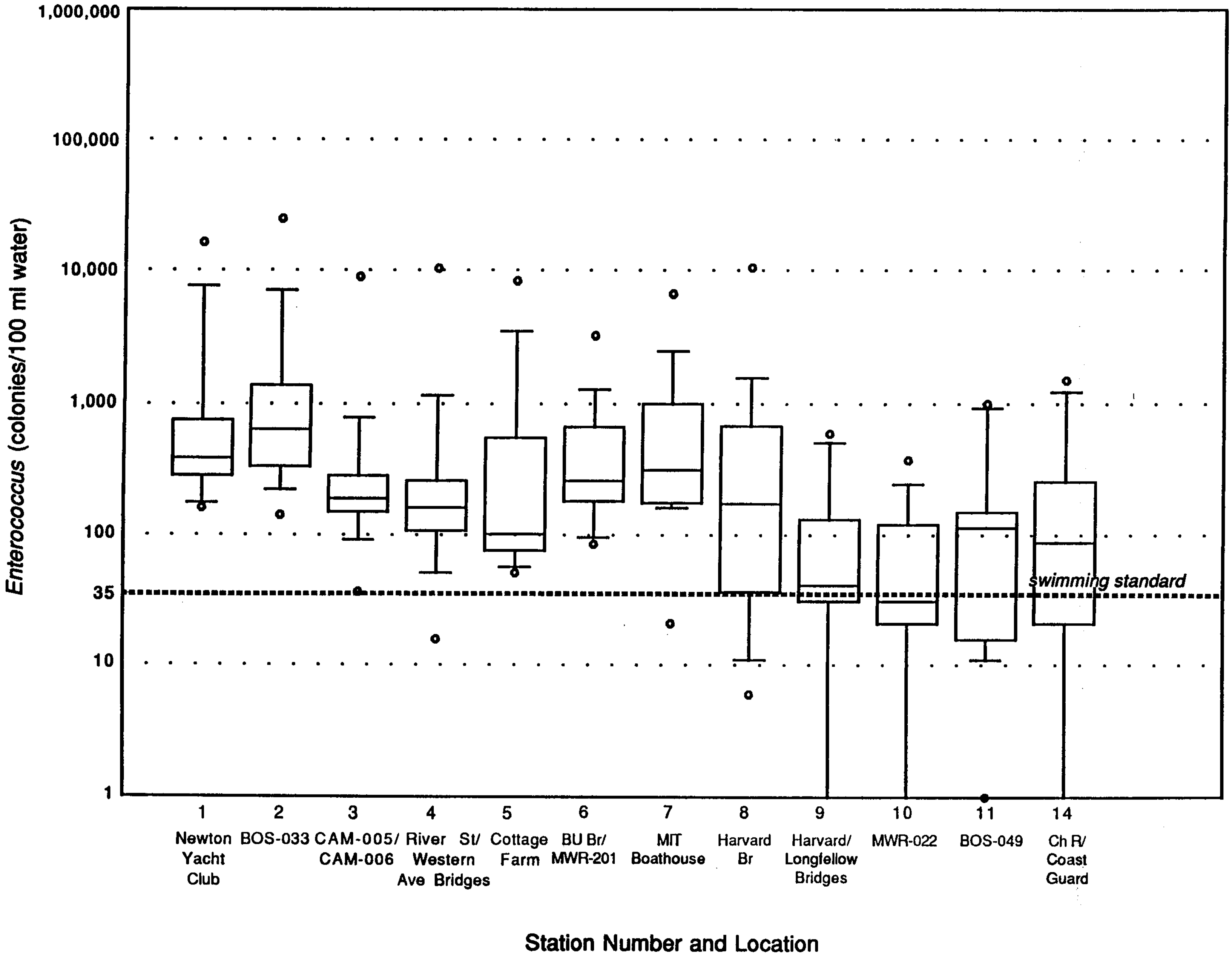


Figure 5.06. Percentile box plots of *Enterococcus* counts from surface samples in the Charles River, summer 1991.

Enterococcus

Figure 5.06 shows percentile box plots of *Enterococcus* counts from surface samples. The spatial pattern of *Enterococcus* was similar to fecal coliform: the highest counts were at upstream stations and at Station 7, with lower counts near the mouth of the river.

Bottom Samples

Fecal coliform

Percentile box plots of fecal coliform counts from bottom water samples are shown in Figure 5.07. Counts in the bottom waters were generally not significantly different (Table 5.01) from counts at the surface, except at Station 10, where bottom fecal coliform numbers were significantly lower than at the surface. The highest counts in the bottom waters were in the more upstream locations--average counts at Stations 6, 7, and 8 exceeded 1,000 col/100 ml, substantially higher than permitted by class B water quality standards. The lowest counts were at the mouth of the river.

Enterococcus

Percentile box plots of *Enterococcus* counts from bottom water samples are shown in Figure 5.08. For *Enterococcus*, there was no clear spatial trend--relatively high average counts were found at the downstream stations as well as at the more upstream locations. The lowest average counts were at Station 10, not at the most downstream locations. Table 5.01 shows that geometric mean bottom counts were not significantly different from surface counts.

5.1.c Relationship between Indicator Bacteria and Rainfall

Fall 1990

There were significant correlations between rainfall variables and bacteria counts in the Charles River when data from all of the stations were considered together (for fecal coliform with three-day summed rain, $r = 0.31$, $p < 0.001$; and for *Enterococcus* with three-day summed rain, $r = 0.40$, $p < 0.001$). However, when considered individually most stations did not have a significant correlation between indicator bacteria counts and rainfall variables. For this time period, correlations between *Enterococcus* counts and three-day summed rain were stronger than for fecal coliform.

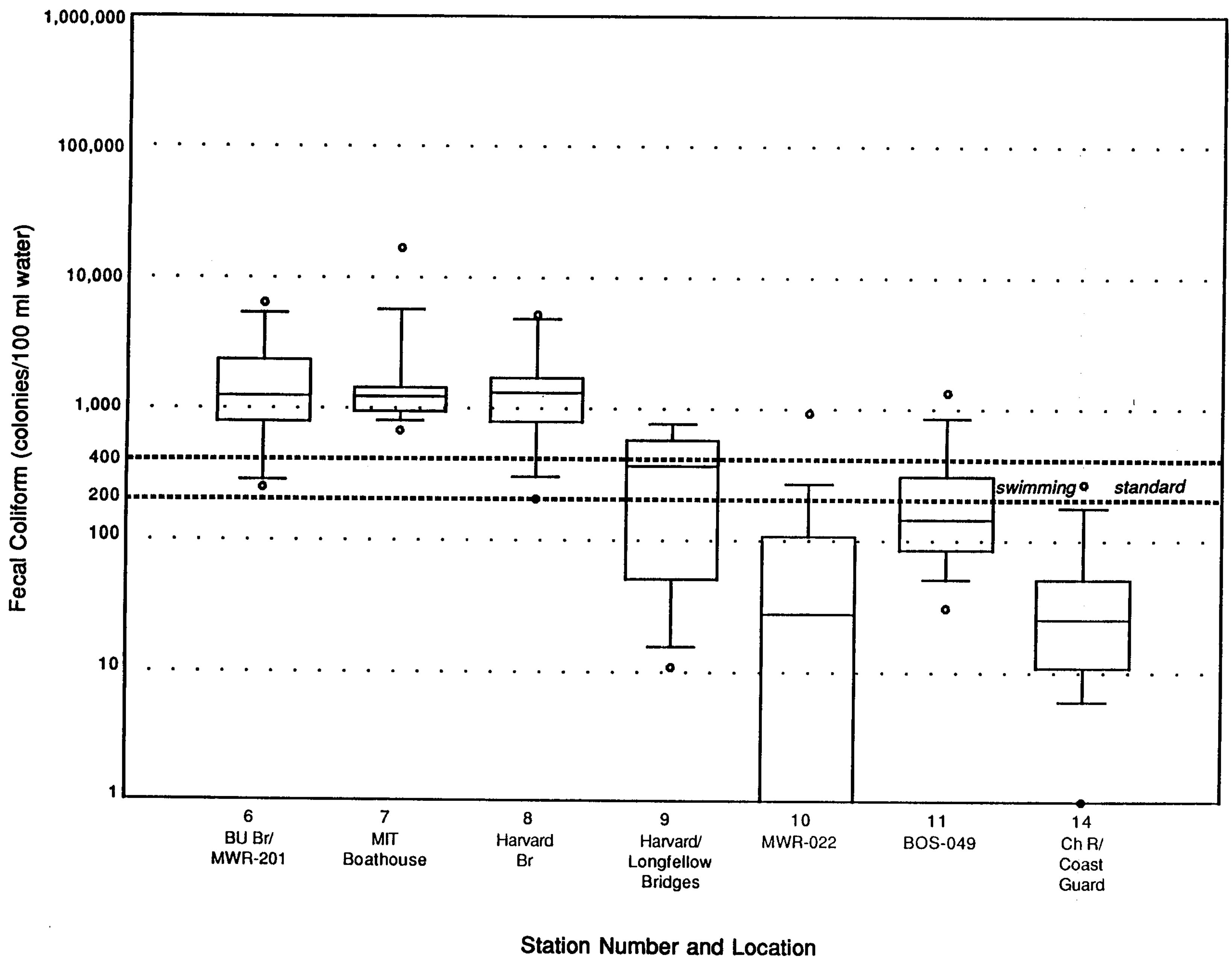


Figure 5.07. Percentile box plots of fecal coliform counts from bottom samples in the Charles River, summer 1991.

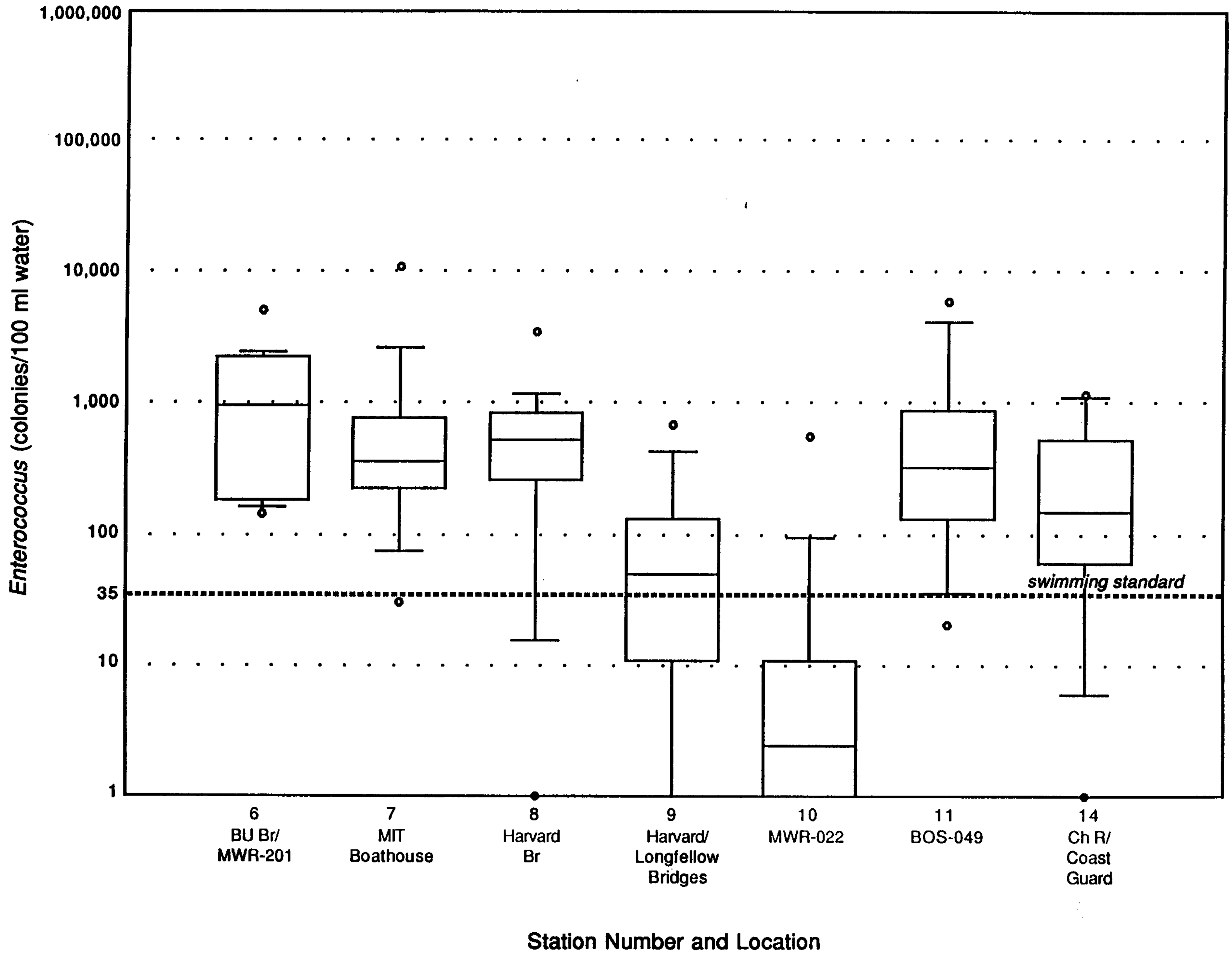


Figure 5.08. Percentile box plots of *Enterococcus* counts from bottom samples in the Charles River, summer 1991.

Summer 1991

When samples from all stations in the Charles were considered together, there were significant relationships between indicator bacteria and rainfall (correlation for fecal coliform with three-day summed rain, $r = 0.28$, $p < 0.001$; and for *Enterococcus* with three-day summed rain, $r = 0.49$, $p < 0.001$). When the relationships between rainfall and indicator bacteria densities were examined at individual stations, statistically significant correlations between fecal coliform counts and rainfall were found at only four locations. During this time period, *Enterococcus* counts were correlated with rainfall more strongly and at more locations than fecal coliform.

Regression Analyses

Log-transformed indicator bacteria counts from samples taken during both the October-November 1990 sampling period and the September 1991 sampling period together were regressed against the rainfall variable having the best overall correlation with counts--three-day summed rainfall (LORNP3). Regressions were calculated for three stations representing three very different environmental conditions in the Charles River with respect to potential effects of CSOs: Station 1, upstream of all CSOs; Station 6, near the Cottage Farm outfall; and Station 7, downstream of the Cottage Farm outfall in the Charles River Basin. Figure 5.09 shows the relationship between fecal coliform and three-day summed rainfall at Stations 1, 6, and 7. The equations for the regressions of fecal coliform against rain are

Upstream of all CSOs (Station 1):

$$\text{Log(fecal coliform/100 ml)} = 2.6 + 0.46[\text{LORNP3}]$$
$$R^2 = 0.46,\ p < 0.001$$

Near Cottage Farm discharge (Station 6):

$$\text{Log(fecal coliform/100 ml)} = 2.9 + 0.3[\text{LORNP3}]$$
$$R^2 = 0.1,\ p = 0.13 \text{ (not significant)}$$

Charles River Basin (Station 7):

$$\text{Log(fecal coliform/100 ml)} = 3.0 + 0.43[\text{LORNP3}]$$
$$R^2 = 0.26,\ p = 0.008$$

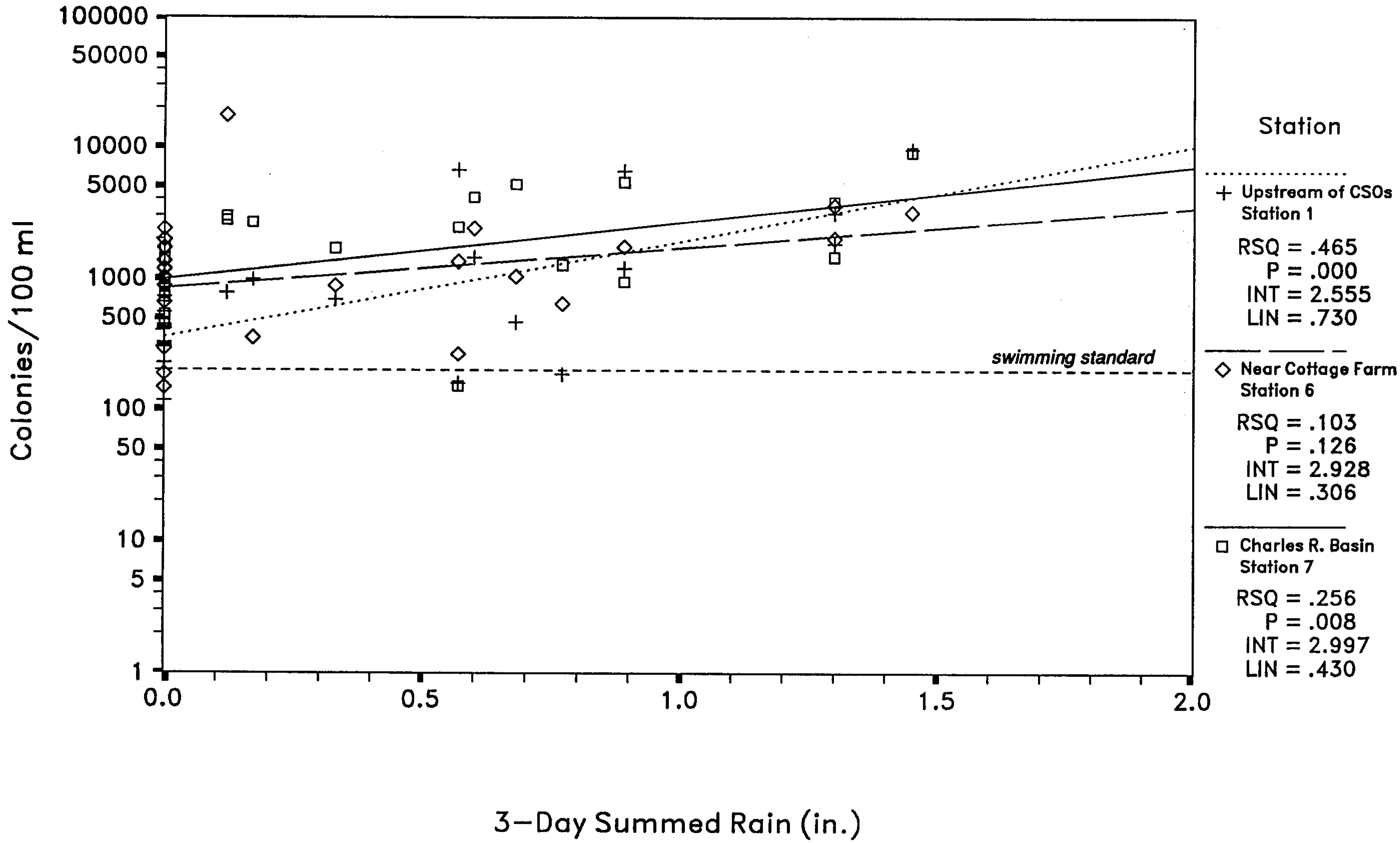


Figure 5.09. Fecal coliform counts regressed against three-day summed rainfall (LORNP3) at three stations in the Charles River.

As shown in Figure 5.09 all for fecal coliform regression lines intercepted the y-axis at values higher than 200 col/100 ml, predicting *dry* weather levels higher than the state water quality standard. Rainfall summed over three days explained 46% of the variance in fecal coliform counts at the upstream station, and 26% of the variance in the basin. The regression equation for the station near Cottage Farm did not show rainfall explaining a significant amount of variation in fecal coliform counts.

The equations for the regressions of *Enterococcus* against rain are

Upstream of all CSOs (Station 1):

$$\text{Log}(\textit{Enterococcus}/100 \text{ ml}) = 2.5 + 0.84[\text{LORNP3}]$$
$$R^2 = 0.45,\ p < 0.001$$

Near Cottage Farm discharge (Station 6):

$$\text{Log}(\textit{Enterococcus}/100 \text{ ml}) = 2.5 + 0.39[\text{LORNP3}]$$
$$R^2 = 0.39,\ p = 0.001$$

Charles River Basin (Station 7):

$$\text{Log}(\textit{Enterococcus}/100 \text{ ml}) = 2.4 + 0.83[\text{LORNP3}]$$
$$R^2 = 0.55,\ p < 0.001$$

All of these regressions are highly significant. The regression lines for Station 1 and Station 7 are very similar, with similar slopes and intercepts. As was true for fecal coliform, there is a stronger relationship between *Enterococcus* counts and rainfall upstream and downstream of the Cottage Farm outfall than near the outfall.

5.1.d Relationship between Indicator Bacteria in the Charles River and Flows from Combined Sewer Treatment Facilities

Cottage Farm CSO Treatment Facility

Most of the combined sewage discharged into the Charles River receives screening and chlorination at the Cottage Farm CSO Facility. Table 5.02 lists rainfall, flows measured at Cottage Farm, and fecal coliform

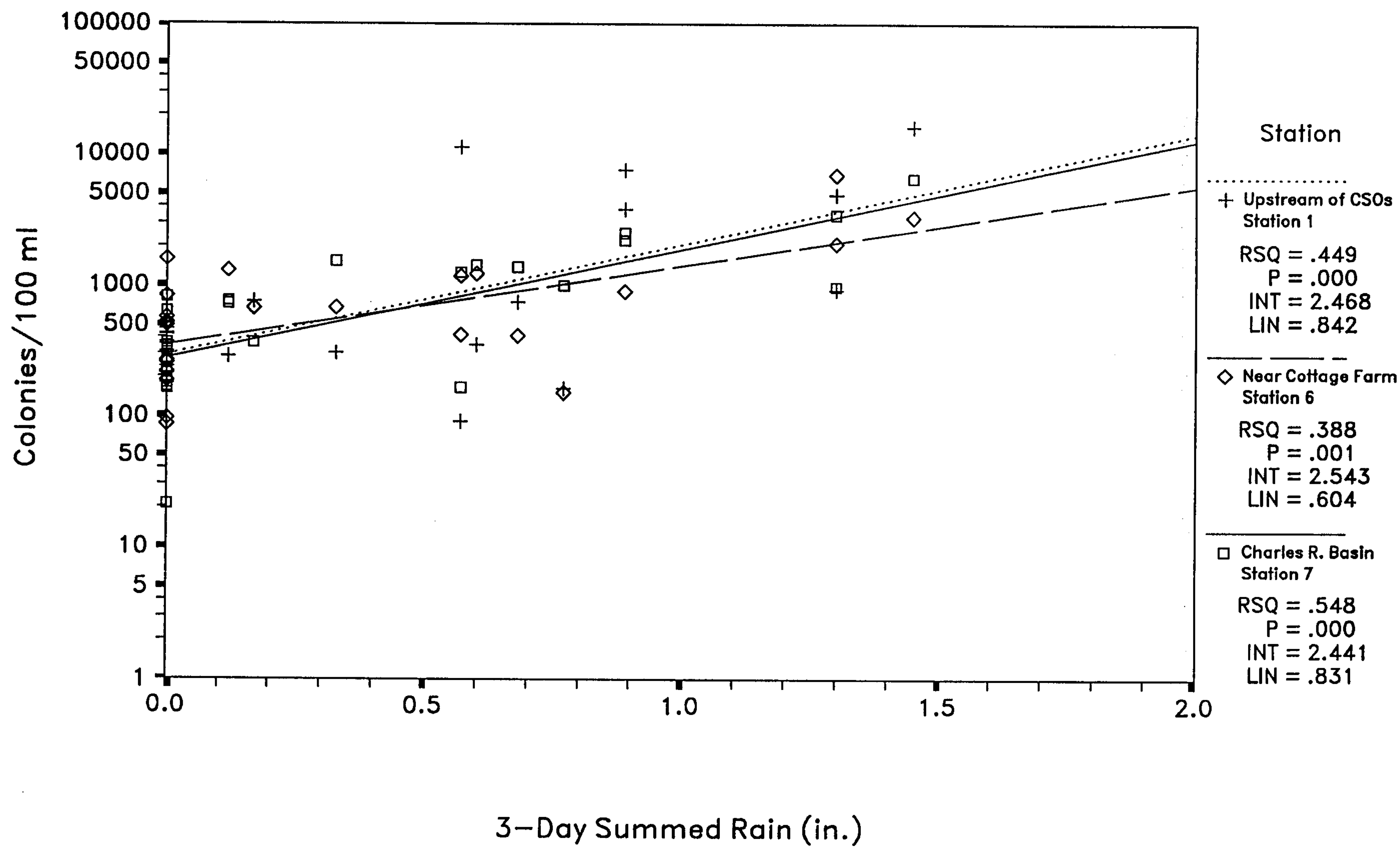


Figure 5.10. *Enterococcus* counts regressed against three-day summed rainfall (LORNP3) at three stations in the Charles River.

Table 5.02. Relationship among rainfall, flow from the Cottage Farm CSO Treatment Facility, and fecal coliform counts at upstream, nearfield, and downstream stations in the Charles River, fall 1990 and summer 1991.

Fall 1990

Date (1990)	Rainfall (in.)	Cottage Farm Flow (M.G.)	Fecal Coliform (col/100 ml) Station 5[a] (Upstream)	Station 6[a] (Nearfield)	Station 7[a] (Downstream: near MIT Boathouse)	Station 8[a] (Downstream: near Stony Brook)
10/18	0.70	0	ND	ND	ND	ND
10/19	0.51	2.8	ND	ND	ND	ND
10/22	0	0	2,275	1,700	440	2,100
10/23	0.68	0	1,000	1,045	5,200	1,925
10/24	0.62	10.31	3,500	3,600	3,850	10,875
10/25	0	0	1,900	2,025	1,475	1,825
10/28	0.33	0.56	ND	ND	ND	ND
10/30	0	0	1,750	885	1,700	1,625
10/31	0	0	1,900	1,013	848	6,850
11/1	0	0	1,470	1,950	968	1,475
11/5	Trace	0	2,050	2,350	528	58
11/6	0.57	0.5	2,750	1,350	2,450	8,800
11/7	Trace	0	363	265	150	258
11/8	0.03	0	2,875	2,400	4,125	1,775

[a] Counts are from surface samples. ND = No Data.

Table 5.02, continued.

Summer 1991

Date (1991)	Rainfall (in.)	Cottage Farm Flow (M.G.)	Fecal Coliform (col/100 ml)			
			Station 5[a] (Upstream)	Station 6[b] (Nearfield)	Station 7[b] (Downstream: near MIT Boathouse)	Station 8[b] (Downstream: near Stony Brook)
9/4	Trace	0	420	1,038	1,408	850
9/5	0.89	1.7	2,150	1,625	925	225
9/6	0	0	777	1,550	5,600	1,669
9/9	0	0	125	290	1,048	3,165
9/10	0	0	140	198	863	1,075
9/11	0	0	440	3,375	1,103	678
9/12	0	0	400	1,213	850	1,393
9/13	0	0	145	688	768	935
9/14	0.05	0	ND	ND	ND	ND
9/15	0.12	0	ND	ND	ND	ND
9/16	Trace	0	710	1,628	1,665	668
9/17	0	0	1,200	11,950	2,850	2,185
9/18	0	0	1,455	1,060	1,403	1,455
9/19	0.77	7.4	505	1,015	1,240	1,638
9/20	0.68	0	1,845	2,800	12,825	6,625

[a] Counts are from surface samples.
[b] Counts are mean of surface and bottom counts.
ND = No data.

counts measured at sampling locations upstream, in the nearfield, and downstream of the discharge. In general, samples collected near the outfall either during or on the day after the discharge did not show higher fecal coliform counts than samples collected upstream of the discharge, indicating effective disinfection of the combined sewage. Samples collected in the Basin area well downstream of the discharge, but near the area potentially affected by the Stony Brook, sometimes had substantially higher fecal coliform counts (e.g., on 10/24/90 and 11/6/90).

Prison Point CSO Treatment Facility

The Prison Point CSO Facility discharges screened and chlorinated effluent at the mouth of the Charles River downstream of the Charles River Dam into marine waters. Table 5.03 lists rainfall, flows measured at Prison Point, and fecal coliform counts measured at locations upstream and downstream of the discharge. The upstream location almost always had higher counts in the receiving water than the nearfield station. One exception was after a rainstorm on 9/19/91 and 9/20/91 (rainfall totalling 1.45 in.) which resulted in 17.9 million gallons of discharge from Prison Point. Samples collected in the inner harbor at the mouth of the river did have higher fecal coliform counts than samples collected upstream of the discharge. The higher counts in the harbor do not necessarily implicate the Prison Point Facility as the source of contamination because there are several CSOs in this area. The high counts in the water are difficult to reconcile with measurements of fecal coliform counts in the effluent, which were 40 col/100 ml on September 19, and <10 col/100 ml on September 20.

5.1.e Dissolved Oxygen

All the dissolved oxygen (DO) measurements made during this monitoring study were collected during daylight hours, when photosynthesis occurs and DO levels are expected to be higher than during the dark. The Massachusetts minimum standard for DO levels in Class B waters is 5.0 mg/l.

Fall 1990

The percentile distributions of surface DO measurements at Charles River stations during the fall 1990 sampling period are shown in Figure 5.11. There were no bottom measurements made during this period. All the dissolved oxygen measurements made during October and November 1990 were well above the minimum standard, with median levels between 7 and 11 mg/l. There is a spatial pattern of decreasing DO levels in the downstream direction.

Table 5.03. Relationship among rainfall, flow from the Prison Point CSO Treatment Facility, and fecal coliform counts at upstream and nearfield stations, fall 1990 and summer 1991.

Date (1990)	Rainfall (in.)	Prison Point Flow (M.G.)		Fecal coliform/100 ml	
				Station 11* (Upstream)	Station 14* (Nearfield)
10/18	0.70	0	S	ND	ND
			B	ND	ND
10/19	0.51	13.8	S	ND	ND
			B	ND	ND
10/22	0	0	S	693	748
			B	ND	15
10/23	0.68	2.2	S	3580	455
			B	ND	8
10/24	0.62	10.3	S	933	978
			B	ND	23
10/25	0	0	S	1100	840
			B	ND	23
10/28	0.33	1.9	S	ND	ND
			B	ND	ND
10/29	0	0	S	833	ND
			B	ND	ND
10/30	0	0	S	6125	673
			B	ND	8
10/31	0	0	S	795	250
			B	30	8
11/1	0	0	S	648	210
			B	ND	28
11/5	Trace	0	S	863	463
			B	ND	40
11/6	0.57	8.2	S	650	25
			B	ND	<10
11/7	Trace	0	S	288	245
			B	ND	10
11/8	0.03	0	S	1575	1173
			B	ND	8

*S = surface sample; B = bottom sample.

Table 5.03, continued.

Date (1991)	Rainfall (in.)	Prison Point Flow (M.G.)		Fecal coliform/100 ml Station 11* (Upstream)	Fecal coliform/100 ml Station 14* (Nearfield)
9/3	0	0	S	60	5
			B	145	0
9/4	Trace	0	S	20	5
			B	30	10
9/5	0.89	5.2	S	100	ND
			B	50	ND
9/6	0	0	S	20	840
			B	550	270
9/9	0	0	S	105	70
			B	130	10
9/10	0	0	S	245	80
			B	150	5
9/11	0	0	S	140	70
			B	145	30
9/12	0	0	S	55	80
			B	85	35
9/13	0	0	S	30	65
			B	70	25
9/14	0.05	0	S	ND	ND
			B	ND	ND
9/15	0.12	0	S	ND	ND
			B	ND	ND
9/16	Trace	0	S	260	55
			B	845	175
9/17	0	0	S	325	100
			B	230	175
9/18	0	0	S	185	35
			B	100	15
9/19	0.77	8.7	S	165	0
			B	305	10
9/20	0.68	9.2	S	740	1855
			B	1340	50

*S = surface sample; B = bottom sample.

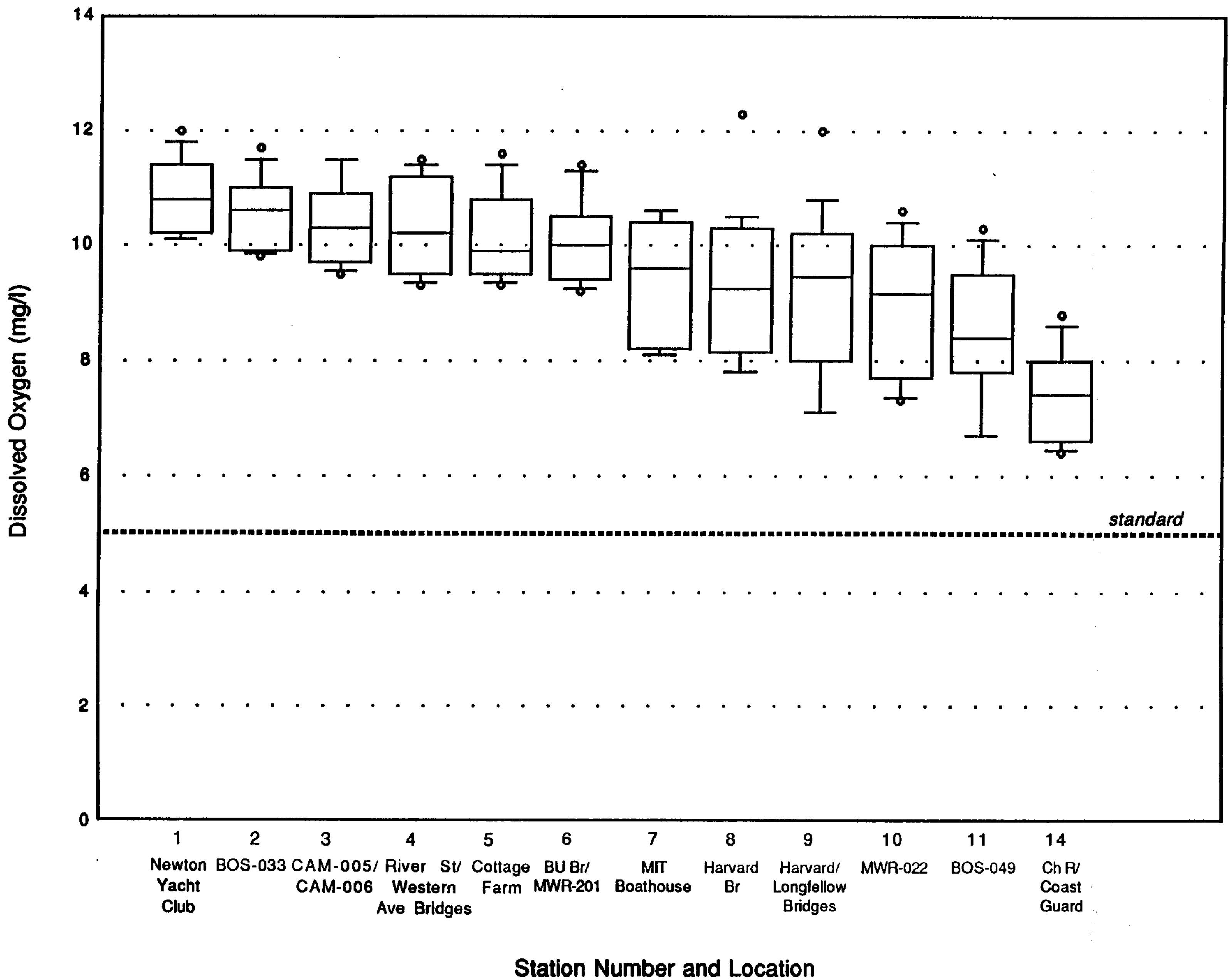


Figure 5.11. Percentile box plots of surface water dissolved oxygen levels in the Charles River, fall 1990.

Summer 1991

Surface DO

Figure 5.12 shows percentile distributions of DO levels from surface measurements taken in the Charles River during the summer 1991 sampling period. Median DO levels were lower during this warmer sampling period, falling to levels between 5 and 8 mg/l. The lowest median DO levels were at station 14, at the mouth of the river, but otherwise there was no clear spatial pattern of increasing or decreasing DO levels along the length of the Charles.

Bottom DO

The measurements of DO in the bottom waters of the Charles offer a contrast to the surface measurements. Figure 5.13 shows percentile distributions of DO from Station 6 downstream. Many measurements at Stations 6 and 7 were well below the 5 mg/l standard, and the median DO measurements at Stations 8, 9, 10, and 11 were less than 2 mg/l. These low measurements at the bottom of the Basin area of the Charles reflect the effect of salt water intrusion into the river, which has become entrained below the fresh water and become anoxic.

5.2 Discussion

On average, water quality in the Charles River during these monitoring periods did not meet state fecal coliform standards (or suggested EPA standards for *Enterococcus*) for class B water in any weather condition. Unlike the pattern observed during the 1989 and 1990 monitoring, the most upstream station did not have counts noticeably higher than at other stations. Not only were the class B (swimming) standards exceeded, but the less stringent water quality standards for recreational boating were typically not met.

There were statistically significant relationships between fecal coliform counts and rainfall and *Enterococcus* counts and rainfall at several sites in the Charles River. The regressions showed that rain explained less variance in bacteria counts, with less statistical significance, at the Cottage Farm Facility outfall location than at sites located upstream and downstream of the outfall. This pattern would be expected if disinfection of the combined sewage effluent from Cottage Farm was effective, reducing bacteria counts at the outfall,

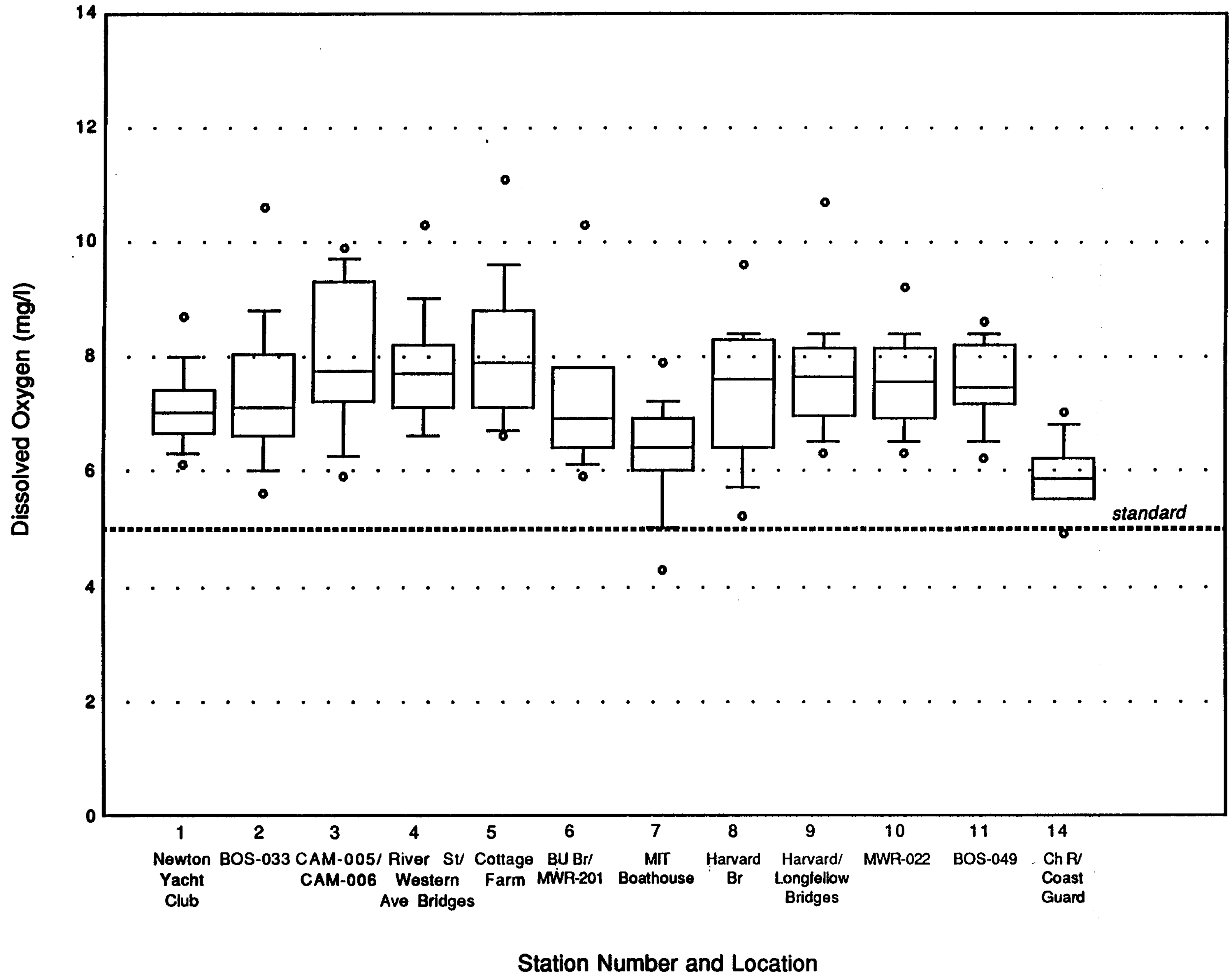


Figure 5.12. Percentile box plots of surface water dissolved oxygen levels in the Charles River, summer 1991.

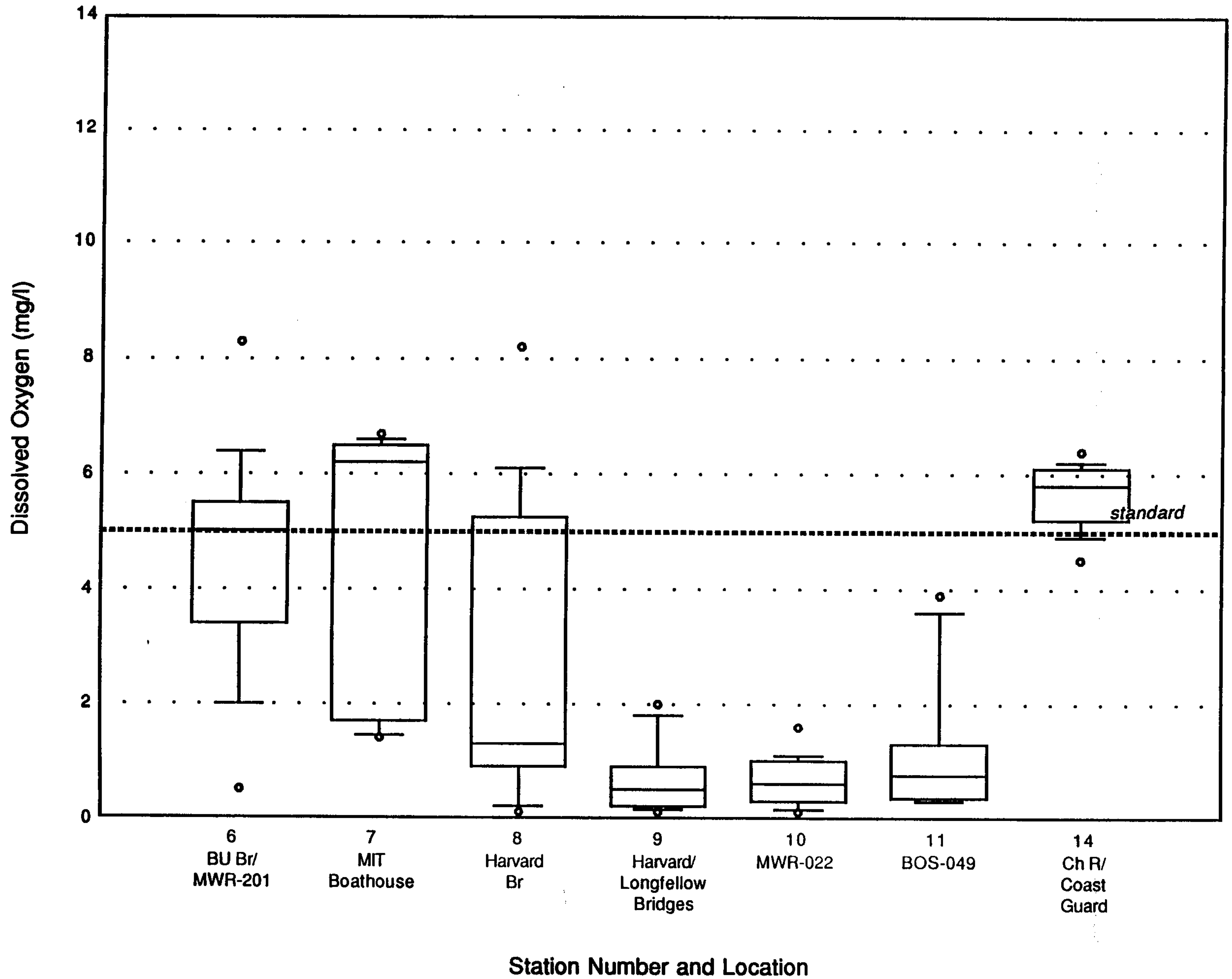


Figure 5.13. Percentile box plots of bottom water dissolved oxygen levels in the Charles River, summer 1991.

and if there are also other significant wet-weather sources of sewage to the river. Interestingly, the station upstream of all CSOs (Station 1) had a stronger relationship between fecal coliform counts and rain than did Station 7, which would presumably be affected by CSO discharges (especially via the Stony Brook). This implies that there are important upstream sources of sewage. The fall 1990 and summer 1991 monitoring periods provided an opportunity to measure water quality in the Charles River during dry and rainy weather. During this year's monitoring periods, there were no rainstorms comparable in size to the nearly three-inch storm in July 1990 which resulted in 95 M.G. discharging from Cottage Farm. The biggest discharge from Cottage Farm during the monitoring discussed in this report was 10.3 M.G.

The anoxic condition of the bottom waters in the Charles River Basin has been previously observed, and appears to be chronic. This anoxia results from the intrusion of saltwater into the river, which settles in a stagnant layer in the deepest areas of the Basin.

5.3 Conclusions

- **Sewage Pollution Levels in the Charles River, and Relationship to Rain and CSOs**

  The Charles River between the Watertown Dam and the Charles River Dam suffered from severely degraded water quality (measured by densities of fecal indicator bacteria), even during dry weather and light rains, and in the absence of combined sewer overflows. Wet-weather but non-CSO sources, such as contaminated storm water, contribute significantly to the pollution of the Charles River. Rain had a significant effect on sewage indicator bacteria counts in the Charles, but less of an effect at the Cottage Farm outfall than at upstream (of all CSOs) and downstream sites. Disinfection of combined sewage at the Cottage Farm Facility is effective at reducing the source of sewage-borne microorganisms to the Charles, but other wet-weather (and dry-weather) sources remain.

- **Aesthetic Problems**

  Although the discharges from the Cottage Farm Treatment Facility are screened an disinfected, greatly lowering the threat to public health, the discharges are unsightly and malodorous, and contain small sewage-related floatables including condoms, toilet paper and tampon applicators. The discharge pipes are in relatively shallow water in a narrow part of the river. Both the river and the shoreline are heavily used recreational areas.

5. The Charles River

Untreated CSOs and contamination from storm drains also contribute significantly to aesthetic degradation of the Charles, flushing both sewage and waste from the streets into the river. After a heavy rainstorm, sewage slicks and floatables are frequently seen at the shoreline.

- **Dissolved Oxygen**

While daytime dissolved oxygen levels in the surface waters in the Charles River generally were well within water quality standards, the bottom waters of the basin were virtually anoxic because of entrained, stagnant saltwater. Previous studies have indicated that large volumes of CSO from Cottage Farm may deplete oxygen levels in the surface waters of the river.

6. Alewife Brook and the Mystic River

Stations in Alewife Brook and the Mystic River were monitored together in order to measure the effect of Alewife Brook on water quality in the Mystic River. The Mystic River has both tidal and freshwater segments, separated by the Amelia Earhart Dam and locks. The dam is located immediately upstream of the outfall for the Somerville Marginal CSO Treatment Facility (MWR-205). Waters downstream of the dam are marine and tidal; upstream of the dam the waters are fresh.

6.1 Results

6.1.a Sampling Locations and Rainfall

Figure 6.01 shows the locations of the stations sampled in Alewife Brook and the Mystic River. Samples were collected periodically on fifteen days between November 15, 1990, and March 5, 1991, and on six days/week between June 24 and July 13, 1991. Figure 6.02 shows the amount of rain that fell each day during the sampling periods.

6.1.b Indicator Bacteria Counts

Fall-Winter 1990-1991

Fecal Coliform

Table 6.01 shows the geometric means with corresponding 95% confidence intervals for fecal coliform counts during the fall-winter 1990-1991 sampling period. Only locations accessible by land (bridges, dam) were sampled during this period. Of the four stations monitored, only Station 67 upstream of the Amelia Earhart Dam had a geometric mean fecal coliform count within water quality standards. The highest geometric mean fecal coliform counts were in Alewife Brook, while bacteria levels at the Somerville Marginal outfall (Station 52) exceeded standards on average by approximately 100 col/100 ml.

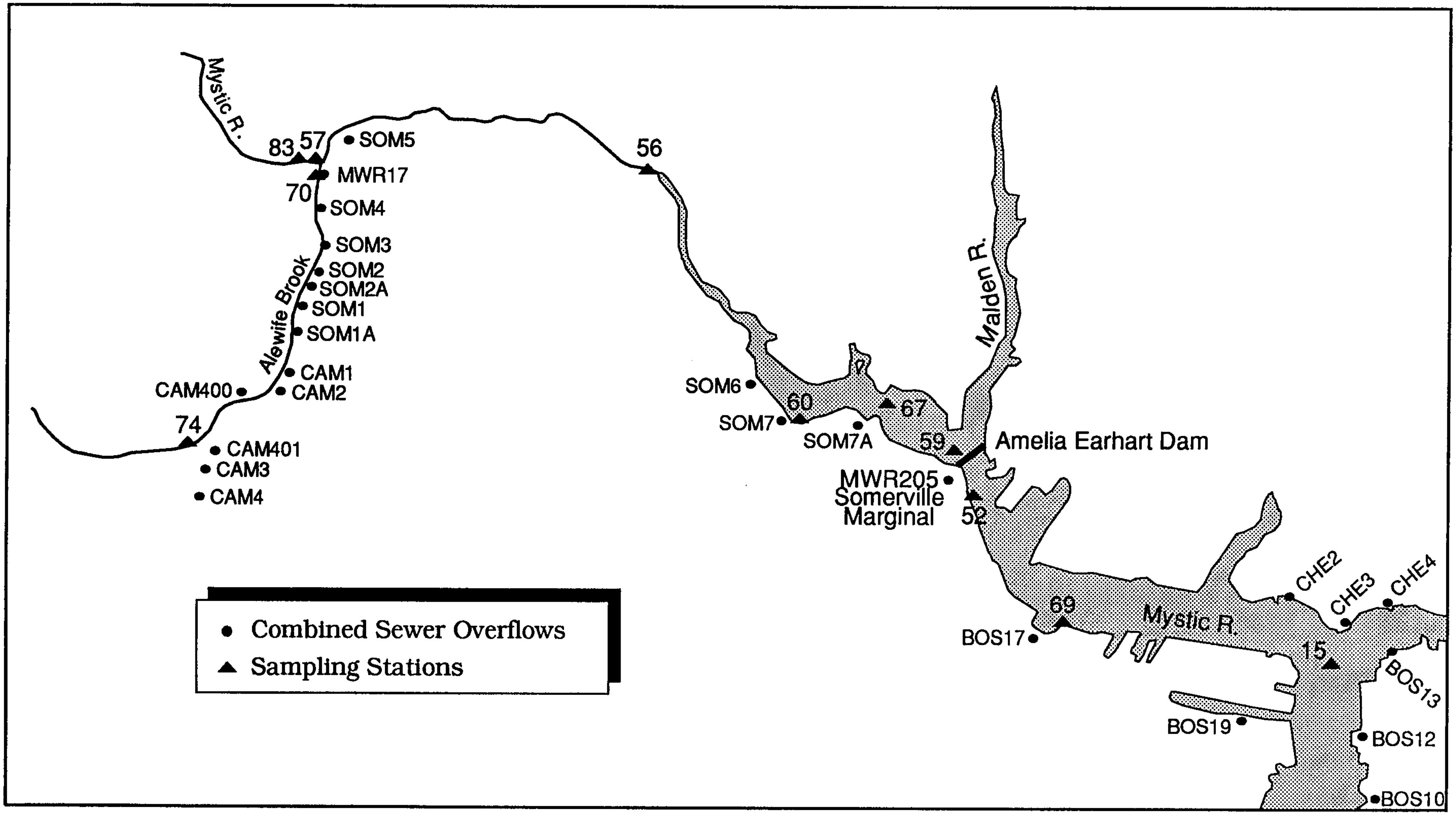


Figure 6.01. Stations sampled in Alewife Brook and the Mystic River.

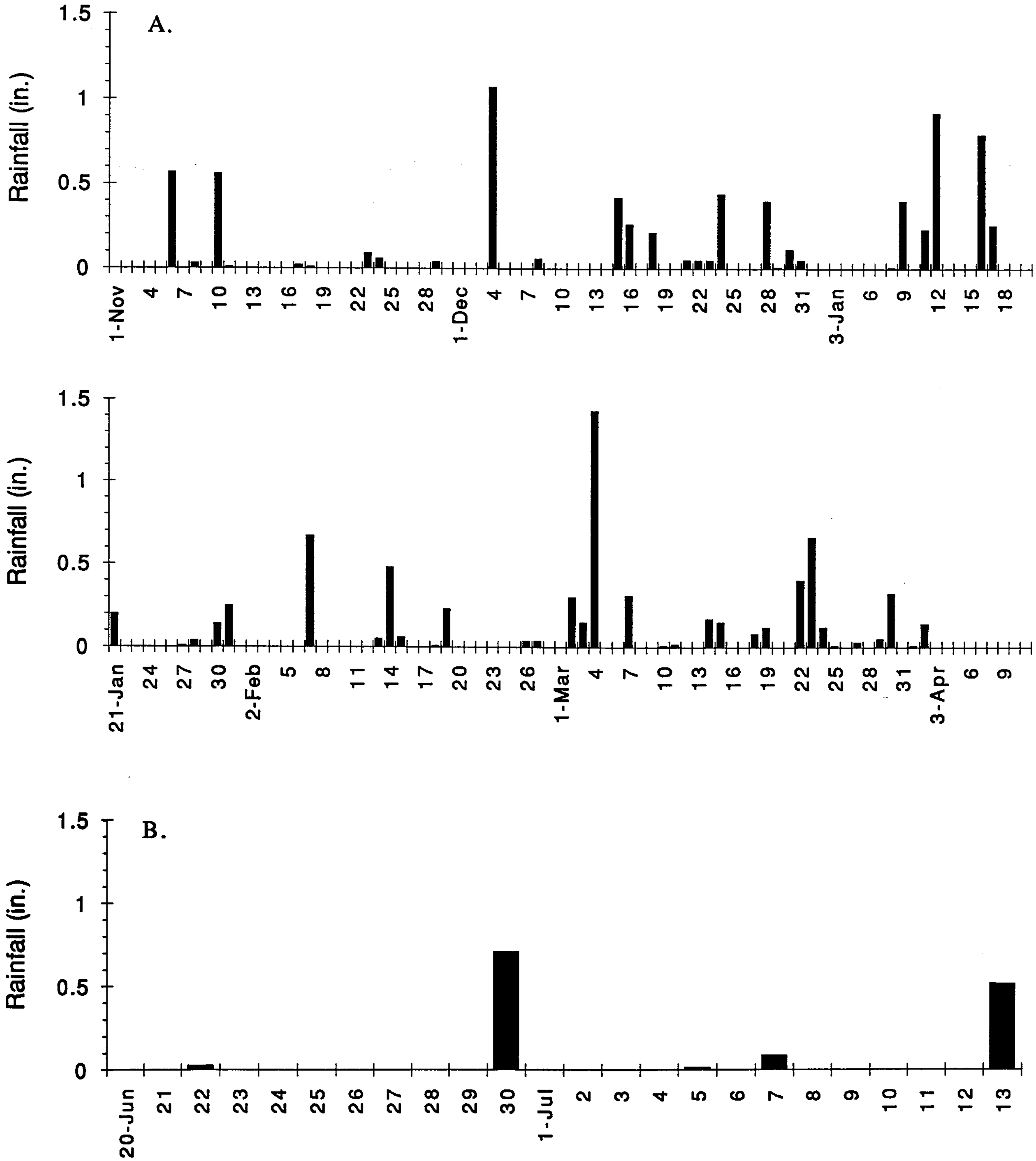


Figure 6.02. Rainfall during the Alewife Brook and Mystic River sampling periods. A. Winter 1990-1991 and B. Summer 1991.

Table 6.01. Geometric means (col/100 ml) with 95% confidence intervals (CI) for fecal coliform and *Enterococcus* counts at stations in Alewife Brook and the Mystic River, winter 1990-1991 and summer 1991.

Station			Winter 1990-1991		Summer 1991	
No.	Location	Depth*	n	mean (CI)	n	mean (CI)
Fecal Coliform						
15	Mystic River/Chelsea River	S	...	...	13	17 (9-30)
		B	...	...	13	5 (1-14)
52	MWR-205/Mystic River	S	13	351 (123-993)	13	657 (144-2987)
		B	...	...	13	300 (176-510)
56	Route 93/Mystic River	S	...	...	12	139 (89-216)
57	Alewife Brook/Mystic River	S	...	...	12	92 (53-161)
59	Mystic River/Malden River	S	...	...	12	73 (49-108)
60	MDC Dock (SOM-007)/Mystic River	S	...	...	12	47 (23-97)
67	Route 28 Bridge/Mystic River	S	8	163 (82-323)	12	49 (27-85)
69	Mystic River (BOS-017)	S	...	...	13	174 (73-411)
		B	...	...	13	42 (26-67)
70	Alewife Brook (SOM-004)	S	11	1590 (593-4262)	12	184 (102-331)
74	Alewife Brook at T station	S	11	1020 (459-2264)	..	...
83	Mystic River, upstream of Alewife	S	...	...	12	58 (31-108)
Enterococcus						
15	Mystic River/Chelsea River	S	...	...	13	3 (1-6)
		B	...	...	13	3 (1-5)
52	MWR-205/Mystic River	S	13	157 (48-512)	13	22 (4-101)
		B	...	...	13	20 (10-41)
56	Route 93/Mystic River	S	...	...	12	49 (28-83)
57	Alewife Brook/Mystic River	S	...	...	12	137 (79-236)
59	Mystic River/Malden River	S	...	...	12	10 (5-19)
60	MDC Dock (SOM-007)/Mystic River	S	...	...	12	12 (7-22)
67	Route 28 Bridge/Mystic River	S	8	78 (29-211)	12	13 (8-22)
69	Mystic River (BOS-017)	S	...	...	13	3 (1-10)
		B	...	...	13	2 (1-4)
70	Alewife Brook (SOM-004)	S	11	1095 (410-2918)	12	270 (179-407)
74	Alewife Brook at T station	S	11	933 (309-2812)	...	...
83	Mystic River, upstream of Alewife	S	...	...	12	156 (103-236)

*S = surface sample; B = bottom sample.

Enterococcus

The pattern of *Enterococcus* counts in these colder months paralleled fecal coliform counts (Table 6.01). Very high geometric mean counts were found in Alewife Brook; somewhat lower counts were found near the Somerville Marginal outfall; and the lowest geometric mean was at Station 67. Although fecal coliform counts at Station 67 met swimming standards, geometric mean *Enterococcus* counts at Station 67 did not meet the 35 col/100 ml swimming standard proposed by EPA. (The EPA-recommended geometric mean for *Enterococcus* at freshwater bathing beaches is 33 col/100 ml, and for marine water bathing beaches it is 35 col/100 ml.)

Summer 1991

Surface Samples

Fecal coliform

The spatial pattern of the distribution of fecal coliform counts along the Mystic River is shown on percentile box plots (Figure 6.03). The boxes are arranged so that the most upstream station (upstream of the confluence of the Mystic River and Alewife Brook) is on the left, and the inner harbor stations on the right. Stations 83, 70, 57, 56, 60, 67, and 59 are all fresh water. Stations 52, 69, and 15 are marine. There was no clear trend of increasing or decreasing counts along the length of the river. At most of the stations sampled during the summer, fecal coliform counts met the state criterion for a geometric mean of no more than 200 col/100 ml, with no more than 10% of samples exceeding 400 col/100 ml. (Geometric mean counts are in Table 6.01.) Stations not meeting this standard were Station 70, in Alewife Brook; Station 52, near MWR-205; and Station 69, near BOS-017.

Enterococcus

Figure 6.04 shows percentile box plots of *Enterococcus* counts. The spatial pattern of *Enterococcus* in the Mystic River differed from fecal coliform. While high counts were found in the Alewife Brook and at the confluence of the brook with the Mystic River, *Enterococcus* counts upstream of the Mystic/Alewife confluence (Station 83) were also high compared to counts at more downstream locations (Stations 60, 67, and 59). EPA guidelines recommend a "steady state" geometric mean for *Enterococcus* of 33 col/100 ml of water, with a "single-sample maximum allowable density" of 151 col/100 ml for fresh water "infrequently used for full body contact recreation." (The recommended single-sample *Enterococcus* maximum for marine water is 500 col/100 ml). The geometric mean of 33 was exceeded at Stations 83, 70, 57, and 56, but the rest of the Mystic River stations generally met the swimming standard, with some very high outlying points (up to approximately 100,000 col/100 ml) near the Somerville Marginal outfall.

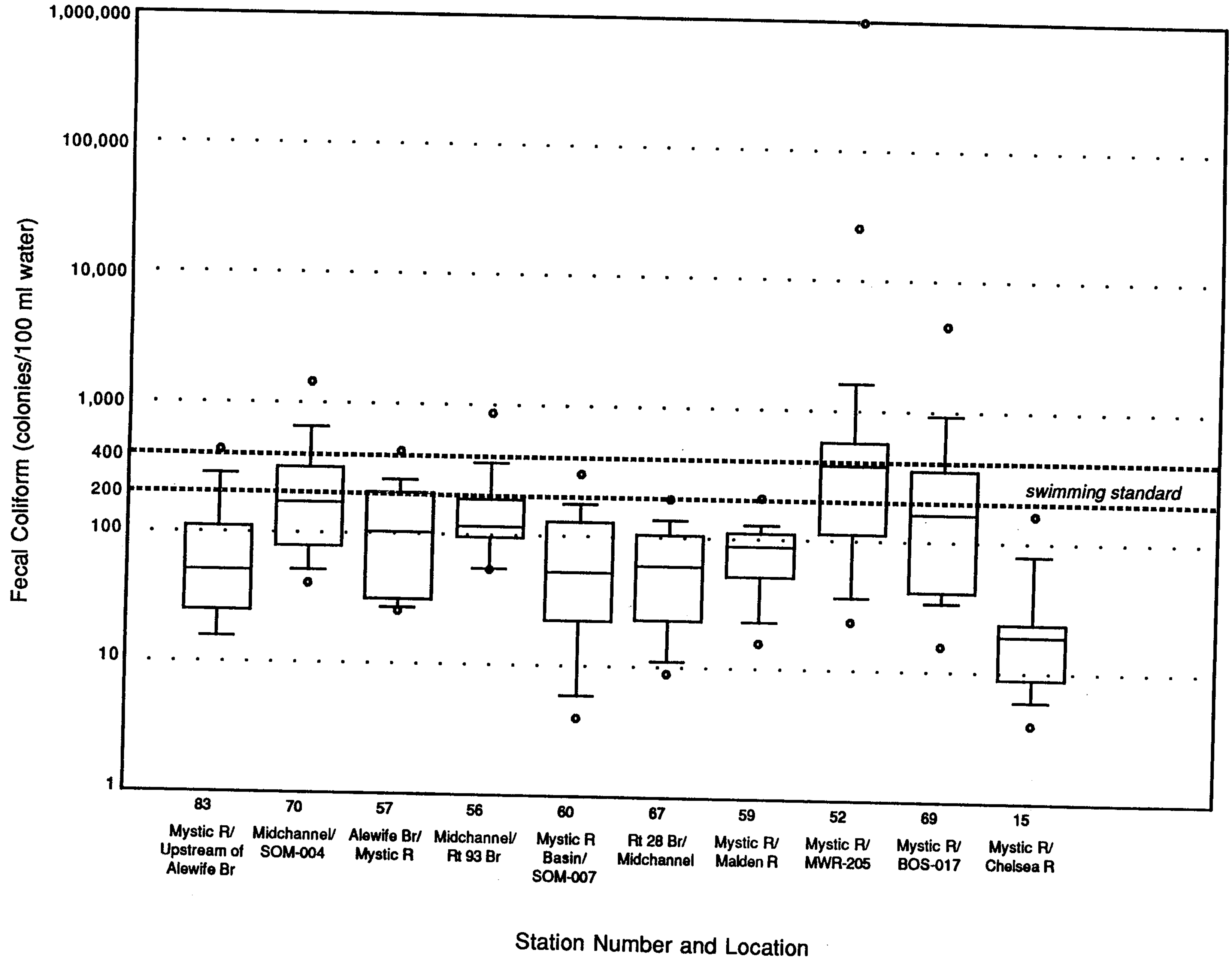


Figure 6.03. Percentile box plots of fecal coliform counts from surface samples in Alewife Brook and the Mystic River, summer 1991.

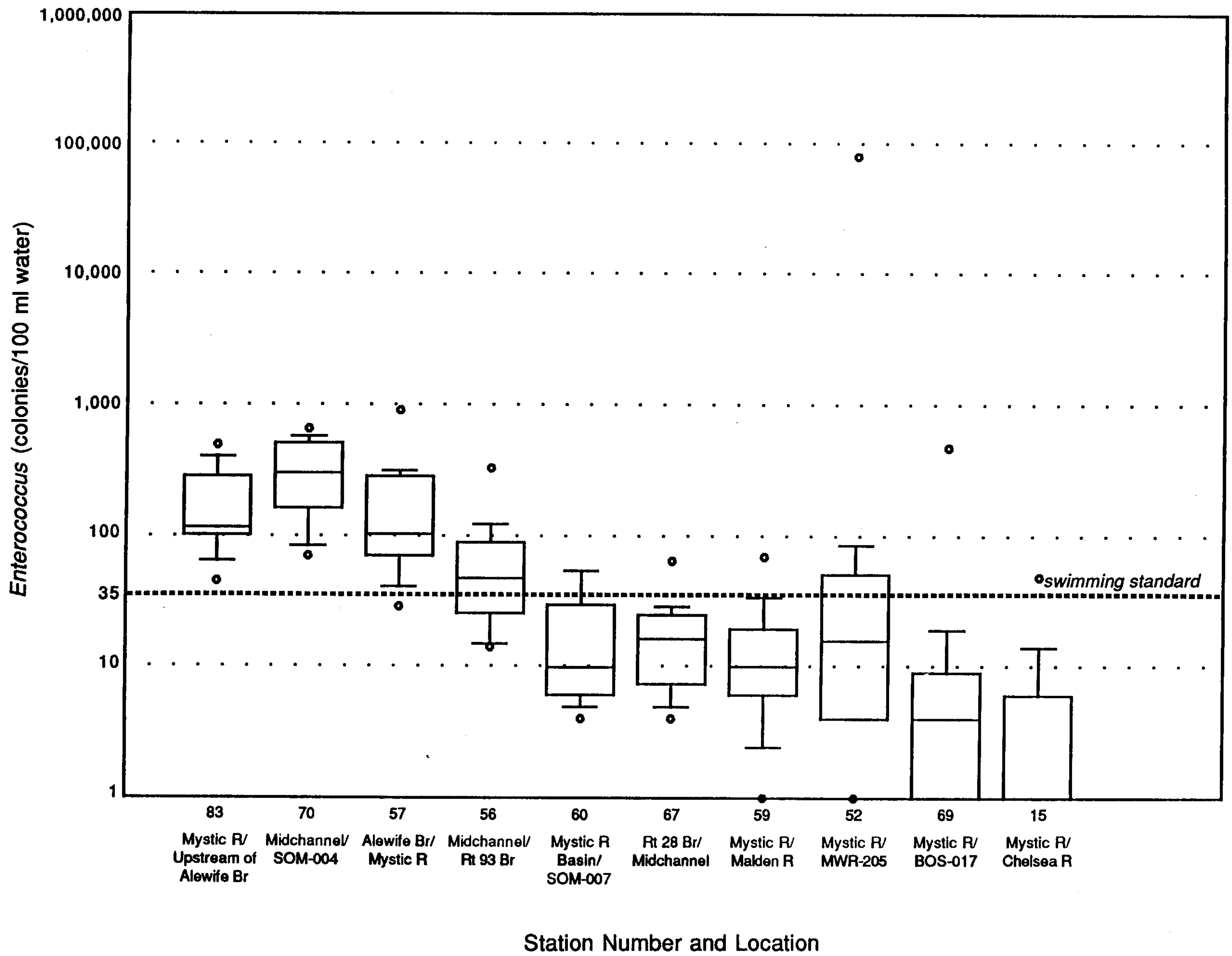


Figure 6.04. Percentile box plots of *Enterococcus* counts from surface samples in Alewife Brook and the Mystic River, summer 1991.

Bottom samples

Bottom samples were collected only at the three marine stations: 52, 69, and 15. Counts of fecal coliform from bottom samples were significantly lower than surface counts at Station 69, but at the other two stations surface and bottom fecal coliform counts were similar. For *Enterococcus*, surface and bottom counts were similar at all three stations.

6.1.c Relationship between Indicator Bacteria and Rainfall

Fall-Winter 1990-1991

When all the stations sampled in the MysticRiver and Alewife Brook during the winter were considered together in the same correlation analysis, rainfall summed over three days was significantly correlated with both fecal coliform counts ($r = 0.5, p = 0.003$) and *Enterococcus* ($r = 0.51, p = 0.002$). However, at individual stations correlations between bacteria counts and rainfall were generally not significant, perhaps because the number of samples was too small. Nevertheless, it is possible to (somewhat arbitrarily) define weather conditions as either "wet" or "dry" and compare average bacteria counts found during different weather conditions. Wet-weather samples were defined as those samples collected the same day as or the day after a rainfall ≥ 0.01 in.; and dry-weather samples were defined as those samples collected when no rain had occurred for three or more days before sampling. Geometric mean counts with upper and lower 95% confidence intervals for fecal coliform (Figure 6.05) and *Enterococcus* (Figure 6.06) are shown for wet compared to dry weather at individual stations sampled during the fall-winter period.

Fecal coliform and *Enterococcus* counts were significantly higher during wet weather at stations 52, 70, and 74.

Summer 1991

When all the freshwater stations monitored during the summer sampling period were considered as a group, there were statistically significant relationships between rainfall variables and bacteria: for log-transformed fecal coliform with rainfall summed over four days, $r = 0.35$, $p = 0.001$; for log-transformed *Enterococcus* with rainfall summed over four days, $r = 0.28$, $p = 0.005$. However, at individual stations no consistent pattern of significant correlations between bacteria counts and rainfall was found.

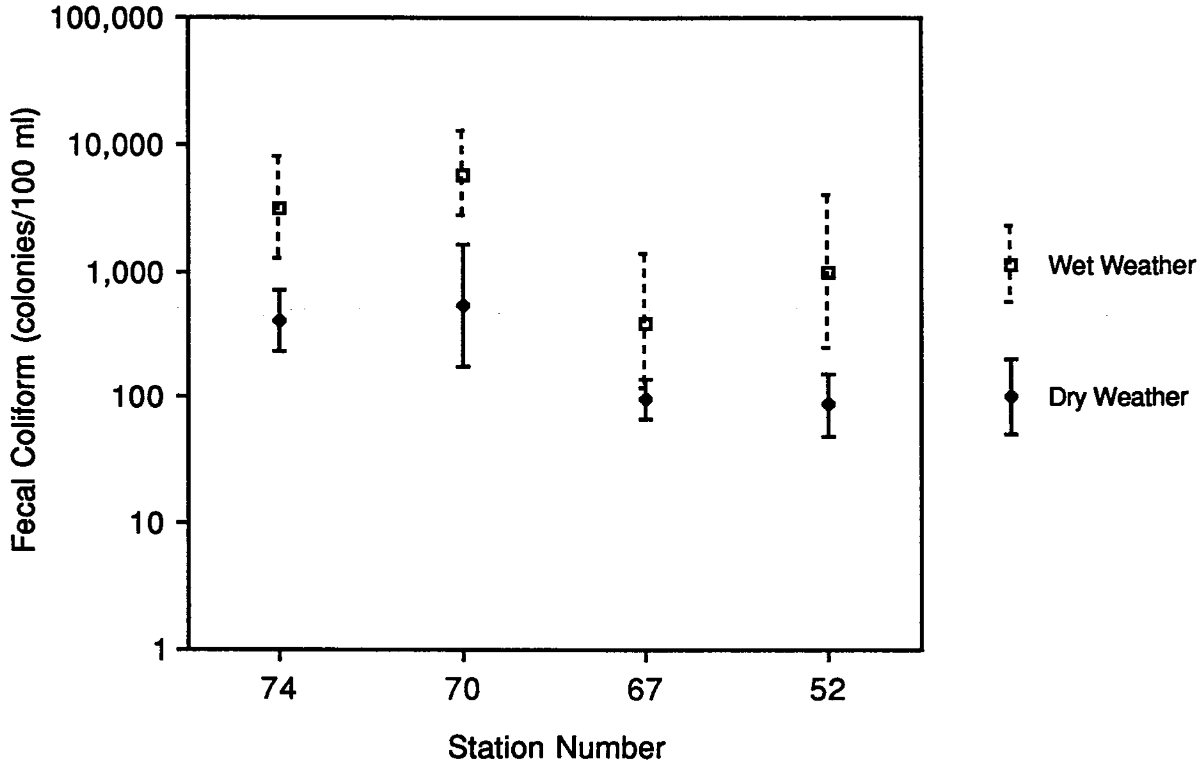


Figure 6.05. Geometric mean counts (col/100 ml) with 95% confidence intervals for fecal coliform under wet and dry weather conditions in the Mystic River and Alewife Brook, winter 1990-1991.

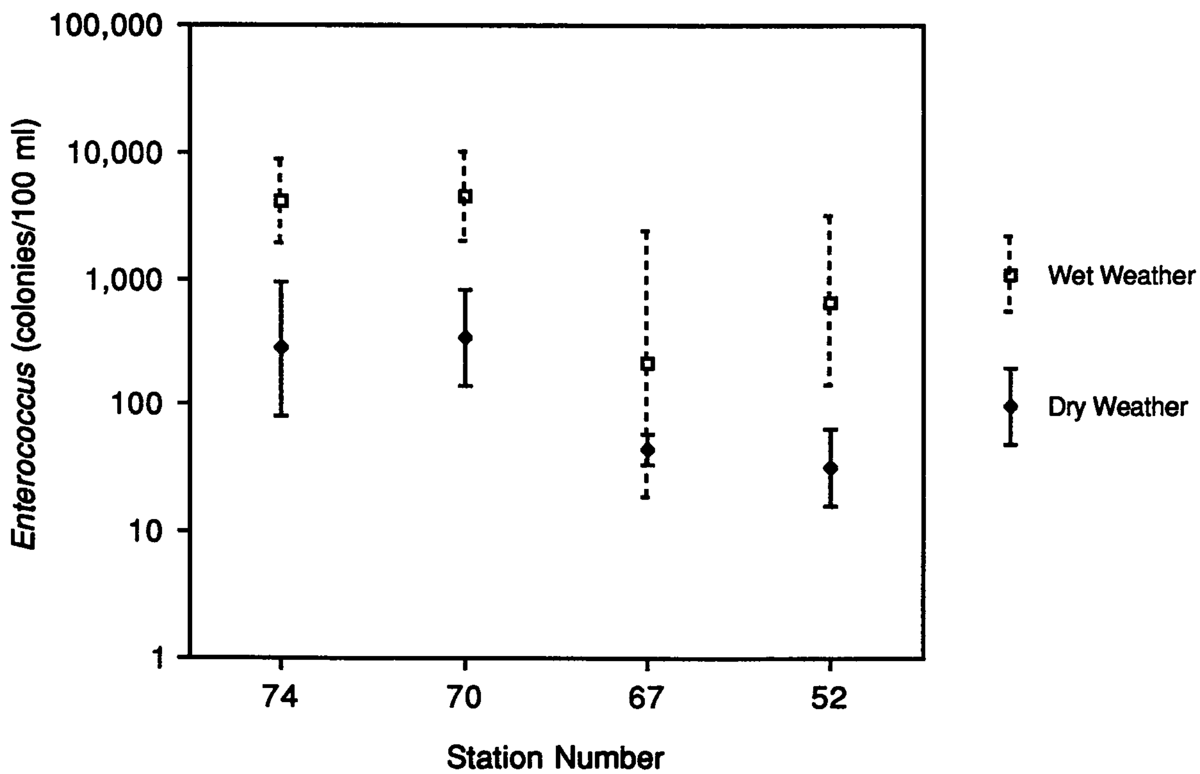


Figure 6.06. Geometric mean counts (col/100 ml) with 95% confidence intervals for *Enterococcus* under wet and dry weather conditions in the Mystic River and Alewife Brook, winter 1990-1991.

6. Alewife Brook and the Mystic River

As was done for the winter sampling, a second analysis was performed to explore whether, during the summer sampling period, any significant differences in bacteria counts could be detected between samples arbitrarily divided into those collected during "wet" and "dry" weather as defined above. Because of the rainfall pattern during the 1991 summer sampling period, only two or three samples for each weather category were collected from each station. The geometric means with corresponding 95% confidence intervals at each station in the Mystic/Alewife area are shown in Figures 6.07 and 6.08. For fecal coliform (Figure 6.07), average counts during wet and dry weather were very similar at Stations 15, 69, 52, 59, and 67, and the confidence intervals overlapped at all the other stations except Station 70 in Alewife Brook. For *Enterococcus* (Figure 6.08), the geometric means of samples collected during wet weather were consistently higher than for those collected during dry weather. At Stations 67, 60, 57, and 83, the differences were significant at the 95% level.

6.1.d Dissolved Oxygen

Fall-Winter 1990-1991

Figure 6.09 shows percentile box plots of dissolved oxygen (DO) levels measured at the four Mystic River/Alewife Brook stations sampled during these colder months. Most of the DO measurements were between 8 and 13 mg/l, and all of the measurements were above the minimum standard of 5 mg/l.

Summer 1991

Surface DO

DO levels measured at the surface of the Mystic River and Alewife Brook during the summer are presented as percentile box plots in Figure 6.10. All of these daytime measurements were above the 5 mg/l standard. The lowest median DO levels (between 6 and 9 mg/l) were in the three marine stations: 52, 69, and 15; while the highest levels (medians between 10 and 12 mg/l) were in the "basin" area of the Mystic and downstream to the Earhart Dam. Median values upstream in the Mystic and at the Mystic/Alewife confluence fell between 8 and 10 mg/l. As shown in the box plots, measurements at each station were distributed over a fairly broad range of values--for example, at Station 57, DO values ranged from 6.5 to 12 mg/l, with 50% of the values falling between 8 and 11 mg/l.

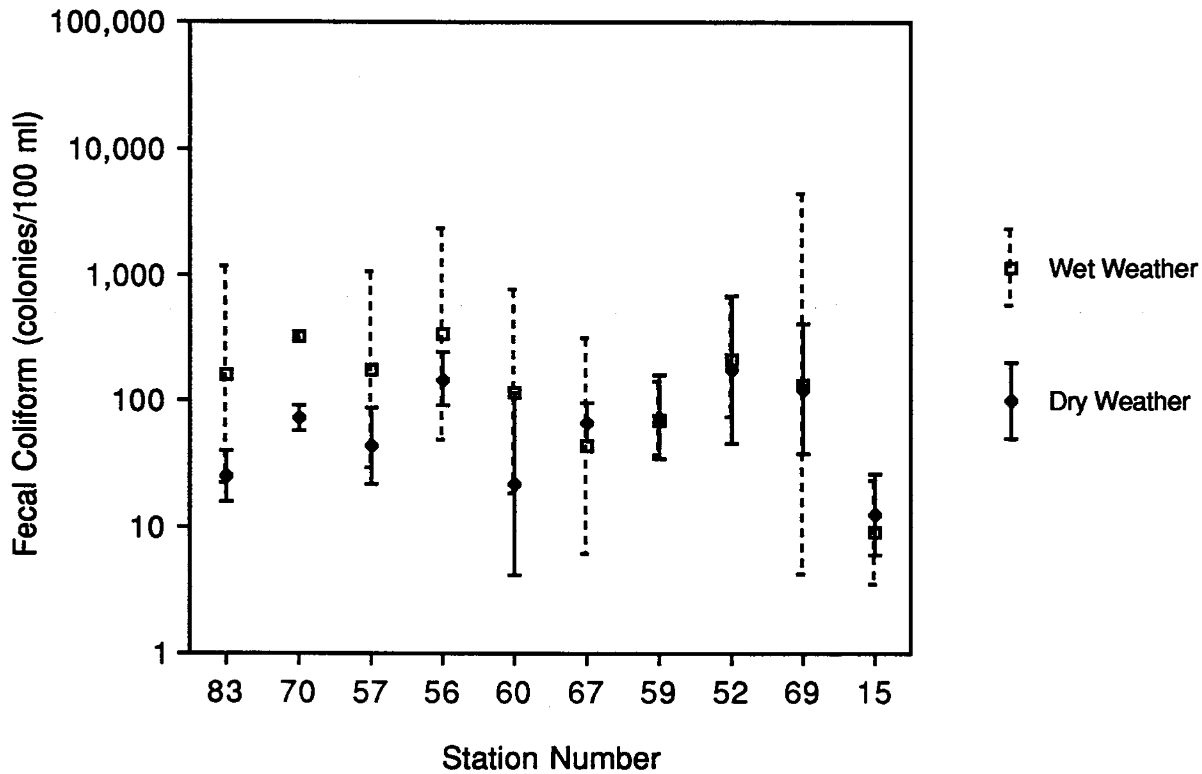


Figure 6.07. Geometric mean counts (col/100 ml) with 95% confidence intervals for fecal coliform under wet and dry weather conditions in the Mystic River and Alewife Brook, summer 1991.

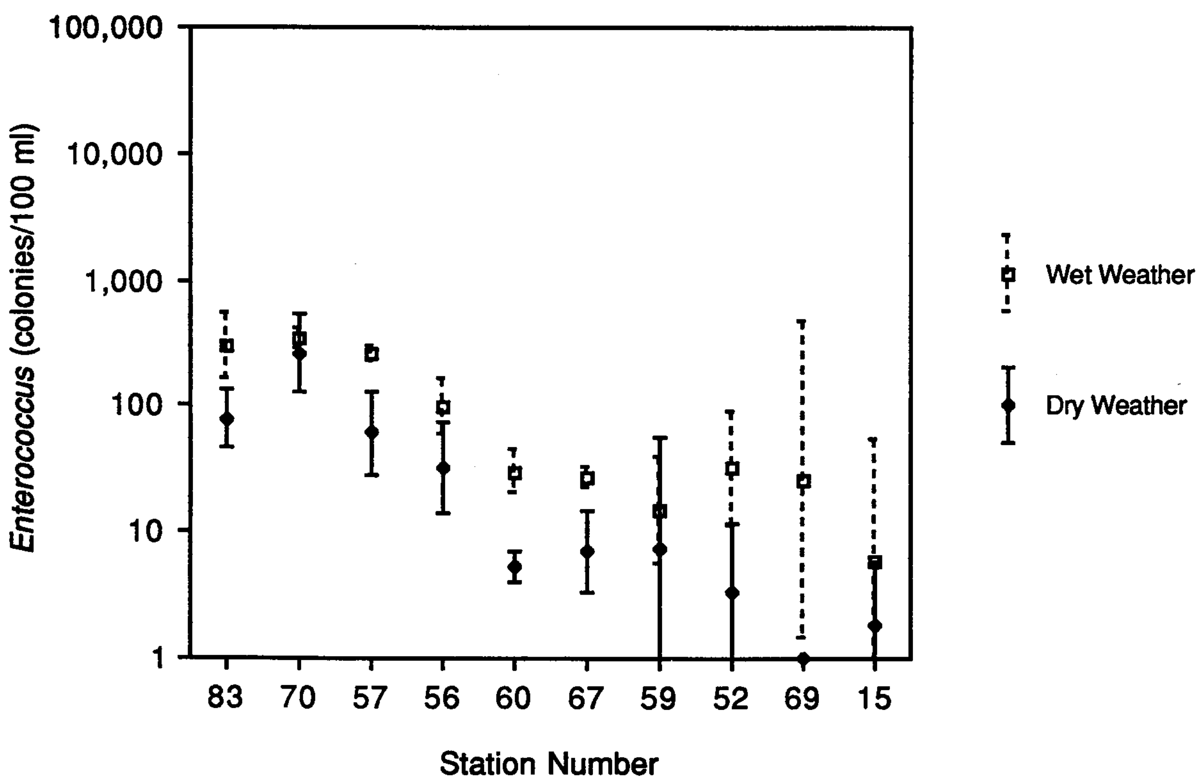


Figure 6.08. Geometric mean counts (col/100 ml) with 95% confidence intervals for *Enterococcus* under wet and dry weather conditions in the Mystic River and Alewife Brook, summer 1991.

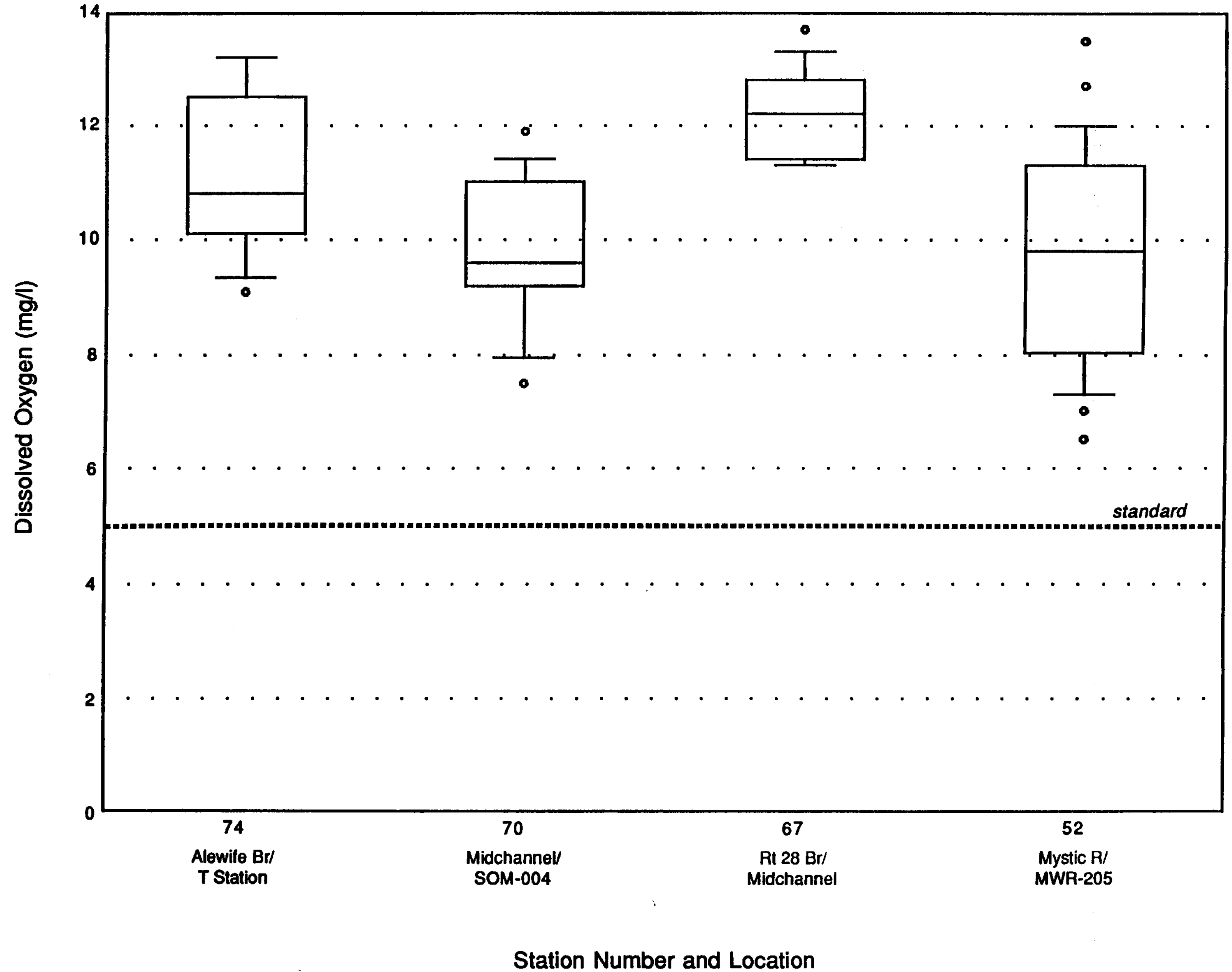


Figure 6.09. Percentile box plots of surface water dissolved oxygen levels in Alewife Brook and the Mystic River, winter 1990-1991.

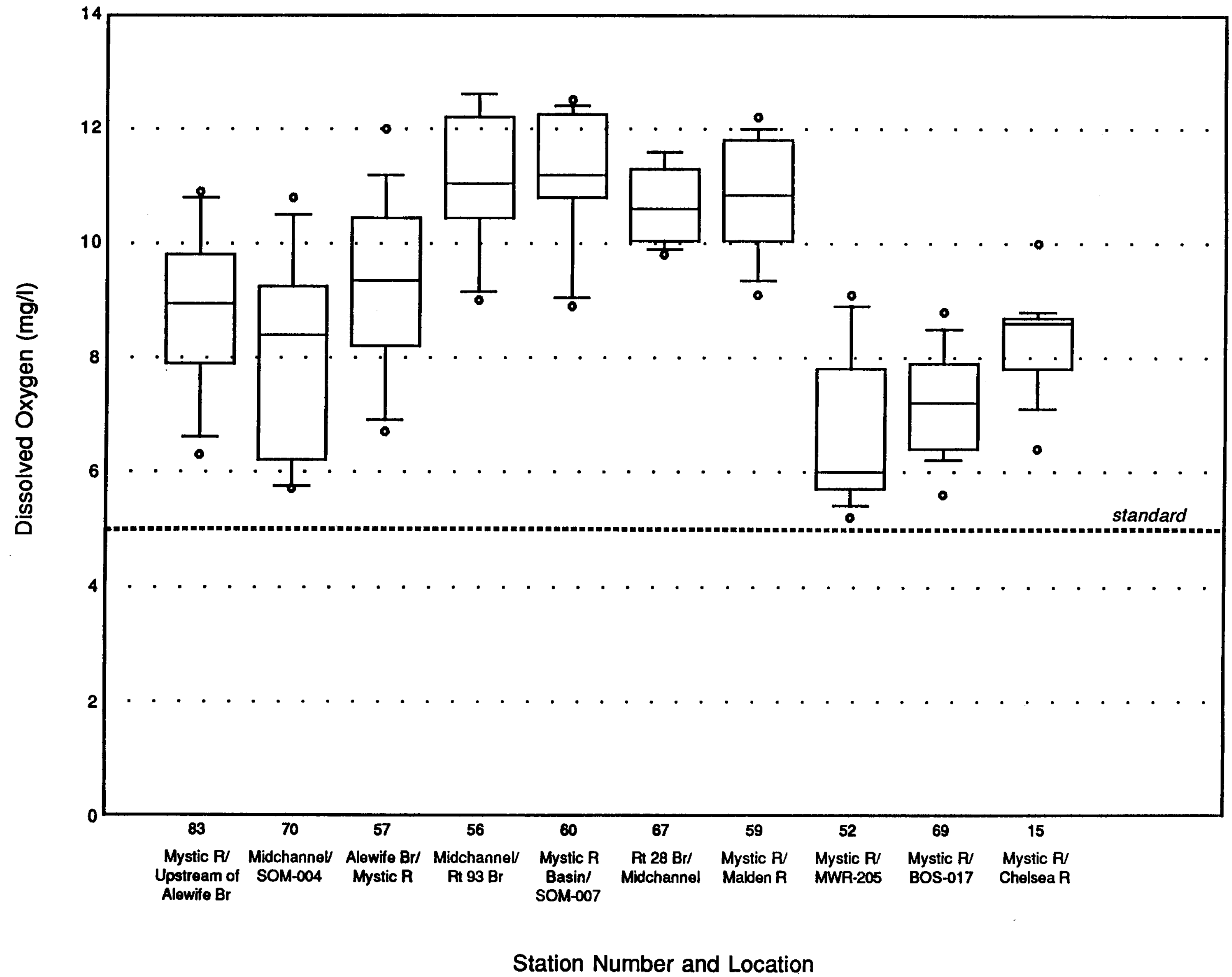


Figure 6.10. Percentile box plots of surface water dissolved oxygen levels in Alewife Brook and the Mystic River, summer 1991.

Bottom DO

Bottom DO was measured at only three stations (Stations 52, 69, and 15) because most of the Mystic River is less than 10 feet deep. Bottom DO levels were considerably lower than those at the surface. At Station 52, almost 50% of the bottom DO measurements were less than 5 mg/l, and at Station 69 approximately 25% of the measurements were below 5 mg/l.

6.1.e Relationship between Indicator Bacteria in the Mystic River and Flows from the Somerville Marginal CSO Treatment Facility (MWR-205)

The 1990-1991 sampling periods included three storm events for which receiving water samples were collected during or shortly after a discharge was recorded from the Somerville Marginal Facility. The results are shown in Table 6.02.

Table 6.02. Relationship between indicator bacteria in the Mystic River and flows from the Somerville Marginal Treatment Facility (MWR-205). Only those discharge events for which water samples were collected on the same day or the following day are shown.

			Fecal coliform (col/100 ml)	
Date	Rainfall (in.)	Flow from MWR-205 (M.G.)	Station 59 (Upstream)	Station 52 (Nearfield)
2/7/91	0.67	0.138	...	16,975*
6/30/91	0.71	0.035	...	...
7/1/91	0	0	108	55
7/13/91	0.52	1.3	100	425

* Count is mean of two samples.

Interestingly, for these few samples, the relationship between the amount of rain falling in a day and the corresponding volume of discharge from MWR-205 was not simple--the lowest amount of rain (7/13/91) was associated with the largest discharge, and the greatest amount of rain (6/30/91) was associated with the smallest discharge. The only dramatic effect on bacterial water quality was after the 2/7/91 discharge, when very high counts (along with odors, a visible plume, and sewage "floatables") were observed.

6.2 Discussion

6.2.a Trends by Geographic Area

Alewife Brook

Alewife Brook remains one of the most polluted streams in the greater Boston area, impacted by industrial pollution, contaminated stormwater, and CSOs.

Because previous work has well established that Alewife Brook is grossly impacted by sewage pollution, and because there has been little variation along the length of the brook (MDEP 1988; MWRA 1991e), during the 1990-1991 fall-winter we sampled only at Station 74 near the head of the brook, and Station 70 near the confluence with the Mystic River. During the summer of 1991, we sampled only at Station 70 in order to assess the impact of Alewife Brook on the Mystic River. The bacterial water quality at Station 70 was significantly poorer during the winter sampling period than during the summer sampling period, probably a reflection of the lesser amounts of rain falling during the summer period.

Mystic River, Freshwater Segment

In addition to the combined sewers in Alewife Brook, which drains into the Mystic River, there are four CSOs in the Mystic upstream of the Earhart Dam.

The spatial pattern of bacteria counts along this portion of the river was similar to that found during the summer 1990 monitoring (MWRA 1991e). During the summer of 1991, counts in the freshwater segment of the river were fairly similar at different locations (on the order of 10^1-10^2 fecal coliform /100 ml). The highest counts were in Alewife Brook in both 1990 and 1991. Counts found at Station 83, located upstream of all CSOs, were similar to counts found in locations potentially impacted by CSOs, indicating that "nonpoint sources" do contribute to bacterial pollution of the Mystic River.

6. Alewife Brook and the Mystic River

Both 1990 and 1991 results contrasted with the pattern found in the 1989 monitoring (MWRA 1991e) which was very high counts (on the order of 10^3-10^4 fecal coliform/100 ml) in Alewife Brook, with bacteria counts generally following a decreasing trend (10^2-10^3 fecal coliform/100 ml) in a downstream direction to the Earhart Dam.

Lower Mystic River, Marine Segment

Bacterial contamination of water downstream of the Earhart Dam is worse than on the upstream side of the dam, presumably reflecting the impact of discharges from MWR-205. On average, wet weather counts at Station 52 are similar to dry-weather counts. Although disinfection of wet weather discharges was generally effective in reducing the loading of fecal coliform to the river, dry weather sewage discharges, possibly a result of illegal discharges into the pipe downstream of the treatment facility, appeared to remain a problem.

6.2.b Comparison of Descriptive Results for Indicator Bacteria from 1991 with Previous Years

Geometric means and confidence intervals for indicator bacteria in 1991 (Table 6.01) were generally not significantly different from 1990, although geometric mean fecal coliform counts were significantly lower at Stations 15 and 56 in 1991.

6.3 Conclusions

- **Alewife Brook**

  Water quality did not come close to meeting standards in Alewife Brook; and pollution from Alewife Brook adversely affected the water quality of the upper portions of the Mystic River.

- **Mystic River**

  During wet weather, the segment of the Mystic River upstream of all CSOs exhibited high counts of fecal indicator bacteria. Stations remote from any known point source of sewage also showed high counts. Both observations imply that there were nonpoint sources to the Mystic, possibly contaminated storm drains. Nevertheless, most locations in the freshwater portion of the Mystic River met or almost met the class SB standard.

- **Somerville Marginal Treatment Facility**

Disinfection at the Somerville Marginal Facility effectively reduced the load of sewage bacteria to the Mystic River, but large sewage discharges can be associated with visually offensive plumes and "floatables," as well as odors. In addition, as noted in previous years, there appears to be a dry-weather source of sewage associated with the discharge pipe.

- **Interannual Comparisons**

Levels of sewage indicator bacteria were generally not significantly different in 1990-1991 from levels found in 1989-1990.

7. Constitution Beach

Monitoring during the summer of 1991 in the area near Constitution Beach was done to assess the effects of the CSO treatment facility and storm drains located near the beach. This area is relatively shallow (less than 10 ft deep) so all samples were collected at the surface.

7.1 Results

7.1.a Sampling Locations and Rainfall

Figure 7.01 shows the locations of the three stations sampled near Constitution Beach. Station 91 is located near a storm drain; Station 92 is directly offshore of the bathhouse; and Station 98 is closest to the outfall pipe for the Constitution Beach CSO Treatment Facility. This CSO facility discharges screened and chlorinated wet-weather flows into a marshy embayment approximately one-quarter mile from the beach area. Samples were collected on 13 days from August 12 through 30. During this time period, heavy rains occurred during and after Hurricane Bob (August 19-21) and light-to-moderate periods of rain occurred on August 9-10, 15, and 31.

7.1.b Indicator Bacteria Counts

The fecal coliform and *Enterococcus* counts found at each sampling station, together with rainfall measurements during the monitoring period, are in Table 7.01. Geometric mean counts at each station are in Table 7.02. Geometric mean counts for fecal coliform and *Enterococcus* were well within state standards. Although the geometric means were similar among stations, the ranges of counts varied among stations. The most contaminated samples were found at Station 91 the day after Hurricane Bob. Twenty-three percent of the samples (3 of 13) collected at Station 91 were above standards for fecal coliform and *Enterococcus*. At Station 92, only one sample (8% of total) was higher than the fecal coliform standard and one sample was higher than the recommended *Enterococcus* standard for beach closure. At Station 98, nearest the CSO facility, no samples were higher than the fecal coliform standard, and two samples exceeded recommended *Enterococcus* levels.

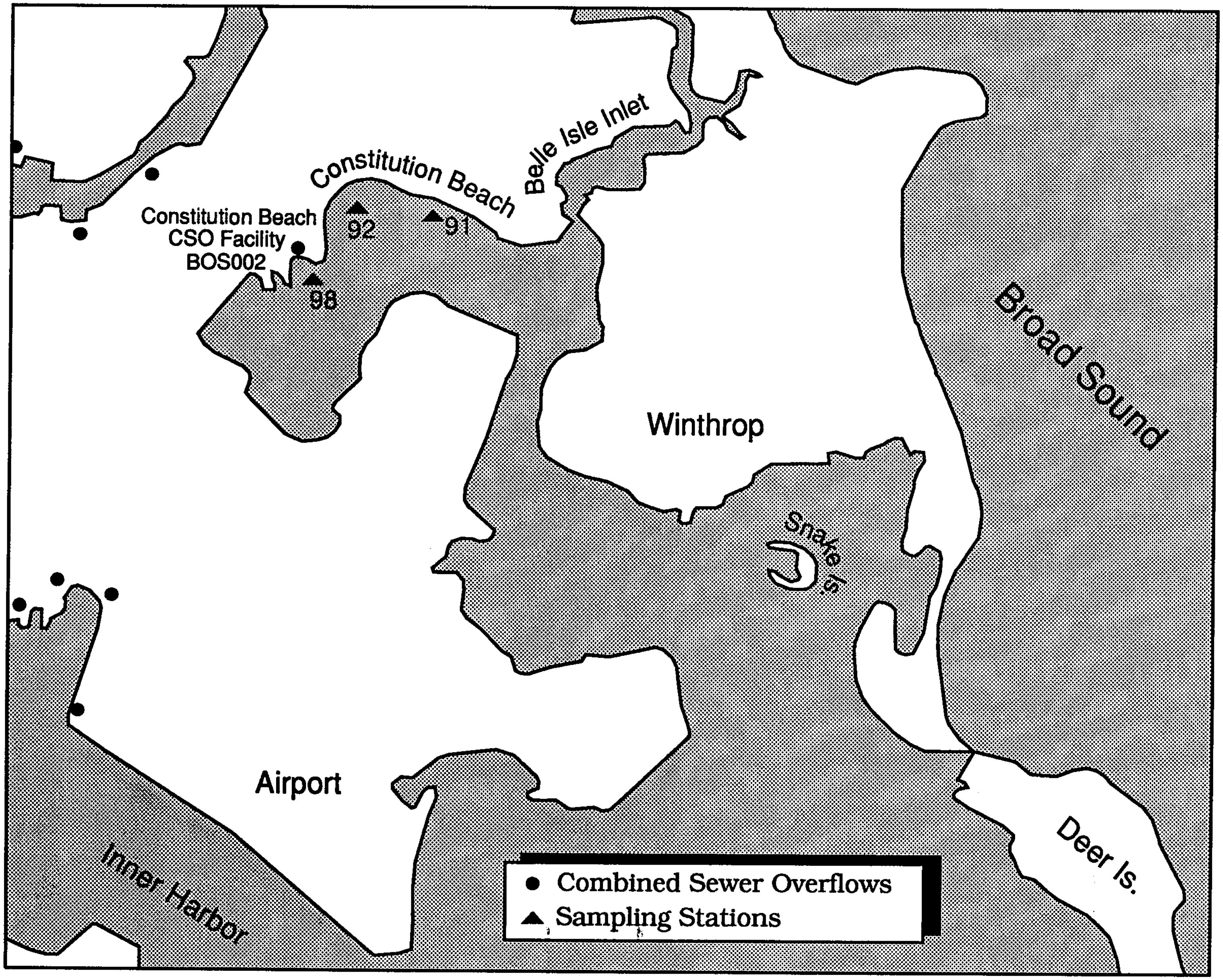


Figure 7.01. Stations sampled at Constitution Beach.

Table 7.01. Indicator bacteria counts and rainfall during Constitution Beach monitoring, August 1991.

		Indicator bacteria counts/100 ml water					
		Sta. 91		Sta. 92		Sta. 98	
Date	Rain (in.)	FC[1]	ENT[2]	FC	ENT	FC	ENT
August							
10	0.49	...	...	...	...	...	...
11	0	...	...	...	...	...	...
12	0	10	20	5	<5	5	<5
13	0	<5	<5	5	<5	40	10
14	0	30	5	20	<5	15	<5
15	0.06	25	<5	260	20	<5	10
16	0	380	<5	115	<5	25	10
17	0	320	125	5	10	10	<5
18	0	...	...	...	...	...	...
19	2.21	...	...	...	...	...	...
20	0.38	9050	2550	150	100	<5	150
21	1.72	...	...	...	...	...	...
22	0	35	30	20	<5	70	5
23	0	25	5	5	<5	40	5
24	0	...	...	...	...	...	...
25	0	...	...	...	...	...	...
26	0	5	<5	15	35	5	5
27	0	55	20	20	10	...	...
28	0	...	...	...	...	...	...
29	0	<5	<5	5	<5	<5	5
30	0.2	5	245	10	120	<5	135

[1]FC = Fecal coliform.
[2]ENT = *Enterococcus.*

Table 7.02. Geometric means (col/100 ml) with 95% confidence intervals (CI) for fecal coliform and *Enterococcus* counts at Constitution Beach stations, summer 1991.

Station No.	Station Location	Depth*	n	mean (CI)
Fecal Coliform				
91	Near storm drain	S	13	29 (7-117)
92	Near bathhouse	S	13	18 (8-39)
98	Near CSO	S	12	6 (2-17)
Enterococcus				
91	Near storm drain	S	13	10 (2-43)
92	Near bath house	S	13	4 (1-13)
98	Near CSO	S	7	12 (2-18)

*S = Surface sample.

7.1.c Relationship between Indicator Bacteria, Rainfall, and CSO Discharge

When all stations were considered as a group, there were significant correlations between indicator bacteria and rainfall. The rainfall variable showing the best correlations between log-transformed indicator bacteria counts and rain was rain summed over two days (for fecal coliform, $r = 0.34$, $p = 0.018$; for *Enterococcus*, $r = 0.45$, $p = 0.002$).

However, when the relationship between rainfall and indicator bacteria counts was examined at individual stations, only Station 91 showed significant correlations between indicator bacteria counts and rainfall. For log-transformed fecal coliform counts with rain summed over two days, $r = 0.61$, $p = 0.012$; and for log-transformed *Enterococcus* with rain summed over two days, $r = 0.62$, $p = 0.012$. Station 91 is the sampling location furthest from the CSO treatment facility, but closest to a storm drain.

The water quality in this area returned to "dry-weather" levels of indicator bacteria relatively rapidly: three days after a hurricane (and only one day after 1.72 in. of additional rain) the bacteria counts were at levels found before the storm.

At the time of the hurricane, the Constitution Beach CSO Treatment Facility reported discharging 1.585 million gallons of treated combined sewage, which was the only reported discharge from that facility for the month of August.

7.1.d Dissolved Oxygen

Daytime surface measurements of dissolved oxygen (DO) levels in the Constitution Beach area ranged from 4.5 mg/l to 11.5 mg/l. The lowest measurements, and the only measurements below the 5.0 mg/l minimum water quality standard, were found on August 22, after the 3-day period of rain associated with Hurricane Bob. The median value of DO was between 7 and 8 mg/l at all three sampling locations.

7.2 Discussion

Indicator bacteria counts at Constitution Beach were consistently within state swimming standards during dry weather, and elevated bacteria counts were associated with rain. Bacteria counts were very sensitive to rainfall: higher than normal counts were found even after very light rains (*e.g.*, on August 15, 16, and 17, after only 0.06 in. of rain fell on August 15). Although bacteria counts were elevated after only a small amount of rain, the effect of even heavy rains lasted a relatively short time. This suggests that the bacterial loadings from potential sources are relatively small and/or there is effective tidal flushing of the area.

A sampling study following a transect parallel to the beach (MWRA 1989, unpublished data) revealed that the storm drain emptying at the beach was a significant source of fecal coliform contamination. A subsequent investigation by the Boston Water and Sewer Commission found that the sanitary drains from many residences in the neighborhood were connected to the storm drain rather than to the sanitary sewer. These improper connections were repaired.

7. Constitution Beach

The operation of the CSO treatment facility, together with the elimination of many raw sewage discharges, resulted in the decline in bacteria levels and beach closings shown in Figure 7.02. This figure shows two statistics that reflect beach water quality--the proportion of samples collected during a bathing season that exceeded water quality standards, and the geometric mean of fecal coliform counts for samples. Both the levels of pollution and the number of days the beach was posted have decreased since 1989. The geometric means of fecal coliform counts measured over a three year period show the most dramatic reduction.

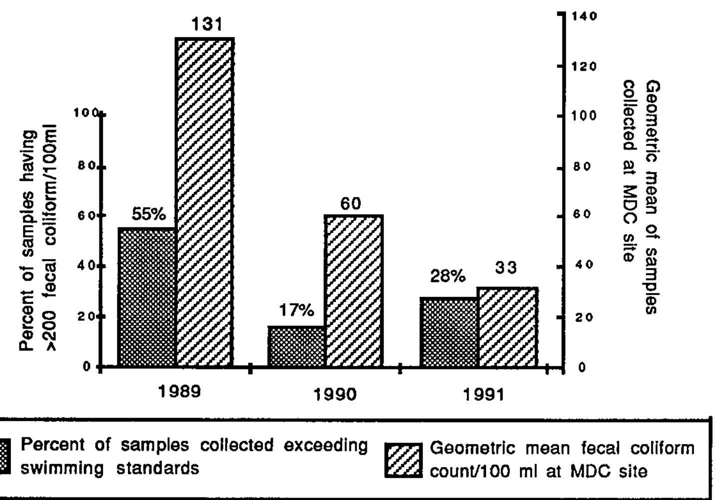


Figure 7.02. Geometric mean fecal coliform counts and the number of beach closings at Constitution Beach have declined since 1989, after the operation of the Constitution Beach CSO Treatment Facility, and the detection and correction of numerous illegal sewer discharges.

The 1991 CSO monitoring data showed that the highest counts and most significant relationship with rainfall were at Station 91. This is consistent with the storm drain as a source of wet-weather contamination to this area. Efforts to detect more potential illegal sewer connections are continuing, and should result in further decrease in contamination of the beach area.

8. Geographic Variation in Effects of CSOs

8.1 Relationship Between Rainfall and Bacteria Counts Compared among Different Areas

How CSOs (and in some cases, stormwater) affect the waters of Boston Harbor and its tributary rivers in different geographic areas have been described in the preceding sections. This section will compare how different areas are affected by CSOs. Because different water bodies were sampled at different times and varying weather conditions, directly comparing bacteria counts only gives a very approximate indication of the relative effects of CSOs. The effect of rain at different locations can be compared using the regression equations that were calculated for fecal coliform counts against three-day rainfall. We compared how different areas would respond to three different weather conditions: dry weather (0 in. of rain falling over three days), moderate rain (1 in. of rain falling over three days), and heavy rain (3 in. of rain falling over three days). Only regressions for locations that were highly significant ($p < 0.01$) were used in this analysis. Table 8.01 shows how the highly significant linear regression analyses presented in the preceding sections of this report compare in relating rain among several different areas to fecal coliform counts in the water.

Table 8.01. Comparing regressions shows the effect of rain on fecal coliform counts at different areas in Boston Harbor and the Charles River.

	Calculated fecal coliform count (colonies/100 ml)[a]				
Three-day summed rain (in.)	Mouth of Fort Point Channel Sta. 18	Mouth of Inner Harbor Sta. 24	Northern Dorchester Bay Sta. 44	Charles River Upstream Sta. 1	Charles River Basin Sta. 7
0[b]	130	6	3	400	1,000
1	830	35	15	1,100	2,700
3	36,000	1,100	290	9,500	19,000

[a] Linear regression analyses used data collected in 1991. See pages 3-17, 3-19, 3-27, and 5-15 for equations. The above table includes results of highly statistically significant analyses ($p < 0.01$).

[b] "0 inches of rain" is equivalent to background, or dry weather conditions.

8. Geographic Variation in Effects of CSOs

Assuming that rain-related sewage pollution in Boston Harbor and its tributary rivers is primarily caused by CSOs, Table 8.01 shows that CSOs have a strong effect in some areas of the harbor, and less effect in other areas.

8.1.a. Areas where CSOs Have the Most Significant Impacts on Water Quality

Inner Harbor

The inner harbor is the area of Boston Harbor most severely degraded by CSOs. Figure 8.01 is a pie chart showing the estimated CSO flows from different sources in 1991. Virtually all untreated CSO flows are discharged into the inner harbor (from the Roxbury Conduit and "Other"). The Roxbury Conduit plus "other" CSOs comprise almost 36% of the total CSO flow in the greater Boston area. The single largest source of untreated CSOs in the greater Boston area is the Roxbury Conduit, which discharges at the head of Fort Point Channel (see Figure 3.01, page 3-2) through BOS-070. Fort Point Channel shows severe effects of CSOs, with one inch of rain predicted to cause fecal coliform counts substantially higher than the 200 col/100 ml standard. Counts at the mouth of the channel (Station 18, Figure 3.01), 2 km distant from the pipe, can exceed 100,000 fecal coliform/100 ml. In addition to sewage bacteria, aesthetically offensive floating debris contaminates the water after a major overflow.

Although Fort Point Channel is the area in the inner harbor most severely affected by CSOs, regression analysis shows that even at a point in the inner harbor relatively distant from large CSOs (Station 24 at the mouth of the inner harbor, Figure 3.01), there was a highly significant relationship between rainfall and fecal coliform levels in the water. Here, however, a one-inch rainstorm is not predicted to cause fecal coliform counts to exceed the standard.

Another area of the inner harbor affected by CSOs is near the Somerville Marginal outfall. Discharges are screened and disinfected, but still cause slicks, odors and contain sewage floatables. The nearby waters also show severe oxygen depletion. Although dry-weather overflows have not been recorded, there appear to be source(s) of sewage downstream of the CSO facility which cause a chronic elevation in bacteria levels.

1991 Total Estimated Flows = 1692 MG

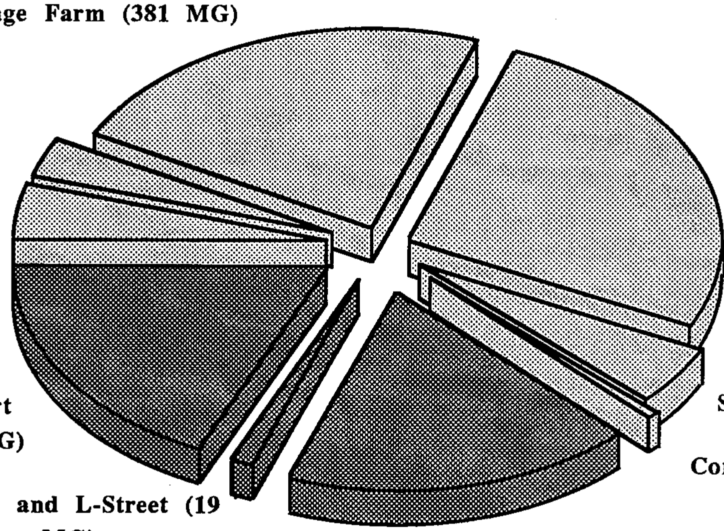


Figure 8.01. Total estimated CSO flows from most of the CSOs in greater Boston in 1991. Flow volumes from Carson and L-Street's seven outfalls, the Roxbury Conduit, the Commercial Point CSO Facility, the Fox Point CSO Facility, and "other" CSOs are from BWSC modeled estimates (BWSC 1992). Flow volumes from Cottage Farm, Somerville Marginal, Constitution Beach, and Prison Point Treatment Facilities are from MWRA's direct measurements. CSOs owned by Cambridge, Somerville, and Chelsea are not included in this chart, and would add an additional 10-15% to the total flow. The flow of Stony Brook, which discharges to the Charles River, is not included.

The more deeply shaded sections of the pie chart represent untreated CSOs. The lightly shaded sections represent sources that are screened and disinfected before discharge.

Charles River Basin

The Charles River receives combined sewage from two major sources--the Stony Brook and the Cottage Farm CSO Treatment Facility--as well as several small CSOs. (The Stony Brook also receives a significant amount of stormwater.) A large proportion (22% in 1991) of the total CSO flow in the greater Boston area is discharged into the Charles River by the Cottage Farm Facility. The flows are screened and chlorinated after a brief settling period. Because these discharges are generally effectively disinfected, the elevated sewage indicator bacteria counts in the river after rainstorms (Table 8.01) are not usually attributable to this source.

The Stony Brook, which receives CSOs from several sources before discharging into the Charles River through MWR-023, is a significant source of contamination to the Charles. Combined sewage can make up approximately 5-10% of the flow of the Stony Brook, contributing to the significant regression between rain and fecal coliform counts in the water shown in Table 8.01. Bacterial water quality in the lower Charles River is among the poorest in the greater Boston area. Figure 5.05 shows that 75-95% of the samples collected in the Basin exceeded fecal coliform standards. This area is heavily used for boating and sailboarding activities entailing infrequent to moderate exposure to the water.

CSOs are not the only source of contamination to the Charles. Upstream sources (see Table 8.01, Charles River upstream) and contaminated storm sewers have been found to contribute to the problem. However, the Cottage Farm Facility ia a major contributor to aesthetic degradation in the river, and a major overflow from Cottage Farm can contribute enough BOD to significantly exacerbate depressed dissolved oxygen levels in the Charles.

Southern Dorchester Bay

Data from southern Dorchester Bay did not yield a highly significant regression of fecal coliform counts against rainfall. Almost all of the combined sewage discharged into this areas is now screened and disinfected at the Fox Point and Commercial Point CSO Facilities. Bacterial water quality at nearby bathing beaches (Tenean and Malibu) has dramatically improved as a result (see Table 4.07 and Figure 4.13). Flows from these two facilities comprised about 8% of the total CSO flow in 1991. Despite these important improvements, these CSOs remain an aesthetic problem. Both are located in shallow nearshore recreational areas, and discharges produce obvious and unsightly slicks and odors, and can contain small floatables (condoms, toilet paper, tampon applicators) which can sometimes pass through the screens.

Bacterial contamination from the Neponset River, BOS-088 in Malibu Bay, contaminated storm drains and dry weather sources still contribute to beach pollution in southern Dorchester Bay (see Figure 4.05).

8.1.b. Moderately Affected: Northern Dorchester Bay

Approximately 1% of the total CSO volume discharged in the greater Boston area in 1991 flowed into Northern Dorchester Bay from seven CSOs located along Carson and L-Street beaches. Because these CSOs overflowed relatively rarely, water quality at these South Boston beaches was usually well within swimming standards. Figure 4.03 shows that almost 90% of the samples collected were within water quality standards. The CSOs in the inner harbor appeared to have a minimal effect on Dorchester Bay. These observations are in agreement with recent modelling predictions (Adams and Zhang 1991).

Although CSOs occur here with low frequency and volume, discharges are completely untreated and occur near beaches. Occasional high counts (> 1,000 col/100 ml) occur, and shellfishing is prohibited.

8.2. Summary

Recent pollution abatement measures have been very effective, particularly those aimed at improving water quality at Boston Harbor beaches--such as construction of CSO control facilities. Average bacteria counts measured at beaches and beach postings have dramatically declined since 1989 (MDC 1989, 1990, 1991).

Screening and disinfection facilities are reducing pollution from sewage bacteria and sewage floatables. However, discharges from these facilities are often aesthetically offensive, especially near the Cottage Farm outfall in the Charles River, the Fox Point and Commercial Point outfalls in southern Dorchester Bay, and near the Somerville Marginal outfall in the lower Mystic River. In addition to aesthetic problems, discharges from two treatment facilities, Cottage Farm and Somerville Marginal, can cause oxygen depletion in the receiving waters.

While CSOs clearly cause most of the sewage bacteria pollution problems in the inner harbor, bacterial water quality problems in all of the rivers are also caused by other sources, *e.g.* stormwater. Upstream monitoring in the Neponset River showed that there are numerous sources of sewage along the length of the river, and pollution from the river probably has impacts on southern Dorchester Bay.

Improved operations of the sewage treatment plants on Deer and Nut Islands have decreased pollution offshore, and fast-track improvements to the sewerage system have decreased the number and volume of CSOs. However, many areas of the harbor and its tributary rivers remain degraded by CSOs, with the degree of impact on water quality varying greatly among different geographic areas.

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A. Appendix: Raw Data

Table A.01. **Rainfall measured by National Weather Service at Logan Airport during 1991 Monitoring: October 1, 1990 - September 30, 1991.**

Date	Rain(in.)	Date	Rain(in.)	Date	Rain(in.)	Date	Rain(in.)
01-Oct	0.00	22-Nov	0.00	13-Jan	0.00	06-Mar	0.00
02-Oct	0.00	23-Nov	0.09	14-Jan	0.00	07-Mar	0.31
03-Oct	0.00	24-Nov	0.06	15-Jan	0.00	08-Mar	0.00
04-Oct	0.47	25-Nov	0.00	16-Jan	0.79	09-Mar	0.00
05-Oct	0.00	26-Nov	0.00	17-Jan	0.25	10-Mar	0.01
06-Oct	0.00	27-Nov	0.00	18-Jan	0.00	11-Mar	0.02
07-Oct	0.00	28-Nov	0.00	19-Jan	0.00	12-Mar	0.00
08-Oct	0.00	29-Nov	0.04	20-Jan	0.00	13-Mar	0.00
09-Oct	0.08	30-Nov	0.00	21-Jan	0.20	14-Mar	0.17
10-Oct	0.01	01-Dec	0.00	22-Jan	0.00	15-Mar	0.15
11-Oct	0.01	02-Dec	0.00	23-Jan	0.00	16-Mar	0.00
12-Oct	0.00	03-Dec	0.00	24-Jan	0.00	17-Mar	0.00
13-Oct	0.57	04-Dec	1.07	25-Jan	0.00	18-Mar	0.08
14-Oct	3.34	05-Dec	0.00	26-Jan	0.00	19-Mar	0.12
15-Oct	0.00	06-Dec	0.00	27-Jan	0.01	20-Mar	0.00
16-Oct	0.00	07-Dec	0.00	28-Jan	0.04	21-Mar	0.00
17-Oct	0.00	08-Dec	0.06	29-Jan	0.00	22-Mar	0.40
18-Oct	0.70	09-Dec	0.00	30-Jan	0.14	23-Mar	0.66
19-Oct	0.51	10-Dec	0.00	31-Jan	0.25	24-Mar	0.12
20-Oct	0.00	11-Dec	0.00	01-Feb	0.00	25-Mar	0.01
21-Oct	0.00	12-Dec	0.00	02-Feb	0.00	26-Mar	0.00
22-Oct	0.00	13-Dec	0.00	03-Feb	0.00	27-Mar	0.03
23-Oct	0.68	14-Dec	0.00	04-Feb	0.00	28-Mar	0.00
24-Oct	0.62	15-Dec	0.42	05-Feb	0.00	29-Mar	0.05
25-Oct	0.00	16-Dec	0.26	06-Feb	0.00	30-Mar	0.32
26-Oct	0.04	17-Dec	0.00	07-Feb	0.67	31-Mar	0.00
27-Oct	0.00	18-Dec	0.21	08-Feb	0.00	01-Apr	0.01
28-Oct	0.33	19-Dec	0.00	09-Feb	0.00	02-Apr	0.14
29-Oct	0.00	20-Dec	0.00	10-Feb	0.00	03-Apr	0.00
30-Oct	0.00	21-Dec	0.05	11-Feb	0.00	04-Apr	0.00
31-Oct	0.00	22-Dec	0.05	12-Feb	0.00	05-Apr	0.00
01-Nov	0.00	23-Dec	0.05	13-Feb	0.05	06-Apr	0.00
02-Nov	0.00	24-Dec	0.44	14-Feb	0.48	07-Apr	0.00
03-Nov	0.00	25-Dec	0.00	15-Feb	0.06	08-Apr	0.00
04-Nov	0.00	26-Dec	0.00	16-Feb	0.00	09-Apr	0.00
05-Nov	0.00	27-Dec	0.00	17-Feb	0.00	10-Apr	0.00
06-Nov	0.57	28-Dec	0.40	18-Feb	0.01	11-Apr	0.00
07-Nov	0.00	29-Dec	0.01	19-Feb	0.23	12-Apr	0.00
08-Nov	0.03	30-Dec	0.11	20-Feb	0.00	13-Apr	0.00
09-Nov	0.00	31-Dec	0.05	21-Feb	0.00	14-Apr	0.00
10-Nov	0.56	01-Jan	0.00	22-Feb	0.00	15-Apr	0.29
11-Nov	0.01	02-Jan	0.00	23-Feb	0.00	16-Apr	0.00
12-Nov	0.00	03-Jan	0.00	24-Feb	0.00	17-Apr	0.01
13-Nov	0.00	04-Jan	0.00	25-Feb	0.00	18-Apr	0.00
14-Nov	0.00	05-Jan	0.00	26-Feb	0.04	19-Apr	0.00
15-Nov	0.00	06-Jan	0.00	27-Feb	0.04	20-Apr	0.00
16-Nov	0.00	07-Jan	0.00	28-Feb	0.00	21-Apr	3.32
17-Nov	0.02	08-Jan	0.01	01-Mar	0.00	22-Apr	0.03
18-Nov	0.01	09-Jan	0.40	02-Mar	0.30	23-Apr	0.00
19-Nov	0.00	10-Jan	0.00	03-Mar	0.15	24-Apr	0.00
20-Nov	0.00	11-Jan	0.23	04-Mar	1.43	25-Apr	0.00
21-Nov	0.00	12-Jan	0.92	05-Mar	0.00	26-Apr	0.00

Table A.01, Continued.

Date	Rain(in.)	Date	Rain(in.)	Date	Rain(in.)	Date	Rain(in.)
27-Apr	0.03	18-Jun	0.00	09-Aug	0.05	30-Sep	0.00
28-Apr	0.00	19-Jun	0.13	10-Aug	0.49		
29-Apr	0.00	20-Jun	0.00	11-Aug	0.00		
30-Apr	1.01	21-Jun	0.00	12-Aug	0.00		
01-May	0.00	22-Jun	0.03	13-Aug	0.00		
02-May	0.00	23-Jun	0.00	14-Aug	0.00		
03-May	0.00	24-Jun	0.00	15-Aug	0.06		
04-May	0.00	25-Jun	0.00	16-Aug	0.00		
05-May	0.00	26-Jun	0.00	17-Aug	0.00		
06-May	0.30	27-Jun	0.00	18-Aug	0.00		
07-May	0.00	28-Jun	0.00	19-Aug	2.21		
08-May	0.00	29-Jun	0.00	20-Aug	0.38		
09-May	0.00	30-Jun	0.71	21-Aug	1.72		
10-May	0.00	01-Jul	0.00	22-Aug	0.00		
11-May	0.00	02-Jul	0.00	23-Aug	0.00		
12-May	0.00	03-Jul	0.00	24-Aug	0.00		
13-May	0.00	04-Jul	0.00	25-Aug	0.00		
14-May	0.00	05-Jul	0.02	26-Aug	0.00		
15-May	0.00	06-Jul	0.00	27-Aug	0.00		
16-May	0.00	07-Jul	0.09	28-Aug	0.00		
17-May	0.38	08-Jul	0.00	29-Aug	0.00		
18-May	0.02	09-Jul	0.00	30-Aug	0.00		
19-May	0.00	10-Jul	0.00	31-Aug	0.20		
20-May	0.00	11-Jul	0.00	01-Sep	0.00		
21-May	0.00	12-Jul	0.00	02-Sep	0.00		
22-May	0.00	13-Jul	0.52	03-Sep	0.00		
23-May	0.00	14-Jul	0.00	04-Sep	0.00		
24-May	0.00	15-Jul	0.00	05-Sep	0.89		
25-May	0.00	16-Jul	0.00	06-Sep	0.00		
26-May	0.00	17-Jul	0.00	07-Sep	0.00		
27-May	0.11	18-Jul	0.00	08-Sep	0.00		
28-May	0.01	19-Jul	0.00	09-Sep	0.00		
29-May	0.05	20-Jul	0.00	10-Sep	0.00		
30-May	0.03	21-Jul	0.00	11-Sep	0.00		
31-May	0.02	22-Jul	0.00	12-Sep	0.00		
01-Jun	0.00	23-Jul	0.15	13-Sep	0.00		
02-Jun	0.00	24-Jul	0.00	14-Sep	0.05		
03-Jun	0.10	25-Jul	0.00	15-Sep	0.12		
04-Jun	0.36	26-Jul	0.86	16-Sep	0.00		
05-Jun	0.07	27-Jul	0.31	17-Sep	0.00		
06-Jun	0.00	28-Jul	0.00	18-Sep	0.00		
07-Jun	0.00	29-Jul	0.00	19-Sep	0.77		
08-Jun	0.00	30-Jul	0.00	20-Sep	0.68		
09-Jun	0.00	31-Jul	0.00	21-Sep	0.00		
10-Jun	0.00	01-Aug	0.00	22-Sep	0.00		
11-Jun	0.11	02-Aug	0.00	23-Sep	0.15		
12-Jun	0.42	03-Aug	0.11	24-Sep	0.05		
13-Jun	0.00	04-Aug	0.05	25-Sep	2.42		
14-Jun	0.00	05-Aug	0.00	26-Sep	1.19		
15-Jun	0.70	06-Aug	0.00	27-Sep	0.00		
16-Jun	0.26	07-Aug	0.00	28-Sep	0.00		
17-Jun	0.00	08-Aug	0.00	29-Sep	0.00		

Table A.02. Key to Abbreviations in Raw Data Tables

Site	Station Number
Samnum	Sample Number
Tide	State of the tide when sample taken. The code used is as follows: 1 High Slack Tide 2 High Ebb Tide 3 Low Ebb Tide 4 Low Slack Tide 5 Low Flood Tide 6 High Flood Tide 9 Freshwater above tidal influence
DS	Depth Sampled (Feet)
Temp	Temperature (Degrees Celsius)
Cond	Conductivity (micromhos)
DO	Dissolved Oxygen (mg/l)
F. Colif.	Fecal Coliform colony counts/100 ml (average of duplicate laboratory filtrations)
Entero.	*Enterococcus* colony counts/100 ml (average of duplicate laboratory filtrations)

Table A.03 Raw Data from MWRA 1991 CSO Receiving Water Monitoring

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
22-Oct-1990										
	1	3241	9	0	13.5	120	0.0	10.2	428	505
	10	3232	9	0	14.5	165	0.0	7.4	900	718
	11	3231	9	0	15.1	290	0.0	6.7	693	605
	14	3230	5	0	14.9	20,000	16.0	6.5	748	338
	14	3229	5	38	12.5	35,000	30.0	6.9	15	35
	2	3240	9	0	13.1	120	0.0	9.9	313	565
	3	3239	9	0	13.1	125	0.0	9.6	725	2,725
	4	3238	9	0	13.5	120	0.0	9.5	1,375	2,400
	5	3237	9	0	13.6	120	0.0	9.5	2,275	1,263
	6	3236	9	0	13.7	120	0.0	9.5	1,700	825
	7	3235	9	0	14.3	130	0.0	8.1	440	343
	8	3234	9	0	14.5	145	0.0	7.8	2,100	1,080
	9	3233	9	0	14.8	186	0.0	7.1	690	635
23-Oct	1	3254	9	0	13.8	130	0.0	10.2	465	743
	10	3245	9	0	15	180	0.0	7.3	663	243
	11	3244	9	0	15.1	260	0.0	6.9	3,580	148
	14	3243	5	0	14.7	22,500	17.0	6.4	455	3,025
	14	3242	5	34	12.1	35,000	30.0	6.5	8	33
	2	3253	9	0	13.8	135	0.0	9.9	908	905
	3	3252	9	0	13.7	130	0.0	9.7	438	495
	4	3251	9	0	13.8	135	0.0	9.4	1,475	1,400
	5	3250	9	0	14	135	0.0	9.9	1,000	975
	6	3249	9	0	13.9	135	0.0	9.3	1,045	410
	7	3248	9	0	14.4	155	0.0	8.2	5,200	1,375
	8	3247	9	0	14.7	150	0.0	8.1	1,925	323
	9	3246	9	0	14.9	170	0.0	7.6	8,550	335
24-Oct	1	3267	9	0	13.8	180	0.0	10.1	3,150	4,925
	10	3258	9	0	14.5	200	0.0	8.0	1,000	400
	11	3257	9	0	14.6	210	0.5	7.8	933	280
	14	3256	5	0	14.3	24,000	17.5	7.1	978	2,900
	14	3255	5	35	11.9	35,700	30.8	6.3	23	65
	2	3266	9	0	13.8	170	0.0	9.8	3,950	6,525
	3	3265	9	0	14	190	0.0	9.7	3,550	6,825
	4	3264	9	0	14.1	190	0.0	9.5	3,875	7,775
	5	3263	9	0	14.1	190	0.0	9.5	3,500	7,275
	6	3262	9	0	14.1	190	0.0	9.4	3,600	6,950
	7	3261	9	0	14.3	200	0.0	9.5	3,850	3,450
	8	3260	9	0	14.4	200	0.0	8.6	10,875	9,275
	9	3259	9	0	14.9	200	0.0	8.7	4,425	1,025
25-Oct	1	3280	9	0	13.4	140	0.0	10.1	1,850	925
	10	3271	9	0	14.5	165	0.0	8.1	1,175	1,050
	11	3270	9	0	14.4	218	0.0	7.8	1,100	613
	14	3269	5	0	13.7	25,300	20.0	6.7	840	395
	14	3268	5	34	11.9	34,900	29.0	6.1	23	10
	2	3279	9	0	13.4	142	0.0	9.9	1,400	1,800
	3	3278	9	0	13.5	139	0.0	9.5	1,725	1,150
	4	3277	9	0	13.6	138	0.0	9.3	2,175	1,875
	5	3276	9	0	13.9	135	0.0	9.3	1,900	1,325
	6	3275	9	0	14	135	0.0	9.2	2,025	2,075
	7	3274	9	0	14.2	148	0.0	8.2	1,475	975
	8	3273	9	0	14.3	151	0.0	8.2	1,825	1,125
	9	3272	9	0	14.3	149	0.0	8.4	2,775	2,200

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
29-Oct	11	3284	9	0	11.4	160	0.5	8.3	833	355
	18	3283	3	0	12.8	33,100	27.2	5.6	16,025	5,100
	18	3282	3	8	13.3	34,900	30.0	5.3	80	175
	75	3281	3	0	13.9	32,900	26.5	2.8	18,425	9,500
	89	3285	3	0	12.9	13,000	10.5	4.1	69,100	90,200
30-Oct	1	3298	9	0	8.3	122	0.0	10.8	695	303
	10	3289	9	0	10.4	180	0.0	8.6	1,250	710
	11	3288	9	0	10.4	290	0.0	8.4	6,125	615
	14	3287	2	0	10.6	27,000	23.5	7.4	673	1,073
	14	3286	2	39	10.8	34,200	30.3	7.0	8	5
	2	3297	9	0	8.1	123	0.0	10.6	675	490
	3	3296	9	0	8.1	125	0.0	10.3	4,350	688
	4	3295	9	0	8.6	128	0.0	10.2	1,128	788
	5	3294	9	0	8.9	129	0.0	9.9	1,750	750
	6	3293	9	0	8.4	128	0.0	10.0	885	678
	7	3292	9	0	9.4	138	0.0	9.6	1,700	1,525
	8	3291	9	0	10.1	160	0.0	8.8	1,625	810
	9	3290	9	0	9.8	162	0.0	9.2	1,475	900
31-Oct	1	3311	9	0	8.5	120	0.0	11.8	550	298
	10	3302	9	0	9.7	155	0.0	9.7	923	43
	11	3301	9	0	10	310	0.0	9.5	795	793
	14	3300	2	0	11.4	29,000	24.5	7.4	250	130
	14	3299	2	34	10.7	34,000	29.0	7.5	8	3
	2	3310	9	0	8.2	120	0.0	11.5	985	480
	3	3309	9	0	8.2	120	0.0	11.5	1,150	565
	4	3308	9	0	8.3	121	0.0	11.4	2,050	900
	5	3307	9	0	8.5	121	0.0	11.6	1,900	638
	6	3306	9	0	8.2	120	0.0	11.3	1,013	568
	7	3305	9	0	8.7	128	0.0	10.6	848	810
	8	3304	9	0	9.1	145	0.0	10.1	6,850	308
	9	3303	9	0	9.7	150	0.0	9.8	1,230	983
01-Nov	1	3324	9	0	8.8	129	0.0	12.0	440	238
	10	3315	9	0	10.3	161	0.0	9.8	850	328
	11	3314	9	0	10	214	0.0	9.4	648	308
	14	3313	2	0	11.1	27,200	27.5	7.6	210	88
	14	3312	2	42	10.4	34,700	29.5	7.6	28	5
	2	3323	9	0	8.2	129	0.0	11.7	645	378
	3	3322	9	0	8.9	129	0.0	11.5	843	625
	4	3321	9	0	9.3	130	0.0	11.2	1,378	878
	5	3320	9	0	9.2	130	0.0	11.4	1,470	575
	6	3319	9	0	8.9	130	0.0	11.4	1,950	513
	7	3318	9	0	8.9	139	0.0	10.6	968	360
	8	3317	9	0	10.4	149	0.0	10.5	1,475	455
	9	3316	9	0	9.7	151	0.0	10.2	1,450	568
05-Nov	1	3337	9	0	10.7	142	0.0	10.9	225	238
	10	3328	9	0	10.6	160	0.0	10.4	1,283	915
	11	3327	9	0	10.2	290	0.0	10.1	863	590
	14	3326	.	0	10.8	22,000	22.1	8.4	463	218
	14	3325	.	41	10.9	33,900	29.5	7.8	40	65
	2	3336	9	0	10.5	148	0.0	10.6	610	493
	3	3335	9	0	10.6	148	0.0	10.5	2,225	575
	4	3334	9	0	10.7	148	0.0	11.5	1,525	1,578
	5	3333	9	0	10.5	145	0.0	10.6	2,050	1,483

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
05-Nov	6	3332	9	0	10.5	145	0.0	10.5	2,350	1,580
	7	3331	9	0	10.2	141	0.0	10.3	528	633
	8	3330	9	0	11.6	148	0.0	12.3	58	533
	9	3329	9	0	10.5	159	0.0	10.8	2,350	1,543
06-Nov	1	3350	9	0	11	135	0.0	10.9	6,700	11,250
	10	3341	9	0	10.2	160	0.0	10.6	1,050	400
	11	3340	9	0	10.3	315	0.0	10.3	650	425
	14	3339	.	0	11.1	16,000	19.0	8.6	25	75
	14	3338	.	41	10.9	33,800	29.8	7.5	0	0
	2	3349	9	0	10.7	145	0.0	10.9	2,500	3,100
	3	3348	9	0	10.5	158	0.0	10.7	3,775	2,150
	4	3347	9	0	10.6	152	0.0	10.7	2,125	825
	5	3346	9	0	10.6	151	0.0	10.6	2,750	3,000
	6	3345	9	0	10.9	152	0.0	10.5	1,350	1,175
	7	3344	9	0	10.8	159	0.0	10.5	2,450	1,250
	8	3343	9	0	11	170	0.0	10.5	8,800	7,175
	9	3342	9	0	10.3	170	0.0	12.0	2,525	1,175
07-Nov	1	3363	9	0	9.8	145	0.0	10.7	158	90
	10	3354	9	0	9.9	190	0.0	9.7	303	238
	11	3353	9	0	10.2	360	0.0	9.4	288	203
	14	3352	.	0	10.6	15,000	27.0	7.6	245	158
	14	3351	.	36	11	33,500	30.0	7.4	10	23
	2	3362	9	0	9.3	150	0.0	10.2	115	255
	3	3361	9	0	9.4	145	0.0	10.1	160	175
	4	3360	9	0	10.1	140	0.0	9.6	408	658
	5	3359	9	0	10.1	140	0.0	9.4	363	448
	6	3358	9	0	9.9	150	0.0	9.5	265	420
	7	3357	9	0	9.8	160	0.0	9.6	150	163
	8	3356	9	0	10.1	165	0.0	9.7	258	248
	9	3355	9	0	9.8	170	0.0	9.7	345	278
08-Nov	1	3376	9	0	9.1	151	0.0	11.4	1,450	350
	10	3367	9	0	9.5	173	0.0	10.2	2,500	1,150
	11	3366	9	0	9.7	292	0.0	10.0	1,575	875
	14	3365	.	0	10.6	18,900	15.0	8.8	1,173	595
	14	3364	.	34	10.7	33,500	29.3	8.0	8	8
	2	3375	9	0	8.8	149	0.0	11.0	3,125	700
	3	3374	9	0	8.9	149	0.0	10.9	4,425	900
	4	3373	9	0	8.8	150	0.0	11.2	3,225	1,025
	5	3372	9	0	8.8	149	0.0	10.8	2,875	1,625
	6	3371	9	0	9.1	149	0.0	10.4	2,400	1,225
	7	3370	9	0	9.6	150	0.0	10.0	4,125	1,425
	8	3369	9	0	9.4	160	0.0	10.1	1,775	1,500
	9	3368	9	0	9.6	170	0.0	10.2	2,475	2,050
14-Nov	11	3384	9	0	6.1	210	0.0	10.4	943	960
	12	3385	9	0	3.8	120	0.0	12.8	245	240
	18	3381	2	0	8.8	31,200	28.6	7.6	195	45
	18	3380	2	31	8.6	32,000	29.8	8.2	15	813
	19.1	3383	2	0	8.8	31,000	28.0	7.6	148	33
	19.1	3382	2	21	8.4	32,000	29.5	8.2	18	20
	55	3378	9	0	3.1	120	0.0	13.4	1,093	538
	75	3379	2	0	9.6	31,000	28.5	6.5	398	295
	89	3377	2	0	6.6	28,000	28.0	9.4	33	98

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
15-Nov	11	3394	9	0	5.8	199	0.0	11.1	725	575
	12	3395	9	0	4.2	112	0.0	13.5	215	180
	18	3391	.	0	9.3	32,000	29.0	8.2	60	10
	18	3390	.	23	8.3	31,900	29.3	8.7	15	13
	19.1	3393	.	0	8.6	30,800	27.8	8.8	108	28
	19.1	3392	.	24	8.4	39,400	29.1	8.8	18	8
	55	3387	9	0	3.8	128	0.0	14.6	3,725	500
	70	3397	9	0	6.1	305	0.0	9.5	128	85
	74	3396	9	0	8.1	365	0.0	10.1	178	48
	75	3389	.	0	10.1	31,500	28.3	7.1	868	320
	75	3388	.	9	9.2	32,000	29.9	7.8	45	28
	89	3386	.	0	6.6	27,300	26.0	10.0	43	28
19-Nov	11	3406	9	0	5.6	190	0.0	11.5	365	535
	12	3407	9	0	5.3	130	0.0	12.4	445	235
	18	3403	.	0	8.7	30,000	27.0	8.5	118	308
	18	3402	.	31	8.3	32,100	30.0	8.2	10	0
	19.1	3405	.	0	7.7	29,000	27.2	9.0	78	20
	19.1	3404	.	28	8.3	32,700	30.5	8.3	5	15
	55	3399	9	0	5.6	163	0.0	12.4	888	300
	70	3409	9	0	6	372	0.0	9.3	258	140
	74	3408	9	0	6.8	382	0.0	9.1	210	55
	75	3401	.	0	9	29,900	27.0	8.1	298	1,500
	75	3400	.	9	9.9	32,100	29.7	8.1	85	75
	89	3398	.	0	6.9	29,000	28.2	9.8	105	90
23-Nov	12	3417	9	0	5.1	140	0.0	12.3	150	95
	18	3414	.	0	8.6	30,000	26.9	7.3	13	13
	18	3413	.	23	7.8	31,900	29.9	7.8	325	293
	19.1	3416	.	0	8.4	30,900	27.9	8.3	120	1,400
	19.1	3415	.	28	7.9	32,000	29.8	7.8	10	93
	55	3411	9	0	5.3	158	0.0	11.8	530	300
	75	3412	.	0	8.9	31,100	28.8	6.9	263	218
	89	3410	.	0	7.3	26,200	25.0	8.3	348	903
26-Nov	11	3425	9	0	5.7	200	0.0	10.2	575	520
	12	3426	9	0	5.6	143	0.0	11.3	318	1,275
	18	3422	.	0	8.3	31,100	28.8	7.7	140	153
	18	3421	.	23	7.6	32,000	30.1	7.4	73	30
	19.1	3424	.	0	7.7	30,700	28.8	7.8	115	185
	19.1	3423	.	18	7.9	32,000	30.0	7.1	13	3
	55	3419	9	0	5.5	160	0.0	11.5	7,175	388
	70	3428	9	0	7.3	360	0.0	8.4	488	813
	74	3427	9	0	7.5	385	0.0	9.6	333	300
	75	3420	.	0	9	30,700	28.0	6.2	258	183
	89	3418	.	0	8	29,000	26.9	7.5	285	343
27-Nov	15.1	3429	.	0	7.3	28,000	26.0	10.9	28	13
	52	3431	.	0	5.3	432	0.5	12.0	93	38
	52	3430	.	10	5.4	2,180	2.0	11.6	120	30
	55	3435	9	0	6.5	232	0.0	11.9	1,268	255
	67	3433	9	0	5.5	351	0.0	11.3	113	45
	67	3432	9	8	5.7	482	0.5	11.4	120	28
	89	3434	.	0	7.9	27,200	25.5	8.0	73	395

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
28-Nov	11	3441	9	0	6.8	215	0.0	12.0	428	298
	12	3442	9	0	6.3	158	0.0	13.0	683	650
	18	3440	.	0	9.3	32,100	29.0	8.5	93	78
	18	3439	.	28	8.1	32,000	30.0	7.9	120	60
	55	3437	9	0	6.6	180	0.0	12.6	958	198
	75	3438	.	0	9.5	32,000	29.2	7.8	85	60
	89	3436	.	0	7.5	26,200	25.0	9.5	75	725
29-Nov	15.1	3445	.	0	9.4	30,000	26.9	10.1	40	35
	15.1	3444	.	28	8.1	32,000	30.0	9.8	8	83
	52	3447	.	0	8.5	5,000	0.0	12.7	108	28
	52	3446	.	10	8.1	2,830	3.4	10.6	88	40
	67	3449	9	0	9	409	0.0	12.3	60	33
	67	3448	9	8	9.1	412	0.0	12.1	103	20
	70	3450	9	0	11.6	440	0.0	7.5	188	168
	74	3451	9	0	10.8	430	0.0	10.1	540	213
	89	3443	.	0	8.9	30,000	27.2	10.7	45	40
03-Dec	11	3455	9	0	6.1	218	0.0	10.5	408	238
	12	3456	9	0	4.9	150	0.0	12.6	80	68
	18	3454	6	0	7.3	29,500	27.9	8.8	43	28
	18	3453	6	23	7.9	31,800	30.5	8.2	18	70
	55	3458	9	0	4.8	165	0.0	12.4	320	240
	75	3452	6	0	8	30,000	28.7	8.4	353	733
	89	3457	2	0	6.1	28,500	27.3	9.5	513	335
04-Dec	11	3464	9	0	6.4	230	0.0	.	390	490
	12	3465	9	0	8	140	0.0	.	4,050	8,225
	18	3461	6	0	8.5	29,900	26.9	7.8	3,450	1,475
	18	3460	6	24	7.8	31,800	29.2	8.0	55	75
	19.1	3463	6	0	8.4	31,500	27.9	7.9	863	1,275
	19.1	3462	6	29	7.8	32,900	31.1	7.7	43	218
	75	3459	6	0	8.9	29,000	27.0	7.4	793	2,100
	89	3466	6	0	8	29,000	28.0	.	158	528
05-Dec	18	3469	.	0	7.7	29,200	27.0	8.5	3,700	2,875
	18	3468	.	19	7.6	31,200	29.8	9.2	228	103
	19.1	3471	.	0	7.6	29,100	26.8	9.1	530	323
	19.1	3470	.	29	7.4	31,400	29.8	9.2	40	38
	55	3473	9	0	6.9	113	0.0	11.4	1,675	5,075
	75	3467	.	0	8.6	30,500	28.5	8.5	1,638	1,168
	89	3472	.	0	6.5	29,500	29.0	9.5	193	265
06-Dec	18	3476	.	0	7.4	30,200	28.2	8.4	1,925	215
	18	3475	.	29	7.4	31,200	29.1	8.8	263	90
	19.1	3478	.	0	7.2	30,200	28.5	8.2	590	140
	19.1	3477	.	29	6.8	30,700	29.2	8.4	40	35
	75	3474	.	0	8.1	31,200	28.5	8.2	53	25
10-Dec	15.1	3481	.	0	5.9	28,000	27.0	9.3	145	108
	15.1	3480	.	18	6.7	30,000	29.0	8.7	15	10
	52	3484	.	0	4.1	301	0.0	11.3	240	153
	52	3483	.	17	4.4	2,300	2.1	10.0	290	240
	67	3482	9	0	4.3	290	0.0	11.7	143	63
	89	3479	.	0	6.7	26,400	25.5	9.0	1,525	818

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
11-Dec	11	3490	9	0	4.2	222	0.0	11.0	573	520
	12	3491	9	0	2.4	112	0.0	14.0	415	285
	18	3487	.	0	5.3	28,500	28.5	8.6	690	323
	18	3486	.	24	6.6	31,000	29.9	8.6	80	38
	19.1	3489	.	0	5.5	28,500	28.0	8.9	168	90
	19.1	3488	.	19	6.1	30,400	29.5	8.1	8	8
	55	3492	9	0	2.5	120	0.0	13.3	983	535
	75	3485	.	0	7.6	30,800	29.0	7.9	428	325
12-Dec	15.1	3494	.	0	5.4	28,000	29.3	9.0	170	18
	15.1	3493	.	29	6.9	30,800	30.1	8.1	63	13
	52	3497	.	0	7.4	31,100	29.8	7.3	83	25
	52	3496	.	17	7.9	31,900	30.2	7.5	75	5
	67	3495	9	0	2.5	320	0.0	11.3	63	30
	89	3498	.	0	5.1	27,300	25.8	9.0	573	303
13-Dec	11	3506	9	0	3.6	178	0.0	11.4	350	1,105
	12	3507	9	0	2.7	115	0.0	13.5	375	180
	18	3503	.	0	7.9	30,000	28.5	8.5	85	133
	18	3502	.	17	6.4	30,600	28.2	8.6	8	25
	19.1	3505	.	0	7.2	28,500	27.0	8.8	290	210
	19.1	3504	.	24	6.3	30,500	29.8	8.3	10	20
	55	3500	9	0	3.1	132	0.0	10.1	1,325	453
	75	3501	.	0	8	30,500	28.2	8.1	650	480
	89	3499	.	0	5	28,500	29.2	10.4	15	10
18-Dec	15.1	3509	.	0	5.2	23,000	25.0	9.9	265	248
	15.1	3508	.	29	5.9	30,000	29.7	8.5	95	65
	52	3512	.	0	5.9	28,000	26.2	9.1	210	45
	52	3511	.	16	7.6	31,100	31.1	7.0	55	25
	67	3510	9	0	3	320	0.0	12.9	325	138
	70	3513	9	0	4.4	345	0.0	9.6	9,075	4,075
	74	3514	9	0	5.4	361	0.0	10.8	2,525	2,400
19-Dec	11	3520	9	0	3.8	168	0.0	12.7	623	588
	12	3521	9	0	4	132	0.0	14.4	133	265
	18	3517	.	0	6.8	29,100	22.9	9.2	780	683
	18	3516	.	17	5.8	31,000	29.3	9.2	40	28
	19.1	3519	.	0	6.2	28,200	27.2	9.5	200	65
	19.1	3518	.	24	5.6	32,000	29.7	8.9	18	35
	75	3515	.	0	7.3	28,900	27.1	8.8	325	555
20-Dec	52	3528	.	0	7.4	30,800	32.6	7.8	85	15
	52	3527	.	16	7.1	30,500	32.5	7.5	88	13
	55	3523	9	0	5	125	0.0	12.6	615	403
	67	3526	9	0	3.8	310	0.0	12.5	133	53
	70	3525	9	0	4.4	330	0.0	9.2	4,325	983
	74	3524	9	0	4	348	0.0	10.2	1,175	1,050
	89	3522	.	0	6	28,000	26.0	9.7	398	223
02-Jan-1991										
	11	3534	9	0	2.9	228	0.0	11.9	393	630
	12	3535	9	0	2.2	139	0.0	14.4	195	200
	18	3531	6	0	5	27,000	27.9	9.6	90	23
	18	3530	6	17	5.7	29,700	28.5	8.9	15	5
	19.1	3533	6	0	4.9	26,500	26.8	8.8	63	43
	19.1	3532	6	24	5.6	29,900	29.9	8.3	5	10
	75	3529	6	0	6.1	29,000	27.4	10.5	193	60

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
03-Jan	55	3537	9	0	1.9	169	0.0	13.6	1,025	203
	89	3536	6	0	3.9	26,200	24.9	11.0	130	85
09-Jan	18	3540	3	0	4	25,800	25.8	9.1	200	153
	18	3539	3	19	4.5	28,500	28.2	8.6	10	18
	19.1	3542	3	0	4.5	27,500	27.3	9.2	208	83
	19.1	3541	3	24	4.1	28,500	28.8	8.5	8	0
	75	3538	3	0	5.3	25,500	25.2	8.0	668	495
10-Jan	18	3544	3	0	4.8	28,900	29.3	8.6	25	63
	18	3543	3	17	4.2	29,000	30.5	9.1	3	0
	19.1	3546	3	0	4.7	27,700	28.0	9.3	70	43
	19.1	3545	3	19	4	28,900	29.1	9.0	5	0
	75	3547	3	0	5.4	26,200	26.5	8.0	763	2,200
16-Jan	18	3550	1	0	2.2	26,100	28.1	9.9	78	58
	18	3549	1	19	2.5	27,600	29.8	9.8	3	0
	19.1	3552	2	0	2.1	23,500	24.0	10.3	108	75
	19.1	3551	2	24	2.5	28,000	29.8	9.2	3	0
	75	3548	6	0	3.5	25,600	27.9	9.1	593	408
	89	3553	2	0	1.5	24,500	25.8	10.4	98	45
17-Jan	18	3556	6	0	4.3	25,700	26.1	9.5	18,150	20,450
	18	3555	6	19	2.6	27,500	30.3	10.0	230	195
	19.1	3558	6	0	4.2	24,000	24.8	9.7	9,150	11,350
	19.1	3557	6	24	2.4	27,800	29.5	10.0	345	275
	55	3559	9	0	1.3	24,800	0.0	13.8	1,300	2,850
	75	3554	6	0	5.2	26,300	26.5	8.9	14,400	16,500
	89	3560	2	0	2	25,800	26.9	11.2	175	185
18-Jan	18	3563	6	0	3.8	26,000	26.5	9.6	600	440
	18	3562	6	29	2.6	27,400	27.1	10.0	10	35
	19.1	3565	2	0	3.4	25,000	26.0	10.1	475	165
	19.1	3564	2	29	2.6	27,650	29.0	10.3	15	30
	75	3561	6	0	4.4	27,200	29.0	9.2	640	470
19-Jan	N-01	3579	.	.	.	.	.	.	0	390
	N-02	3574	.	.	.	.	.	.	10	10
	N-03	3575	.	.	.	.	.	.	160	210
	N-04	3571	.	.	.	.	.	.	0	170
	N-05	3572	.	.	.	.	.	.	50	260
	N-07	3580	.	.	.	.	.	.	320	10
	N-08	3578	.	.	.	.	.	.	130	370
	N-10	3576	.	.	.	.	.	.	320	320
	N-11	3573	.	.	.	.	.	.	280	510
	N-12	3577	.	.	.	.	.	.	240	600
	N-13	3569	.	.	.	.	.	.	740	610
	N-13A	3570	.	.	.	.	.	.	1,100	510
	N-14	3567	.	.	.	.	.	.	870	580
	N-16	3568	.	.	.	.	.	.	1,750	1,000
	N-17	3566	.	.	.	.	.	.	630	380
28-Jan	11	3586	9	0	0.7	225	0.0	13.3	238	150
	18	3583	3	0	3.8	28,000	30.0	10.1	.	.
	18	3582	3	24	2.7	28,000	30.0	10.1	40	5
	19.1	3585	3	0	2.9	26,000	27.5	11.0	8	15
	19.1	3584	3	29	2.6	27,900	30.1	9.9	15	0
	75	3581	2	0	3.7	27,500	28.2	10.3	105	285

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
29-Jan	15.1	3590	2	0	1.9	22,800	24.3	11.2	20	20
	15.1	3589	2	29	2.4	27,500	29.8	10.4	40	15
	52	3592	2	0	4.4	27,500	27.8	11.3	23	13
	52	3591	2	16	4.6	28,800	29.2	9.1	38	13
	55	3588	9	0	0.5	209	0.0	13.5	775	390
	70	3593	9	0	3.3	520	0.0	10.6	1,975	960
	74	3594	9	0	5.1	530	0.0	12.5	533	2,400
	89	3587	6	0	1.1	25,200	28.7	11.8	50	38
31-Jan	11	3600	9	0	1	212	0.0	14.2	88	80
	18	3597	6	0	3.3	23,000	24.0	10.8	448	425
	18	3596	6	24	2.6	28,000	30.0	11.1	10	8
	19.1	3599	6	0	3.2	25,400	27.0	11.1	103	208
	19.1	3598	6	29	2.9	28,000	30.4	11.2	3	15
	55	3602	9	0	1.6	170	0.0	14.1	780	830
	75	3595	6	0	4.4	27,500	24.1	10.3	238	215
	89	3601	6	0	2.2	26,500	31.0	11.1	30	75
04-Feb	11	3608	9	0	1.7	245	0.0	12.6	193	220
	12	3609	9	0	1.6	145	0.0	15.8	368	313
	18	3605	6	0	3.6	25,200	26.9	10.6	315	68
	18	3604	6	19	3.1	28,000	29.5	10.3	8	3
	19.1	3607	6	0	3.3	26,800	27.6	10.5	10	3
	19.1	3606	6	26	2.8	28,200	29.9	10.9	0	3
	75	3603	5	0	4.9	27,600	27.8	10.3	50	113
05-Feb	89	3610	5	0	2.8	27,000	36.1	11.3	10	3
06-Feb	11	3616	9	0	1.8	225	0.0	13.6	265	108
	12	3617	9	0	2.3	148	0.0	15.6	253	303
	18	3613	5	0	4.5	25,000	25.9	10.7	200	168
	18	3612	5	24	2.9	27,900	29.5	11.0	10	3
	19.1	3615	5	0	3.7	22,500	23.0	11.6	28	20
	19.1	3614	5	29	2.9	28,000	29.3	10.7	10	3
	75	3611	5	0	5.2	22,000	28.9	9.7	678	308
07-Feb	52	3621	5	0	3.1	2,000	1.5	13.5	1,850	240
	52	3624	5	0	.	.	.	.	32,100	19,350
	52	3620	5	9	4.4	18,000	18.9	11.3	1,600	208
	55	3618	9	0	3.2	148	0.0	13.2	963	1,025
	70	3622	9	0	5.1	410	0.0	10.4	18,200	17,375
	74	3623	9	0	5.5	418	0.0	11.8	11,850	19,150
	89	3619	3	0	3.5	14,900	14.8	11.5	478	190
13-Feb	55	3625	9	0	0.5	137	0.0	14.8	893	580
	89	3626	2	0	1.4	24,600	27.2	11.5	13	8
14-Feb	18	3631	2	0	3.9	24,000	24.5	8.6	438	775
	18	3630	2	26	3.8	28,800	30.2	7.7	518	650
	52	3629	2	0	3.2	11,200	11.0	9.9	2,350	2,000
	52	3628	2	14	6.5	29,800	28.8	6.5	283	110
	89	3627	6	0	1.7	24,000	25.8	12.2	115	23
19-Feb	52	3635	6	0	4.2	23,800	22.0	10.1	1,525	773
	52	3634	6	19	6.2	29,000	28.6	8.3	425	375
	55	3633	9	0	1	201	0.0	14.1	1,050	725

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
19-Feb	70	3636	9	0	2.8	1,305	0.0	11.4	6,150	6,525
	74	3637	9	0	4.4	650	0.0	13.2	4,050	2,800
	89	3632	5	0	3.8	28,500	18.6	9.9	1,250	1,500
20-Feb	18	3641	5	0	5	22,200	27.3	11.5	363	180
	18	3640	5	17	2.7	22,600	29.3	11.9	15	10
	19.1	3643	6	0	4.3	26,700	26.9	11.6	380	55
	19.1	3642	6	29	2.5	22,400	29.0	11.9	3	13
	54	3638	5	0	2.8	9,000	9.0	13.5	1,225	538
	75	3639	5	0	4.9	28,200	28.6	10.8	160	148
21-Feb	52	3645	5	0	4.4	27,800	27.2	9.5	270	920
	52	3644	5	3	5.2	29,000	19.5	9.7	43	38
	67	3646	9	0	2.9	510	0.2	13.7	148	30
	70	3647	9	0	3.4	456	0.0	11.9	2,800	2,025
	74	3648	9	0	6.3	495	0.0	13.2	650	2,425
04-Mar	11	3657	9	0	4.6	252	0.0	12.3	230	470
	12	3658	9	0	6	168	0.0	10.6	360	1,720
	18	3654	6	0	5	21,000	20.2	10.9	470	1,700
	18	3653	6	24	3.5	28,300	29.9	10.7	25	70
	19.1	3656	6	0	4.2	20,000	19.5	11.3	305	590
	19.1	3655	6	24	3.5	28,300	29.3	10.9	10	25
	54	3651	5	0	5.9	8,200	7.3	11.6	1,525	2,850
	55	3650	9	0	6.6	171	0.0	11.6	1,115	2,600
	75	3652	5	0	6	18,000	17.0	10.0	19,750	42,950
	89	3649	5	0	5	26,100	26.0	10.5	8,150	19,950
05-Mar	52	3663	5	0	5.7	11,900	11.0	11.1	240	125
	52	3662	5	9	4.2	27,600	28.9	9.7	70	115
	67	3661	9	0	5.6	313	0.0	12.8	1,270	2,150
	70	3660	9	0	6.3	415	0.0	11.0	2,200	1,850
	74	3659	9	0	6.6	418	0.0	11.0	3,700	3,400
07-Mar	18	3669	5	0	6.8	25,600	29.2	9.9	238	173
	18	3668	5	24	4.2	28,800	29.2	10.5	20	20
	19.1	3671	5	0	5.8	24,100	23.2	10.8	138	50
	19.1	3670	5	29	4.3	28,800	29.4	10.3	8	8
	54	3665	3	0	6.2	6,000	5.5	12.2	2,275	1,650
	55	3664	9	0	7.1	138	0.0	11.6	1,425	1,375
	75	3667	5	0	6.1	27,400	27.4	9.5	425	3,600
	89	3666	3	0	7.5	8,000	7.0	10.1	37,100	35,500
11-Mar	54	3674	3	0	2.5	3,420	4.8	13.7	815	315
	55	3673	9	0	3	134	0.0	14.1	650	673
	89	3672	3	0	3.8	22,800	23.8	9.9	2,300	1,045
13-Mar	11	3681	9	0	4.1	182	0.0	13.5	205	218
	18	3678	2	0	4.1	29,000	29.0	10.7	18	20
	18	3677	2	24	3.2	28,700	31.0	11.4	50	25
	19.1	3680	3	0	4.4	27,000	28.1	11.5	3	18
	19.1	3679	3	29	5	29,000	30.0	11.0	3	8
	75	3676	2	0	5.6	28,100	28.1	8.8	210	88
	89	3675	2	0	3.8	15,400	15.4	12.6	28	10
25-Mar	11	3713	9	0	5	210	0.0	13.8	315	455
	18	3710	3	0	4.4	20,900	20.5	11.4	305	385
	18	3709	3	24	4.2	28,200	29.0	11.1	15	100

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
25-Mar	19.1	3712	3	0	4.5	20,800	20.5	12.1	255	250
	19.1	3711	3	29	4.1	28,400	29.0	10.9	15	235
	75	3708	3	0	5.1	24,500	24.0	8.1	3,850	3,100
	89	3707	3	0	4.4	17,800	17.2	10.4	2,550	1,900
26-Mar	11	3719	9	0	6.3	203	0.0	13.4	328	210
	18	3716	2	0	5.3	24,800	23.9	11.2	170	125
	18	3715	2	24	4.5	28,600	29.0	10.6	3	23
	19.1	3718	2	0	5.4	24,200	23.3	11.5	190	108
	19.1	3717	2	29	4.2	28,500	29.0	10.5	3	10
	75	3714	2	0	6	23,900	23.2	9.7	710	495
	89	3720	2	0	5.8	17,300	16.5	12.3	140	35
27-Mar	89	3721	2	0	4.8	25,000	25.0	10.3	743	428
28-Mar	11	3728	9	0	6.1	250	0.0	11.9	313	243
	18	3725	2	0	6.8	28,000	28.0	9.1	90	88
	18	3724	2	24	4.3	28,600	28.5	9.2	38	3
	19.1	3727	2	0	7.3	27,500	26.0	10.1	80	98
	19.1	3726	2	29	4.1	28,900	29.3	9.8	35	8
	75	3723	2	0	7.3	28,100	26.8	10.3	138	53
	89	3722	2	0	6.1	27,100	27.5	11.4	18	8
03-Apr	41	3741	6	0	6.1	26,100	25.0	12.2	8	5
04-Apr	41	3748	6	0	6	28,000	27.0	12.3	0	5
	89	3742	5	0	7.7	16,000	14.1	11.0	100	13
05-Apr	44	3750	5	0	5.8	28,800	28.2	12.4	0	0
	44	3749	5	15	4.7	28,800	30.1	11.3	15	5
08-Apr	41	3762	3	0	11.1	23,600	19.9	11.1	75	38
	44	3756	3	0	8.6	30,900	28.2	14.3	3	0
	44	3757	3	17	6.7	30,000	27.5	14.0	5	8
	89	3755	3	0	8.6	26,400	24.8	9.7	215	145
09-Apr	41	3769	3	0	11.1	28,000	23.8	10.7	83	10
	44	3764	3	0	10.6	30,200	25.1	14.1	0	0
	44	3763	3	19	6.2	29,600	28.6	6.0	0	40
10-Apr	41	3775	3	0	9.4	29,000	22.5	11.4	68	13
11-Apr	11	3776	9	0	12.5	229	0.0	10.7	108	45
	12	3777	9	0	13.7	198	0.0	11.1	208	225
	18	3779	2	0	8.5	29,100	26.5	12.4	5	13
	18	3778	2	24	7.2	29,900	24.6	13.1	8	8
	75	3780	2	0	7.7	30,000	28.1	11.2	233	83
	89	3781	3	0	8.4	29,000	26.2	9.6	95	125
16-Apr	41	3787	6	0	8.3	29,600	27.5	9.6	8	5
17-Apr	41	3793	6	0	7.6	28,000	26.2	10.4	88	20
	89	3788	5	0	8.1	13,400	11.8	8.1	475	180
18-Apr	89	3794	5	0	7.9	21,100	19.1	10.0	400	1,375

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
20-Apr	N-01	3803	.	.	.	.	.	.	20	200
	N-02	3804	.	.	.	.	.	.	0	20
	N-03	3805	.	.	.	.	.	.	260	40
	N-04	3806	.	.	.	.	.	.	0	130
	N-05	3807	.	.	.	.	.	.	10	50
	N-07	3808	.	.	.	.	.	.	10	20
	N-08	3809	.	.	.	.	.	.	0	10
	N-10	3810	.	.	.	.	.	.	60	20
	N-11	3811	.	.	.	.	.	.	160	100
	N-12	3812	.	.	.	.	.	.	260	140
	N-13	3798	.	.	.	.	.	.	40	20
	N-13A	3799	.	.	.	.	.	.	190	120
	N-14	3800	.	.	.	.	.	.	1,185	110
	N-16	3801	.	.	.	.	.	.	700	80
	N-17	3802	.	.	.	.	.	.	260	90
22-Apr	36	3818	3	0	7.2	27,500	25.3	10.2	340	115
	38	3820	3	0	7.2	27,300	25.8	10.0	340	1,550
	38	3819	3	8	7	29,800	28.1	9.9	95	175
	39	3814	3	0	7.3	19,800	17.9	10.1	2,400	1,070
	41	3821	3	0	7.6	15,800	13.9	10.2	2,750	1,950
	89	3813	3	0	7.7	18,800	17.4	9.2	16,850	9,200
23-Apr	36	3826	3	0	7.3	29,200	28.0	10.0	10	20
	38	3825	3	0	7.1	29,900	27.8	10.1	50	10
	38	3824	3	10	6.6	29,900	28.7	10.3	15	20
	39	3823	2	0	7.9	23,200	20.9	10.4	155	85
	41	3830	3	0	8.5	18,500	16.4	10.0	670	240
	89	3822	2	0	7.5	27,900	26.0	9.4	100	30
24-Apr	36	3831	2	0	8.5	29,400	26.9	9.5	10	3
	38	3836	3	0	9.4	27,500	25.5	8.9	38	5
	38	3835	3	10	7	30,400	28.4	10.1	3	0
	39	3838	3	0	10.9	22,200	18.6	8.4	73	8
	41	3837	3	0	10	21,000	18.0	9.0	200	70
25-Apr	36	3842	2	0	9.6	29,800	26.1	9.5	5	0
	38	3841	2	0	10.6	29,100	25.7	9.1	0	0
	38	3840	2	13	7.3	30,200	26.9	10.4	0	0
	39	3839	2	0	10.1	26,800	23.2	8.7	25	0
	41	3846	2	0	11.5	20,100	16.7	8.6	143	13
29-Apr	36	3849	6	0	9.5	31,000	27.9	9.7	13	3
	38	3848	6	0	9.1	30,200	27.8	11.7	5	410
	38	3847	6	13	8.5	30,800	28.9	11.3	0	10
	39	3854	1	0	11.6	27,800	23.4	8.5	200	8
	41	3853	6	0	10.4	28,500	24.8	9.2	38	8
30-Apr	36	3857	6	0	9.3	32,000	29.2	10.3	3	15
	38	3856	6	0	8.8	34,900	29.0	9.9	10	3
	38	3855	6	12	8.7	32,000	29.1	9.9	5	8
	39	3862	1	0	10.1	25,700	21.9	9.0	340	73
	41	3861	6	0	9.7	31,000	24.2	9.2	95	73

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
01-May	36	3867	6	0	9.5	31,100	27.8	9.7	0	3
	38	3866	6	0	9.3	25,900	23.4	9.2	78	50
	38	3865	6	9	8.8	27,200	24.5	9.9	60	228
	39	3864	5	0	10.6	18,800	15.9	8.4	2,530	575
	41	3871	6	0	10.9	27,300	23.5	8.5	668	208
	89	3863	5	0	11.3	18,800	15.2	6.3	20,380	18,725
02-May	38	3876	6	0	10.5	30,900	26.5	10.5	10	3
	38	3875	6	11	8.7	31,500	26.0	10.8	5	90
	39	3878	6	0	12.4	26,000	20.6	9.1	120	.
	41	3877	6	0	10.9	29,000	25.0	9.6	110	25
07-May	89	3879	6	0	9.8	31,800	28.3	9.2	213	103
23-May	39	3906	3	0	15.8	35,300	27.3	8.7	18	3
	41	3905	3	0	16.1	32,300	24.8	8.4	43	10
29-May	39	3911	6	0	18.2	37,000	27.3	8.4	10	20
	49	3910	6	0	18.2	36,200	25.8	8.0	0	40
30-May	39	3916	6	0	19	38,000	28.1	7.5	13	10
	41	3915	6	0	18	37,000	27.1	7.7	90	40
04-Jun	39	3918	5	0	17.8	37,400	24.9	7.2	65	3
	89	3917	5	0	18.4	33,200	21.8	5.0	9,525	2,525
05-Jun	39	3920	5	0	16.1	35,200	28.0	6.3	1,275	65
	89	3919	5	0	16.7	28,300	17.3	2.4	54,600	115,900
06-Jun	39	3925	6	0	17.4	37,900	28.3	6.2	5	0
	41	3924	3	0	18	30,100	22.0	6.9	228	15
24-Jun	15	4047	2	0	19.3	40,000	29.3	7.1	10	0
	15	4046	2	46	16.5	37,900	29.0	.	15	8
	52	4051	2	0	20.5	38,200	26.2	6.0	1,625	15
	52	4050	2	12	18.8	39,500	29.0	.	343	20
	56	4055	9	0	22.6	600	0.2	9.3	55	25
	57	4056	9	0	23.8	500	0.1	8.7	170	313
	59	4052	9	0	23.2	1,500	1.0	12.0	93	13
	60	4054	9	0	23.6	900	0.3	12.4	23	15
	67	4053	9	0	23.2	1,100	0.7	10.8	33	5
	69	4049	2	0	20.5	38,200	27.2	6.2	353	0
	69	4048	2	24	19.3	39,800	29.0	.	98	0
	70	4058	9	0	23.6	500	0.2	8.2	195	578
	83	4057	9	0	23.7	600	0.2	9.5	43	210
25-Jun	15	4060	6	0	21	38,500	29.1	6.4	78	5
	15	4059	6	45	17.8	38,100	28.7	.	8	0
	52	4064	1	0	20	39,700	27.8	5.5	578	15
	52	4063	1	14	19.4	40,000	27.9	4.9	425	13
	56	4068	9	0	23.2	462	0.0	10.5	110	50
	57	4069	9	0	24.9	461	0.0	9.7	153	75
	59	4065	9	0	23.6	1,260	1.0	12.0	83	15
	60	4067	9	0	23.9	790	0.0	12.1	140	20
	67	4066	9	0	23.3	1,150	0.0	11.6	90	25
	69	4062	6	0	21.8	33,200	22.8	6.4	805	5

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
25-Jun	69	4061	6	8	19.9	40,000	28.4	5.6	283	8
	70	4071	9	0	20.8	550	0.0	6.0	660	198
	83	4070	9	0	24.8	440	0.0	9.6	15	105
26-Jun	15	4073	6	0	20.5	38,800	27.5	7.8	20	5
	15	4072	6	45	17.1	38,300	28.9	5.3	33	3
	52	4077	6	0	20.9	40,200	28.5	5.4	175	8
	52	4076	6	13	19.6	39,800	28.8	3.1	190	3
	56	4081	9	0	24.9	500	0.2	12.6	90	15
	57	4082	9	0	25.3	500	0.1	11.2	88	65
	59	4078	9	0	23.2	1,500	1.0	10.4	110	10
	60	4080	9	0	24.3	1,100	0.5	12.3	55	5
	67	4079	9	0	23.6	1,360	0.8	11.0	48	13
	69	4075	6	0	21.2	41,200	28.5	5.6	160	0
	69	4074	6	21	18.3	33,900	27.0	5.3	118	3
	70	4084	9	0	25	490	0.0	8.6	93	290
	83	4083	9	0	24.7	480	0.1	10.9	15	110
27-Jun	15	4086	6	0	20.2	40,000	28.9	8.7	5	0
	15	4085	6	45	17.2	38,200	28.0	7.1	0	3
	52	4090	6	0	20.1	40,000	28.8	5.7	55	3
	52	4089	6	15	19.4	39,200	28.2	3.6	48	5
	56	4094	9	0	24.7	490	0.2	12.1	173	68
	57	4095	9	0	24.8	500	0.5	6.7	33	113
	59	4091	9	0	24	1,200	0.9	10.4	108	33
	60	4093	9	0	24.6	1,320	0.8	11.0	3	5
	67	4092	9	0	23.7	1,500	0.9	11.3	73	5
	69	4088	6	0	20.7	41,000	29.0	6.4	38	0
	69	4087	6	27	19	39,200	29.0	6.2	20	0
	70	4097	9	0	25.6	499	0.2	10.5	65	458
	83	4096	9	0	25.5	470	0.0	10.8	30	95
01-Jul	15	4099	6	0	17.4	38,500	28.9	7.7	8	3
	15	4098	6	44	15	38,300	29.0	7.4	3	3
	52	4103	6	0	18.2	39,200	29.6	8.9	70	10
	52	4102	6	12	17.4	39,200	29.7	6.7	313	75
	69	4101	6	0	18	38,800	28.6	7.6	15	8
	69	4100	6	18	17.3	38,300	28.9	7.0	25	3
02-Jul	15	4105	5	0	18	39,000	29.1	8.7	3	0
	15	4104	5	39	15.2	37,000	28.9	6.8	3	8
	52	4109	5	0	18.4	34,000	24.5	5.2	343	50
	52	4108	5	8	17.5	39,000	29.1	7.2	453	85
	56	4113	9	0	23	600	0.3	10.9	873	73
	57	4114	9	0	23.5	400	0.1	8.5	433	238
	59	4110	9	0	23.5	2,030	1.5	12.2	50	8
	60	4112	9	0	23.2	2,020	1.2	12.5	303	23
	67	4111	9	0	22.9	2,100	1.2	9.8	118	23
	69	4107	5	0	17.3	39,000	29.5	7.2	33	3
	69	4106	5	27	16.6	38,300	29.2	6.9	25	3
	70	4115	9	0	23.7	400	0.1	7.3	313	375
	83	4116	9	0	23.1	410	0.5	6.3	438	403

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
03-Jul	15	4118	5	0	17.8	39,000	29.2	8.6	18	5
	15	4117	5	39	15.8	37,500	28.9	6.3	160	0
	52	4122	5	0	17.6	38,000	28.5	5.7	425	15
	52	4121	5	7	17.4	38,800	29.0	5.5	625	83
	56	4126	9	0	23.2	780	0.0	12.3	100	105
	57	4127	9	0	23.1	4,100	0.0	10.0	265	295
	59	4123	9	0	23.3	1,850	0.5	11.6	50	68
	60	4125	9	0	23.3	2,100	0.0	12.2	175	53
	67	4124	9	0	23.2	3,140	0.0	11.3	133	63
	69	4120	5	0	18.5	39,500	29.8	6.8	213	8
	69	4119	5	24	16.5	38,200	29.0	5.9	25	3
	70	4129	9	0	22.8	409	0.0	8.6	1,450	580
	83	4128	9	0	23.2	250	0.0	8.5	75	505
05-Jul	15	4131	3	0	19	39,800	29.3	8.5	163	8
	15	4130	3	39	16.3	38,200	29.8	6.4	28	0
	52	4135	3	0	19.3	26,100	20.2	6.7	1,000,000	79,100
	52	4134	3	7	19.1	40,100	29.8	4.8	2,025	195
	56	4139	9	0	22.1	428	0.0	9.0	363	333
	57	4140	9	0	22.3	451	0.0	9.0	250	913
	59	4136	9	0	22.4	2,230	1.2	9.6	75	5
	60	4138	9	0	22.6	1,900	1.1	10.7	78	53
	67	4137	9	0	22.4	2,130	1.2	10.4	8	10
	69	4133	3	0	19.4	39,900	28.9	8.5	98	18
	69	4132	3	24	16.6	38,900	29.7	6.2	65	0
	70	4142	9	0	20.9	460	0.0	6.4	150	665
	83	4141	9	0	22.7	445	0.0	8.7	160	383
08-Jul	15	4144	3	0	20.4	41,000	29.0	8.8	23	5
	15	4143	3	42	17.6	39,000	29.5	6.7	0	8
	52	4148	3	0	21	35,500	25.0	6.9	25,375	85
	52	4147	3	11	19.9	40,500	29.3	5.2	78	10
	56	4152	9	0	23	4,150	0.2	11.6	53	13
	57	4153	9	0	23.2	4,550	0.1	7.9	25	93
	59	4149	9	0	22.3	2,000	1.1	9.7	128	5
	60	4151	9	0	22.5	1,820	1.0	9.2	20	5
	67	4150	9	0	22.9	1,800	1.0	11.6	33	18
	69	4146	3	0	20.9	41,400	29.5	7.9	40	0
	69	4145	3	30	20.3	41,000	29.3	7.2	25	3
	70	4155	9	0	22.4	500	0.2	5.7	113	233
	83	4154	9	0	22.9	4,400	0.2	6.9	20	90
09-Jul	15	4157	2	0	20.5	38,000	29.5	8.8	28	0
	15	4156	2	44	17.3	38,000	29.0	7.9	0	0
	52	4161	2	0	20.1	41,000	29.5	7.8	288	3
	52	4160	2	11	19.6	41,000	27.9	5.5	285	3
	56	4165	9	0	22.9	470	0.2	11.2	118	43
	57	4166	9	0	24	470	0.2	10.2	120	58
	59	4162	9	0	22.9	1,850	1.0	10.8	208	5
	60	4164	9	0	23.2	1,490	1.0	10.9	115	5
	67	4163	9	0	23	1,900	1.2	10.1	198	8
	69	4159	2	0	20.5	41,000	29.0	8.2	935	0
	69	4158	2	19	19.3	41,000	28.5	7.1	70	5
	70	4168	9	0	22.7	489	0.2	8.7	288	100
	83	4167	9	0	23.4	460	0.2	8.6	288	110

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
10-Jul	15	4170	2	0	19.2	40,000	29.8	8.7	5	13
	15	4169	2	44	17.9	38,200	28.5	7.9	0	3
	52	4174	2	0	19.6	40,000	29.5	8.7	23	3
	52	4173	2	14	19.1	40,000	28.5	6.3	115	8
	56	4178	9	0	23.4	850	0.8	10.4	108	25
	57	4179	9	0	23.7	500	0.0	10.7	28	90
	59	4175	9	0	23.6	1,720	1.0	11.1	15	8
	60	4177	9	0	23.4	1,550	1.0	10.9	8	5
	67	4176	9	0	23	1,880	1.0	10.0	13	18
	69	4172	2	0	20.1	41,100	29.8	7.8	133	3
	69	4171	2	29	17.7	39,200	29.0	6.8	13	3
	70	4181	9	0	23.1	482	0.0	9.8	40	70
	83	4180	9	0	23.8	460	0.0	9.2	75	120
11-Jul	15	4183	2	0	20	41,200	30.0	10.0	15	0
	15	4182	1	45	16.9	39,200	29.5	8.6	0	13
	52	4187	2	0	20	40,800	29.6	9.1	593	0
	52	4186	2	11	19.4	40,900	29.5	7.0	675	15
	56	4191	9	0	24	6,000	0.0	12.6	203	28
	57	4192	9	0	25.1	5,100	0.0	12.0	28	28
	59	4188	9	0	24.3	1,700	1.8	10.9	33	0
	60	4190	9	0	24.1	1,530	1.8	11.4	48	3
	67	4189	9	0	23.8	1,890	2.0	10.0	88	3
	69	4185	2	0	20.6	40,900	29.6	8.8	300	0
	69	4184	2	11	18.2	39,600	28.7	6.7	28	0
	70	4194	9	0	25.4	5,000	0.0	10.8	65	130
	83	4193	9	0	24.9	4,900	0.0	10.0	33	45
13-Jul	15	4221	1	0	18.3	.	.	8.1	20	48
	15	4220	1	46	16.8	39,000	30.0	8.2	20	8
	52	4225	6	0	20.2	33,500	23.5	6.0	425	55
	52	4224	6	10	19.2	40,200	29.4	6.4	375	30
	56	4229	9	0	22.7	445	0.2	10.5	125	123
	57	4230	9	0	23.3	500	0.3	7.1	70	278
	59	4225	9	0	23.3	1,700	1.0	9.1	100	23
	60	4228	9	0	23.2	1,580	0.9	8.9	45	35
	67	4227	9	0	23.3	1,530	0.9	10.4	15	28
	69	4223	6	0	19.9	35,300	25.9	6.9	4,550	483
	69	4222	6	5	19.3	40,800	29.9	7.3	25	13
	70	4232	9	0	21.5	620	0.3	5.8	325	313
	83	4231	9	0	23.3	480	0.5	7.3	58	218
20-Jul	NE01	4242	9	0	.	.	.	.	15	65
	NE02	4245	9	0	.	.	.	.	3,350	425
	NE03	4248	9	0	.	.	.	.	1,350	465
	NE04	4249	9	0	.	.	.	.	25	43
	NE05	4243	9	0	.	.	.	.	770	7,000
	NE07	4250	9	0	.	.	.	.	15	25
	NE08	4247	9	0	.	.	.	.	0	13
	NE10	4241	9	0	.	.	.	.	585	3,200
	NE11	4244	9	0	.	.	.	.	295	88
	NE12	4246	9	0	.	.	.	.	1,525	1,025
	NE13	4236	9	0	.	.	.	.	193	285
	NE13A	4237	9	0	.	.	.	.	470	1,053
	NE14	4238	9	0	.	.	.	.	550	250
	NE16	4239	9	0	.	.	.	.	1,140	1,128
	NE17	4240	9	0	.	.	.	.	340	673

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
22-Jul	24	4263	3	0	19	41,000	30.0	8.2	3	50
	24	4262	3	40	15	37,800	30.0	7.6	8	30
	33	4258	2	0	21	42,000	29.2	8.6	83	30
	36	4259	2	0	20.5	42,000	30.2	8.8	3	168
	38	4257	2	0	20.3	42,000	30.2	8.8	3	110
	38	4256	2	11	18.8	40,000	29.8	8.1	38	268
	39	4264	3	0	22.2	43,500	30.5	7.0	95	0
	40	4251	2	0	22.2	42,000	30.0	7.7	8	0
	41	4252	2	0	21.8	42,100	29.5	7.0	8	3
	42	4253	2	0	22.8	42,000	28.4	7.1	15	8
	44	4261	3	0	19.3	41,000	29.9	8.6	8	3
	44	4260	3	18	17.2	39,000	29.5	8.1	200	33
	84	4255	2	0	20.4	42,000	30.2	7.8	165	0
	84	4254	2	24	18.2	40,000	30.2	7.1	50	173
23-Jul	100	4266	2	0	19.9	41,900	29.1	7.2	63	78
	24	4271	2	0	19	41,800	31.1	8.0	13	0
	24	4270	2	44	15.1	38,200	30.2	8.3	20	5
	33	4274	2	0	22.1	43,900	30.9	7.6	5	0
	36	4275	2	0	21.7	43,200	30.2	8.0	3	5
	38	4277	2	0	19.6	42,000	30.3	8.3	21	10
	38	4276	2	13	16.4	39,200	30.2	8.3	5	3
	39	4284	3	0	25.4	42,900	28.0	6.6	1,100	58
	40	4280	2	0	23.1	43,000	29.6	8.0	5	3
	41	4283	3	0	22	42,500	29.9	7.5	.	.
	42	4281	2	0	22.5	41,900	28.6	6.9	1,275	43
	42	4282	2	18	19.2	40,600	27.9	6.7	48	8
	44	4273	2	0	17.4	40,200	31.0	8.8	0	3
	44	4272	2	22	15.2	38,400	30.7	8.3	145	13
	54	4268	2	0	24.1	40,800	25.2	5.9	270	23
	55	4267	9	0	26.5	389	0.0	7.3	363	153
	84	4279	2	0	20.1	42,100	30.4	7.9	13	10
	84	4278	2	24	16.7	39,900	30.5	7.5	25	3
	89	4265	2	0	21.5	42,000	29.1	6.0	588	103
24-Jul	100	4286	3	0	21.1	42,100	29.1	6.2	450	8
	24	4292	2	0	19.5	42,000	31.0	8.4	23	0
	24	4291	2	44	14.3	37,800	30.0	8.5	8	3
	28	4289	2	0	21.5	43,600	29.3	8.2	0	3
	33	4295	2	0	19.7	42,400	31.0	8.9	3	0
	36	4296	2	0	19.5	42,200	31.0	8.2	53	5
	38	4298	2	0	19.3	42,000	31.1	9.1	3	0
	38	4297	2	13	18.1	40,900	31.0	8.7	23	3
	39	4290	3	0	20.5	41,100	29.2	6.6	775	5
	40	4301	2	0	20.9	43,100	31.0	7.9	55	5
	41	4302	2	0	20.3	42,400	30.5	7.4	85	3
	42	4304	2	0	22	42,500	29.7	7.0	823	0
	42	4303	2	19	18.5	41,000	30.8	7.1	143	40
	44	4294	2	0	18	41,500	31.7	8.9	0	0
	44	4293	2	22	14.5	38,200	30.0	8.6	0	0
	54	4288	2	0	22.5	41,000	27.1	5.5	1,175	15
	55	4287	9	0	25.7	440	0.0	3.3	4,975	495
	84	4300	2	0	19.4	42,000	31.0	8.2	55	0
	84	4299	2	26	16.1	39,300	30.5	7.8	20	3
	89	4285	3	0	20.3	41,500	29.0	6.6	2,400	125

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
25-Jul	100	4306	6	0	19.6	41,600	30.0	7.1	800	153
	24	4311	6	0	17.6	40,000	30.5	9.0	3	45
	24	4310	6	43	15	37,900	29.0	8.5	48	238
	28	4309	6	0	20.5	42,700	29.3	7.3	75	50
	33	4314	6	0	18.9	41,000	29.0	9.3	0	3
	36	4315	6	0	19.2	41,000	29.2	9.3	3	3
	38	4317	6	0	18.6	41,000	29.5	9.1	0	0
	38	4316	6	13	17.5	39,900	29.2	8.5	15	110
	39	4324	2	0	20.6	41,000	29.2	7.3	1,150	0
	40	4320	6	0	20.4	41,000	29.2	7.5	13	5
	41	4321	6	0	19.5	41,000	30.0	7.8	10	3
	42	4323	1	0	20.1	41,000	30.0	7.1	65	3
	42	4322	1	15	19.2	41,000	30.0	7.3	30	398
	44	4313	6	0	17.8	40,000	30.5	9.1	0	3
	44	4312	6	20	14.5	37,500	29.8	9.0	43	5,500
	54	4308	6	0	21.3	40,900	28.0	5.7	283	18
	55	4307	9	0	25.2	450	0.0	6.2	620	148
	84	4319	6	0	18.6	41,000	30.8	8.5	0	0
	84	4318	6	26	17.1	39,800	29.5	7.9	8	15
	89	4305	6	0	20.4	42,000	28.0	5.6	1,550	130
26-Jul	100	4326	6	0	21.4	40,500	27.0	6.1	118	10
	24	4342	6	0	17.3	40,200	31.0	8.1	0	3
	24	4341	6	43	13.6	37,100	31.1	8.3	8	3
	28	4329	6	0	22.2	43,200	30.0	8.2	65	20
	33	4337	6	0	18.9	41,800	31.0	7.6	43	58
	36	4338	6	0	20	42,200	31.0	7.2	30	3
	38	4336	6	0	18.1	40,800	30.6	8.6	3	23
	38	4335	6	13	17	40,000	30.1	7.8	3	58
	39	4343	1	0	19.1	41,200	30.2	6.3	5	30
	40	4330	6	0	20	41,000	29.1	6.8	50	10
	41	4332	6	0	19.6	41,200	29.9	6.3	370	20
	42	4331	6	0	20.2	49,000	9.3	6.4	80	13
	44	4340	6	0	15.3	38,700	31.0	8.7	3	3
	44	4339	6	21	19.1	37,100	30.5	8.2	70	67
	54	4328	6	0	21.4	40,000	27.1	4.9	75	65
	55	4327	9	0	23.8	406	0.0	2.4	1,400	543
	84	4334	6	0	18.5	41,000	31.0	7.9	5	3
	84	4333	6	25	17.5	39,400	29.8	7.5	13	3
	89	4325	6	0	19.9	40,800	28.3	6.2	5,575	463
27-Jul	100	4345	6	0	19.9	39,100	26.5	4.9	6,750	2,000
	24	4362	6	0	17.5	39,200	30.0	3.7	380	128
	24	4361	6	42	14.2	37,200	30.0	3.3	555	368
	28	4346	6	0	19.4	40,900	28.0	6.8	700	618
	33	4357	6	0	18.3	40,000	29.8	1.2	363	1,125
	36	4358	6	0	19.1	41,000	30.0	2.3	315	250
	38	4356	6	0	17.6	39,700	29.0	2.2	263	125
	38	4355	6	13	16.7	33,900	26.7	0.8	345	238
	39	4363	6	0	18.7	39,800	29.2	1.6	2,350	678
	40	4349	6	0	20.1	39,900	28.5	5.9	2,200	663
	41	4350	6	0	20	38,100	22.1	4.3	0	0
	42	4352	6	0	20.8	32,300	23.0	1.3	4,725	3,475
	42	4351	6	18	19.4	40,000	29.0	2.6	1,035	1,725
	44	4360	6	0	15.2	38,000	30.0	5.2	25	153
	44	4359	6	19	14.6	37,800	30.5	4.2	280	168
	54	4348	6	0	21.4	30,700	19.1	4.4	9,975	3,100

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
27-Jul	55	4347	9	0	22.1	48,000	0.0	6.2	10,250	15,000
	84	4354	6	0	18.8	40,000	29.9	1.7	243	170
	84	4353	6	24	17.4	39,900	30.0	1.5	230	65
	89	4344	6	0	19.9	33,000	21.6	5.4	0	0
29-Jul	100	4365	6	0	20.3	33,900	23.2	5.8	400	0
	24	4377	6	0	17.4	39,300	29.2	7.4	1,550	33
	28	4366	6	0	19.6	42,000	29.2	10.4	0	40
	33	4374	6	0	18.1	40,000	29.9	6.7	30	3
	36	4375	6	0	19.1	40,800	30.5	7.3	118	3
	38	4373	6	0	18.2	39,800	29.6	6.9	0	0
	39	4378	6	0	19	39,900	28.0	5.4	0	26
	40	4369	5	0	19.7	37,900	27.1	6.0	95	13
	41	4370	5	0	19.4	33,500	23.8	4.9	313	125
	42	4371	5	0	20.5	30,800	21.0	5.2	478	80
	44	4376	6	0	17.4	39,100	29.2	7.2	43	0
	54	4368	6	0	20.8	29,000	20.0	4.8	425	200
	55	4367	9	0	22.1	388	0.0	7.2	2,125	2,000
	84	4372	6	0	18.4	39,400	29.3	6.7	10	3
	89	4364	5	0	20.5	34,000	22.7	5.0	295	98
30-Jul	100	4397	5	0	21	34,100	22.4	7.1	555	25
	24	4380	5	0	17.1	39,000	29.0	7.8	5	5
	24	4379	5	35	16.1	38,500	29.0	7.4	5	0
	28	4398	5	0	19.5	41,800	28.8	8.2	0	30
	33	4383	5	0	18.1	39,000	28.7	7.5	5	5
	36	4384	5	0	19.3	41,000	28.5	6.7	5	0
	38	4386	5	0	18.1	39,300	29.0	6.8	0	0
	38	4385	5	9	17.8	39,000	28.5	7.6	0	0
	39	4393	6	0	18.8	39,000	28.5	5.8	60	0
	40	4389	6	0	19.3	37,000	27.0	6.2	55	0
	41	4390	6	0	19.3	36,200	25.5	6.1	115	25
	42	4392	6	0	20	25,000	7.0	6.6	315	10
	42	4391	6	15	18.5	38,100	28.0	6.0	30	25
	44	4382	5	0	17.6	39,200	28.0	8.2	0	40
	44	4381	5	14	16.2	38,500	29.0	7.6	0	5
	54	4395	5	0	20.7	25,600	17.0	5.0	915	185
	55	4394	9	0	22	38,300	6.3	6.5	1,650	800
	84	4388	5	0	18.1	39,100	29.0	7.2	0	20
	84	4387	5	21	17.7	37,100	28.7	6.4	10	100
	89	4396	5	0	20.7	35,300	23.9	4.6	730	425
31-Jul	100	4402	6	0	21.1	39,000	26.7	7.0	35	10
	24	4405	5	0	18.3	38,000	28.0	8.5	0	0
	24	4404	5	35	16.7	39,000	29.0	7.5	5	0
	28	4403	6	0	20.3	41,800	29.6	9.2	0	5
	33	4409	6	0	20.7	41,000	28.3	7.9	40	0
	36	4408	6	0	19.2	40,000	27.2	8.9	0	0
	38	4411	6	0	19.1	37,500	28.5	8.1	0	0
	38	4410	6	9	18	39,000	28.2	8.8	0	0
	39	4418	6	0	20.7	37,000	25.3	6.5	70	0
	40	4414	6	0	19.9	38,000	26.0	7.3	25	10
	41	4415	6	0	19.6	37,200	26.0	6.9	45	25
	42	4417	6	0	20.7	35,000	24.0	6.7	105	25
	42	4416	6	16	18.8	38,000	27.0	6.6	15	30
	44	4407	5	0	18.4	39,400	28.8	8.8	0	5
	44	4406	5	14	16.8	38,700	29.3	7.7	15	0

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
31-Jul	54	4400	6	0	21.4	28,200	18.3	7.2	570	80
	55	4399	9	0	22.2	359	0.0	6.7	1,525	1,450
	84	4413	6	0	18.9	39,000	27.2	7.7	5	0
	84	4412	6	21	17.7	39,000	28.0	6.9	0	0
	89	4401	6	0	19.6	39,100	27.5	5.0	465	1,550
01-Aug	100	4422	5	0	26.6	31,500	18.2	12.0	700	125
	24	4425	5	0	19	40,100	29.0	8.3	25	5
	24	4424	5	34	17	39,100	30.0	6.3	165	10
	28	4423	5	0	19.2	41,200	29.2	7.2	0	125
	33	4428	5	0	19.6	40,200	29.1	8.8	15	5
	36	4429	5	0	19.4	40,100	29.1	8.0	0	0
	38	4431	5	0	18.9	39,200	29.0	8.0	30	0
	38	4430	5	8	18.5	39,100	29.0	8.4	5	5
	39	4438	5	0	20.5	38,100	26.6	6.9	25	0
	40	4434	5	0	20.2	39,100	28.0	7.1	45	0
	41	4435	5	0	19.5	38,800	27.5	6.9	45	5
	42	4437	5	0	21.3	36,300	27.0	6.4	1,385	10
	42	4436	5	16	19	38,300	28.3	6.8	60	0
	44	4427	5	0	18.8	40,000	29.0	8.3	10	5
	44	4426	5	13	17.6	39,300	29.9	7.6	5	0
	54	4420	5	0	20.9	27,400	17.5	3.4	630	85
	55	4419	9	0	22.4	350	0.0	5.3	1,200	445
	84	4433	5	0	18.9	39,200	29.0	7.7	5	10
	84	4432	5	19	18.3	39,000	29.0	7.3	35	5
	89	4421	5	0	19.7	25,000	16.5	4.7	5,950	2,630
02-Aug	100	4442	3	0	24	35,000	13.0	9.3	440	150
	24	4445	5	0	19.3	40,500	29.0	8.3	0	5
	24	4444	5	33	16.8	39,000	29.5	7.1	0	5
	28	4443	5	0	19.6	41,300	28.5	7.6	10	5
	33	4448	5	0	19.8	41,200	29.8	8.2	10	5
	36	4449	5	0	19.8	41,200	29.8	7.6	5	0
	38	4451	5	0	19.2	40,100	29.9	7.7	5	5
	38	4450	5	7	18.8	40,000	29.5	7.6	0	0
	39	4458	5	0	21.8	41,000	29.2	6.8	0	0
	40	4454	5	0	20.4	40,200	28.1	7.7	15	0
	41	4455	5	0	20.5	39,000	27.2	6.7	145	0
	42	4457	5	0	21.5	36,800	25.9	5.9	55	20
	42	4456	5	14	20.4	38,100	26.2	5.6	115	30
	44	4447	5	0	18.9	41,000	30.9	8.0	0	0
	44	4446	5	13	17.4	39,900	29.8	7.7	0	0
	54	4440	3	0	21.7	31,000	21.5	5.2	490	300
	55	4439	9	0	23.4	352	0.0	5.5	1,595	920
	84	4453	5	0	19.5	40,200	29.5	7.4	0	0
	84	4452	5	19	19	40,200	29.5	7.8	0	10
	89	4441	3	0	19.5	27,800	18.8	1.4	3,900	1,330
03-Aug	100	4462	3	0	21.6	31,000	20.0	9.7	665	240
	24	4475	4	0	18.8	40,000	29.9	7.0	120	5
	24	4474	4	29	15.9	38,100	28.2	7.4	35	0
	33	4472	3	0	19	40,500	30.1	7.5	35	5
	36	4473	3	0	18.8	40,800	30.1	6.8	50	10
	38	4471	3	0	18.6	40,000	29.8	6.9	0	5
	38	4470	3	7	18.2	39,900	29.2	7.1	450	10
	39	4478	5	0	19.8	40,500	30.0	5.8	20	5
	40	4464	3	0	20	399	28.0	6.0	50	5

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
03-Aug	41	4465	3	0	19.4	39,900	28.9	6.5	120	30
	42	4467	3	0	20.9	36,500	25.5	4.6	340	60
	42	4466	3	11	20.7	37,000	26.1	4.7	425	30
	44	4477	5	0	18.8	40,100	29.8	7.1	55	0
	44	4476	4	14	16.6	38,900	29.8	7.4	55	0
	54	4460	3	0	21.6	34,000	21.2	5.5	570	155
	55	4459	9	0	23.3	320	0.0	5.5	7,000	865
	84	4469	3	0	19.2	39,800	27.8	6.6	25	5
	84	4468	3	19	18.8	39,200	27.0	6.8	90	0
	89	4461	3	0	19.3	32,500	22.2	2.9	2,150	4,900
05-Aug	100	4482	3	0	20	40,000	27.5	6.8	30	30
	24	4485	3	0	18.1	39,200	28.6	6.4	45	0
	24	4484	3	39	13.6	36,200	28.8	7.8	5	5
	28	4483	3	0	18.5	40,100	29.1	5.8	10	0
	33	4488	3	0	18.2	39,400	28.8	6.8	0	0
	36	4489	3	0	18.4	39,900	28.8	6.3	5	0
	38	4491	3	0	17.9	39,200	29.2	6.6	10	5
	38	4490	3	10	16.1	37,900	28.9	7.2	5	5
	39	4498	3	0	18.8	39,200	27.9	6.0	10	0
	40	4494	3	0	18.7	39,200	28.2	6.1	30	30
	41	4495	3	0	19	39,000	28.5	6.0	45	70
	42	4497	3	0	19.9	35,500	24.8	4.6	865	125
	42	4496	3	15	19	38,100	27.2	4.7	150	75
	44	4487	3	0	17.1	39,000	29.5	6.5	15	50
	44	4486	3	17	14.6	36,800	28.9	7.7	0	25
	54	4480	3	0	21.2	30,000	19.9	4.5	1,000	120
	55	4479	9	0	21.7	365	0.1	5.8	8,100	1,122
	84	4493	3	0	18.5	39,200	28.8	6.3	20	20
	84	4492	3	21	16.8	38,500	28.5	6.2	10	0
	89	4481	3	0	18.8	39,700	28.0	4.7	1,280	380
06-Aug	100	4502	2	0	19.5	37,000	28.0	5.5	100	30
	24	4517	2	0	16.9	38,900	29.2	6.8	5	0
	24	4516	2	39	14.4	38,000	28.9	7.3	10	0
	28	4503	2	0	19.1	41,140	30.0	7.1	15	15
	33	4512	2	0	17.1	39,200	29.2	7.7	5	5
	36	4513	2	0	17	39,000	29.3	7.6	5	5
	38	4511	2	0	17.1	39,000	29.3	7.3	0	0
	38	4510	2	11	15.6	38,000	29.4	7.3	0	0
	39	4518	2	0	17.4	39,000	29.3	6.0	25	0
	40	4504	2	0	18.9	39,400	29.0	6.4	140	70
	41	4505	2	0	18.1	39,300	29.2	6.6	0	0
	42	4507	2	0	19.3	38,000	27.0	5.8	100	10
	42	4506	2	18	18.1	39,300	29.7	5.9	20	15
	44	4515	2	0	16.7	39,500	29.1	7.0	15	0
	44	4514	2	17	14.8	37,000	28.2	7.7	0	0
	54	4500	2	0	20.7	30,500	20.0	4.9	600	140
	55	4499	9	0	21.7	405	0.0	3.9	3,800	1,085
	84	4509	2	0	17.6	39,000	29.1	7.0	0	0
	84	4508	2	22	16.1	38,400	28.5	6.7	0	0
	89	4501	2	0	18.8	40,000	28.8	5.3	185	105
07-Aug	100	4522	2	0	20.5	40,000	27.0	6.7	290	60
	24	4525	2	0	17.5	38,800	29.6	7.0	0	0
	24	4524	2	41	15	37,700	28.7	8.2	0	10
	28	4523	2	0	20.2	42,300	29.3	7.0	95	105

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
07-Aug	33	4528	2	0	17.7	39,400	28.9	8.2	5	20
	36	4529	2	0	18.3	39,900	28.9	8.2	0	5
	38	4531	2	0	18.1	39,600	28.8	8.0	0	0
	38	4530	2	12	16.5	38,100	28.3	7.5	0	0
	39	4538	2	0	19.3	39,400	27.9	6.1	10	0
	40	4534	2	0	19.7	39,300	28.1	6.8	30	0
	41	4535	2	0	18.6	39,000	28.2	7.0	10	0
	42	4537	2	0	19.4	38,100	27.4	6.1	65	5
	42	4536	2	18	18.2	38,500	28.3	6.0	30	15
	44	4527	2	0	16.5	38,900	29.9	7.3	0	0
	44	4526	2	22	14.8	37,400	29.7	8.1	10	0
	54	4520	2	0	21.1	29,000	17.8	5.3	820	105
	55	4519	9	0	22.2	400	0.0	5.4	1,850	1,010
	84	4533	2	0	18.3	39,100	28.1	7.6	0	5
	84	4532	2	22	16.6	38,400	27.9	7.1	15	0
	89	4521	2	0	18.5	39,000	24.9	6.3	20	15
08-Aug	100	4542	2	0	20.5	41,200	29.3	7.0	35	20
	24	4557	2	0	17.7	39,700	29.5	8.3	0	10
	24	4556	2	43	16	38,000	29.2	8.4	0	20
	28	4543	2	0	20.7	42,900	30.5	8.1	0	45
	33	4552	2	0	18.7	41,000	31.1	9.4	5	0
	36	4553	2	0	19.1	41,000	30.0	9.5	0	0
	38	4551	2	0	18	40,000	30.4	8.3	5	120
	38	4550	2	15	16.8	38,700	30.3	8.4	0	465
	39	4558	2	0	18.7	40,000	29.2	7.2	25	5
	40	4544	2	0	19.8	39,800	27.0	7.2	0	30
	41	4545	2	0	19.2	40,000	27.0	7.6	0	10
	42	4547	2	0	19.3	39,500	26.8	7.4	5	650
	42	4546	2	21	18.3	39,600	26.2	5.9	15	1,800
	44	4555	2	0	16.6	39,300	31.0	8.4	0	175
	44	4554	2	21	16.1	39,000	30.4	8.5	0	480
	54	4540	2	0	22.3	33,700	22.1	5.3	270	80
	55	4539	9	0	23.8	415	0.0	6.8	1,095	465
	84	4549	2	0	17.7	39,300	30.0	8.0	15	45
	84	4548	2	26	17.2	38,400	29.7	7.3	0	0
	89	4541	2	0	20.5	41,200	29.3	7.0	15	30
10-Aug	100	4562	6	0	18.6	39,900	28.5	7.9	650	625
	24	4577	6	0	17	39,000	29.8	4.9	50	30
	24	4576	6	42	16.8	38,800	29.9	7.2	100	35
	28	4563	6	0	18.7	38,500	27.7	7.9	1,165	3,400
	33	4572	6	0	18.5	39,800	29.6	6.9	3,200	1,200
	36	4573	6	0	18.7	39,100	29.1	5.9	5,000	1,910
	38	4571	6	0	17.3	39,200	29.9	7.4	10	55
	38	4570	6	15	17.3	39,200	29.5	7.5	5	30
	39	4578	6	0	19.4	38,800	28.2	5.2	685	4,800
	40	4564	6	0	19.3	38,600	28.0	6.5	495	1,148
	41	4565	6	0	18.8	35,300	27.0	6.6	49,500	54,000
	42	4567	6	0	19.2	38,700	28.0	6.1	645	1,310
	42	4566	6	21	18.5	39,300	28.5	7.0	150	345
	44	4575	6	0	15.9	38,100	30.0	7.3	0	30
	44	4574	6	22	15.9	38,200	29.9	7.3	0	75
	54	4560	6	0	19.7	37,800	26.1	5.8	1,525	1,500
	55	4559	6	0	21	312	0.0	6.6	25,500	80,250
	84	4569	6	0	17.7	39,400	29.9	7.5	0	60
	84	4568	6	26	17.7	39,200	29.6	7.4	5	385
	89	4561	6	0	19.4	36,800	25.3	6.2	89,000	84,500

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
12-Aug	11	4586	9	0	24.8	1,220	0.3	8.9	50	5
	14	4588	6	0	20.5	35,000	20.0	6.6	125	10
	14	4587	6	35	17.3	39,000	29.2	6.1	5	5
	15	4584	6	0	19.8	41,000	29.2	8.1	80	10
	18	4581	6	0	20	41,000	25.8	6.3	135	0
	18	4580	6	16	19.2	40,300	26.4	6.4	180	10
	19	4590	6	0	19.8	37,900	26.8	7.3	10	0
	19	4589	6	28	17.2	39,000	29.0	6.4	0	0
	21	4592	6	0	18.9	40,000	29.0	8.0	0	0
	21	4591	6	44	17.3	38,400	29.3	7.1	0	0
	22	4594	6	0	20.8	42,000	29.8	6.8	5	50
	22	4593	6	42	16.9	38,500	28.9	6.9	10	5
	24	4596	6	0	17.5	39,000	29.2	7.6	10	20
	24	4595	6	40	17	38,000	29.0	7.3	0	355
	27	4585	6	0	19.6	40,300	29.1	8.2	40	15
	44	4601	6	0	16.2	37,300	28.6	7.6	0	0
	44	4600	6	21	15.8	38,000	28.2	7.6	0	0
	52	4582	6	0	19.6	41,000	29.3	5.7	995	125
	52	4583	6	0	19.8	38,500	27.5	4.8	375	70
	75	4579	6	0	19.4	39,000	25.0	5.3	12,900	44,500
	91	4597	6	0	19.1	41,000	29.0	6.2	10	20
	92	4598	6	0	19.1	40,300	29.0	6.3	5	0
	98	4599	6	0	19.4	40,200	25.0	6.7	5	0
13-Aug	11	4605	5	0	25.4	1,170	0.5	10.7	0	5
	14	4607	5	0	20.5	39,300	27.9	8.5	5	0
	14	4606	5	35	17.5	38,700	28.5	6.4	5	0
	15	4610	6	0	21.3	41,000	28.3	9.0	10	5
	18	4604	6	0	21	41,500	29.5	5.6	475	20
	18	4603	6	24	18.9	40,100	28.5	6.8	100	5
	19	4613	6	0	20.7	40,300	28.2	9.5	10	10
	19	4612	6	27	17.6	38,700	28.2	7.1	0	0
	21	4615	6	0	20.4	40,800	28.7	9.3	15	5
	21	4614	6	39	17.4	38,100	28.7	8.6	5	15
	22	4617	6	0	22	42,400	28.5	7.0	0	0
	22	4616	6	40	16.5	37,800	28.3	7.9	0	0
	24	4619	6	0	18.7	39,600	28.3	10.1	0	0
	24	4618	6	39	16.6	38,000	28.1	7.9	0	0
	27	4611	6	0	20.4	39,900	28.2	8.8	10	0
	44	4624	6	0	15.3	37,100	28.6	8.4	0	0
	44	4623	6	21	15.3	37,000	28.6	8.5	0	0
	52	4609	6	0	20.7	38,200	26.4	4.9	355	55
	52	4608	6	10	20.6	41,000	28.8	5.8	590	20
	75	4602	6	0	21.1	40,900	28.5	6.0	400	20
	91	4620	6	0	19.9	40,100	27.3	8.0	0	0
	92	4621	6	0	19.9	40,300	28.5	7.9	5	0
	98	4622	6	0	20.2	40,700	28.5	8.3	40	10
14-Aug	11	4634	9	0	26.1	14,000	0.4	9.4	30	5
	14	4633	5	0	20	40,000	29.2	8.8	15	20
	14	4632	5	33	17.1	39,000	29.5	7.3	10	5
	15	4630	5	0	20.7	41,000	28.8	8.1	5	5
	18	4627	6	0	20.9	42,200	29.7	6.1	1,079	25
	18	4626	5	16	18.1	40,000	29.2	6.3	60	10
	19	4636	5	0	20.5	41,000	29.0	8.8	75	5
	19	4635	5	26	17.1	38,800	26.9	6.9	10	5
	21	4638	5	0	19.7	40,800	31.1	8.7	15	0

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
14-Aug	21	4637	5	37	16.1	38,100	29.0	7.9	10	0
	22	4640	5	0	20.4	42,100	30.0	7.0	10	10
	22	4639	5	37	16	38,000	29.9	8.0	5	85
	24	4642	5	0	18.5	40,000	30.0	9.7	15	10
	24	4641	5	37	15.8	38,000	29.5	7.9	0	5
	27	4631	5	0	19.5	40,000	29.1	7.7	20	10
	44	4647	6	0	17.5	39,900	30.0	9.2	10	0
	44	4646	6	18	15.8	38,500	30.0	8.2	0	5
	52	4629	5	0	21.1	35,500	25.0	5.3	360	110
	52	4628	5	4	20.9	39,000	28.7	5.0	2,000	135
	75	4625	5	0	20.8	40,900	28.8	5.6	500	40
	91	4643	5	0	20.2	41,500	31.1	8.4	30	5
	92	4644	5	0	19.8	41,400	30.2	9.1	20	0
	98	4645	6	0	21.3	42,100	30.0	9.2	15	0
15-Aug	11	4657	9	0	26.5	1,410	0.8	8.9	30	0
	14	4656	5	0	20.6	41,000	29.1	7.5	60	20
	14	4655	5	33	16.7	39,100	28.0	7.1	15	130
	15	4653	5	0	21.2	42,600	30.5	6.9	165	25
	18	4650	5	0	19.9	41,200	29.3	6.0	1,030	55
	18	4649	5	16	18.2	39,500	28.1	6.4	75	5
	19	4659	5	0	19.3	41,000	29.0	7.2	55	145
	19	4658	5	37	16.5	39,000	27.6	7.6	0	285
	21	4661	5	0	20.1	41,500	29.6	7.9	30	110
	21	4660	5	32	16.5	39,000	27.8	7.6	0	20
	22	4663	5	0	20.6	42,300	30.5	6.9	5	0
	22	4662	5	34	16.4	39,000	27.6	7.5	0	5
	24	4665	5	0	18.3	40,000	28.5	8.6	5	25
	24	4664	5	35	15.8	38,700	27.0	8.0	0	20
	27	4654	5	0	20	41,100	29.5	7.5	40	15
	44	4670	6	0	18.3	40,200	28.9	8.7	5	15
	44	4669	6	18	16.2	39,000	27.8	7.2	0	35
	52	4652	5	0	21.1	36,000	24.9	5.1	65,800	17,450
	52	4651	5	7	19.8	41,500	29.5	3.9	1,145	230
	75	4648	5	0	20.9	40,500	28.5	4.6	2,225	120
	91	4666	5	0	20	41,900	29.8	6.9	25	0
	92	4667	5	0	19.9	41,900	29.9	7.5	260	20
	98	4668	5	0	19.9	41,800	29.8	6.8	0	10
16-Aug	11	4680	9	0	26.6	1,340	1.0	8.2	50	0
	14	4679	5	0	20.5	40,300	28.8	6.9	5	5
	14	4678	5	32	16.5	38,800	30.0	7.1	25	0
	15	4676	5	0	21.2	42,300	29.9	7.1	155	0
	18	4672	5	0	20.2	41,100	28.8	5.6	25	10
	18	4671	5	22	17.8	39,300	28.8	6.1	20	15
	19	4682	5	0	20.3	41,900	30.3	7.2	25	10
	19	4681	5	24	16.7	39,300	30.8	7.1	0	10
	21	4684	5	0	20.4	41,800	30.0	8.0	25	35
	21	4683	5	34	15.5	38,300	30.9	7.8	20	0
	22	4686	5	0	21.1	42,900	30.6	7.1	15	50
	22	4685	5	34	15.4	38,300	30.4	7.8	5	0
	24	4688	5	0	18.8	40,300	30.2	8.5	80	0
	24	4687	5	35	15	38,100	30.3	8.1	0	0
	27	4677	5	0	21.3	42,100	29.8	8.0	50	0
	44	4693	5	0	18.5	39,900	30.2	8.8	290	0
	44	4692	5	16	15.7	38,200	30.2	8.1	30	15
	52	4675	5	0	21	33,800	23.5	4.9	100,000	100,000

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
16-Aug	52	4674	5	6	19.8	41,200	29.9	4.9	630	240
	75	4673	5	0	20.8	41,200	28.8	5.0	240	65
	91	4689	5	0	20	41,500	30.3	9.2	380	0
	92	4690	5	0	19.8	41,800	30.3	9.3	115	0
	98	4691	5	0	21.1	39,200	30.2	7.9	25	10
17-Aug	11	4701	9	0	26.9	92	0.7	8.2	275	40
	14	4705	5	0	20.9	41,300	29.1	7.5	0	535
	14	4704	5	33	15.7	38,800	29.7	7.5	10	735
	15	4697	3	0	21.6	43,000	31.0	8.2	295	10
	18	4696	5	0	21	42,100	29.2	6.0	10	5
	18	4695	5	20	17.4	39,500	29.1	6.7	35	5
	19	4703	4	0	20.2	41,500	30.4	7.4	65	95
	19	4702	4	35	15.5	38,500	26.0	7.6	5	495
	21	4707	5	0	20.7	42,000	30.5	8.0	5	215
	21	4706	5	36	15	38,000	31.0	7.4	50	50
	22	4709	5	0	20.3	42,500	30.5	7.1	0	50
	22	4708	5	34	15	38,000	29.5	7.8	100	85
	24	4710	5	0	19.7	42,000	30.5	8.8	10	220
	24	4711	5	36	15	38,000	30.0	8.0	385	830
	27	4700	3	0	21.8	43,000	31.0	9.3	0	30
	44	4716	5	0	17.8	40,500	29.4	8.7	0	20
	44	4715	5	17	15	38,000	30.7	8.0	395	50
	52	4699	3	0	20.5	38,000	28.0	5.2	1,950	105
	52	4698	3	9	19.3	41,500	30.8	3.5	620	115
	75	4694	5	0	21.6	40,900	27.3	3.5	1,270	370
	91	4712	5	0	21.4	43,200	30.0	6.4	320	125
	92	4713	5	0	21	43,000	30.0	7.3	5	10
	98	4714	5	0	23.2	44,500	32.0	11.5	10	0
20-Aug	11	4726	3	0	23.9	1,200	1.0	6.5	650	100
	14	4725	3	0	20	31,200	23.5	6.3	1,850	700
	14	4724	3	34	15.9	38,000	29.9	6.7	0	0
	15	4722	3	0	19.8	34,900	24.5	6.0	2,100	350
	18	4719	3	0	20.4	30,000	20.0	5.3	112,500	5,600
	18	4718	3	24	17.1	39,000	26.9	5.7	950	3,150
	19	4728	3	0	19.9	34,000	24.5	6.9	1,550	200
	19	4727	3	28	16.3	38,000	29.9	5.2	50	0
	21	4730	3	0	19.8	35,100	25.0	7.3	500	150
	21	4729	3	39	15.1	37,000	29.0	7.5	450	0
	22	4732	3	0	19.9	34,000	24.4	6.9	5,000	1,150
	22	4731	3	38	15.1	37,000	29.9	7.4	400	100
	24	4734	3	0	19.5	35,500	25.0	7.3	1,300	1,150
	24	4733	3	39	15.1	32,100	29.4	7.5	400	1,850
	27	4723	3	0	19.5	35,000	25.0	6.8	1,800	300
	44	4739	3	0	18.8	37,000	27.5	7.2	850	200
	44	4738	3	16	17.1	38,500	29.5	7.1	150	0
	52	4721	3	0	18.9	32,000	15.0	6.3	2,950	950
	52	4720	3	13	17.6	38,000	25.0	4.4	2,200	1,650
	75	4717	3	0	21.1	32,900	22.0	3.6	263,000	46,500
	91	4735	3	0	20.2	40,100	28.5	6.2	9,050	2,550
	92	4736	3	0	20.1	40,000	28.5	6.3	150	100
	98	4737	3	0	20	40,000	28.0	5.2	0	150
21-Aug	11	4753	9	0	22.6	1,300	0.8	4.2	2,350	340
	14	4752	2	0	19	28,100	19.2	5.9	1,500	1,005
	14	4751	2	41	16.1	38,200	29.9	4.2	70	25

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
21-Aug	15	4749	2	0	19.3	30,000	21.4	5.9	17,500	3,950
	18	4745	3	0	18.5	10,200	6.7	5.9	281,000	114,000
	18	4744	3	19	17.2	39,300	29.6	4.6	500	1,300
	19	4755	2	0	19.2	28,900	21.5	.	2,050	1,500
	19	4754	2	29	16.6	38,200	27.5	.	95	45
	21	4757	2	0	19.5	30,500	22.1	.	2,050	1,480
	21	4756	2	41	16.5	36,800	29.2	.	50	55
	22	4759	2	0	19.5	31,500	24.6	.	3,550	1,350
	22	4758	2	41	16.5	37,800	30.0	.	80	40
	24	4761	2	0	19	32,100	23.8	.	2,130	570
	24	4760	2	40	16.2	36,500	29.8	.	110	220
	27	4750	2	0	17.6	33,800	25.0	6.0	48,500	14,200
	42	4746	2	0	18	10,800	10.0	6.9	44,000	28,400
	44	4763	2	0	19	33,500	26.8	.	785	260
	44	4762	2	20	16.5	37,200	29.2	.	190	210
	52	4748	2	0	19.5	21,200	15.5	6.6	42,000	3,550
	52	4747	2	10	19	37,000	27.5	3.5	11,500	3,300
	54	4741	2	0	18.9	3,750	2.1	7.9	17,000	16,850
	55	4740	2	0	18.9	210	0.0	7.9	8,300	9,500
	75	4743	3	0	18.4	4,200	2.5	6.7	344,500	256,500
	89	4742	2	0	17.2	7,800	5.0	8.3	0	0
22-Aug	11	4773	9	0	22.7	1,100	0.5	4.7	905	65
	14	4772	2	0	20	32,200	22.9	5.2	940	100
	14	4771	2	39	16.3	38,300	30.1	4.7	105	390
	15	4769	2	0	21.2	28,900	20.0	6.7	4,250	105
	18	4766	3	0	21.5	34,300	22.7	4.3	7,100	200
	18	4765	2	23	17.5	39,000	29.0	3.9	850	250
	19	4775	2	0	20.1	34,300	24.8	5.3	1,350	90
	19	4774	2	29	16.6	38,700	30.0	5.6	70	25
	21	4777	2	0	19.6	34,900	24.5	5.6	1,140	90
	21	4776	2	41	15.9	37,700	29.9	5.2	40	355
	22	4779	2	0	20.3	35,900	25.6	5.8	625	100
	22	4778	2	39	15.9	37,900	29.9	6.0	45	180
	24	4781	2	0	19.6	35,100	25.3	6.0	1,035	15
	24	4780	2	40	15.8	37,800	29.9	6.1	15	320
	27	4770	2	0	19.8	31,700	22.3	6.3	1,800	120
	44	4786	2	0	19.3	37,800	27.4	5.7	70	0
	44	4785	2	19	16	37,400	29.5	6.0	15	105
	52	4768	2	0	20.2	34,800	24.7	5.0	1,950	65
	52	4767	2	15	18.9	38,800	25.3	3.4	3,600	1,030
	75	4764	2	0	21.4	32,000	21.0	2.5	15,500	4,100
	91	4782	2	0	20.5	38,500	27.4	5.1	35	30
	92	4783	2	0	20	38,300	27.7	4.5	20	0
	98	4784	2	0	19.8	38,900	28.0	4.5	70	5
23-Aug	11	4796	9	0	22.9	70	0.5	6.1	905	4,550
	14	4795	2	0	20	28,700	20.0	5.6	1,130	95
	14	4794	2	40	16.3	37,200	28.2	5.5	20	20
	15	4792	1	0	19.9	33,000	22.9	6.1	545	15
	18	4789	2	0	19.6	38,600	26.9	4.4	645	65
	18	4788	2	28	17.6	39,200	28.8	3.5	1,000	245
	19	4798	2	0	19.7	36,000	25.2	5.9	180	40
	19	4797	2	31	16.3	38,000	29.5	6.2	25	5
	21	4800	2	0	19	35,000	25.0	6.4	230	40
	21	4799	2	41	16.1	37,000	27.5	6.9	20	25
	22	4802	2	0	21.6	41,800	27.8	5.9	0	5

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
23-Aug	22	4801	2	40	16	37,000	28.0	6.2	15	0
	24	4804	2	0	18.7	37,000	27.0	6.5	75	5
	24	4803	2	43	15.9	37,000	28.0	7.1	5	0
	27	4793	1	0	19.4	35,500	25.5	6.2	200	30
	44	4809	2	0	18.4	38,000	28.0	6.8	70	0
	44	4808	2	19	15.8	37,000	28.1	7.6	45	5
	52	4791	6	0	20.3	39,600	28.3	4.9	1,050	145
	52	4790	6	14	19.6	39,000	28.3	2.1	1,900	425
	75	4787	2	0	20	37,700	26.3	3.6	5,900	1,535
	91	4805	2	0	19.3	35,000	27.0	6.5	25	5
	92	4806	2	0	19.4	38,700	27.5	6.4	5	0
	98	4807	2	0	19.9	39,000	27.0	5.9	40	5
24-Aug	11	4819	9	0	22.8	900	0.3	6.5	465	205
	14	4818	6	0	20	34,000	22.0	5.7	140	10
	14	4817	6	40	16.2	37,200	27.3	4.7	20	5
	15	4815	6	0	20	36,700	26.0	6.5	50	10
	18	4812	6	0	19.4	32,600	27.9	5.8	405	1,095
	18	4811	6	24	17.1	38,400	28.9	4.4	270	70
	19	4821	1	0	20	32,200	22.6	5.9	240	125
	19	4820	1	41	16.4	37,100	27.2	6.1	5	5
	21	4823	2	1	19.4	36,000	25.5	6.5	80	15
	21	4822	1	42	16	37,100	27.6	6.1	20	10
	22	4825	2	0	21.1	40,700	28.2	5.9	10	70
	22	4824	2	43	16.5	37,100	27.2	6.1	5	25
	24	4827	2	0	18.1	37,900	27.3	6.7	0	0
	24	4826	2	43	16.1	37,000	27.5	7.1	0	30
	27	4816	6	0	19.3	37,300	26.7	6.6	0	5
	44	4829	2	0	16.9	37,800	28.0	7.3	45	0
	44	4828	2	20	16	36,900	27.4	7.6	240	20
	52	4814	6	0	21.1	36,600	26.0	4.9	730	65
	52	4813	6	13	20.8	40,200	28.3	4.1	510	255
	75	4810	6	0	19.9	36,900	26.0	5.4	4,600	405
26-Aug	11	4839	9	0	22.2	9,189	1.0	8.6	1,225	55
	14	4838	6	0	20	30,300	20.5	6.7	545	1,690
	14	4837	6	38	16.5	37,800	29.0	4.7	5	1,030
	15	4835	6	0	19.8	37,000	26.0	6.6	75	15
	18	4832	6	0	19.8	36,900	25.8	4.4	70	15
	18	4831	6	24	17.4	38,100	26.8	3.7	150	30
	19	4841	6	0	20.1	37,100	27.1	7.8	5	115
	19	4840	6	30	16.7	37,900	29.0	6.3	0	0
	21	4843	6	0	19.8	37,100	27.1	8.6	30	10
	21	4842	6	41	16.8	38,000	29.1	7.6	5	2,025
	22	4845	6	0	20.8	40,400	29.1	6.8	0	110
	22	4844	6	40	16.7	37,800	29.1	7.3	0	1,695
	24	4847	6	0	18.2	37,200	28.1	8.4	10	125
	24	4846	6	43	16.8	37,800	29.0	8.0	0	95
	27	4836	6	0	19.7	31,200	22.0	7.9	85	25
	44	4852	6	0	17.2	38,200	29.8	8.8	0	90
	44	4851	6	20	16.7	38,000	29.1	8.2	0	470
	52	4834	6	0	21	37,200	26.9	5.4	2,250	150
	52	4833	6	12	20	39,400	28.0	4.0	700	325
	75	4830	6	0	19.8	37,000	24.6	4.4	1,950	2,335
	91	4848	6	0	19.8	39,000	28.1	7.1	5	0
	92	4849	6	0	19.2	38,100	28.0	6.8	15	35
	98	4850	6	0	19.6	38,800	28.2	7.5	5	5

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
27-Aug	11	4862	6	0	22.9	7,500	0.2	8.6	445	75
	14	4861	6	0	20.1	29,000	20.9	7.3	255	345
	14	4860	6	37	16.7	38,400	27.0	5.6	15	765
	15	4858	6	0	21.1	38,000	26.5	8.2	115	15
	18	4855	6	0	19.5	38,900	27.7	5.0	550	60
	18	4854	6	24	18	38,100	27.9	4.4	10	25
	19	4864	6	0	20.2	39,100	27.8	8.2	80	130
	19	4863	6	29	16.9	38,600	27.1	7.2	0	235
	21	4866	6	0	19.4	38,900	27.3	8.6	915	525
	21	4865	6	40	16.9	38,900	27.2	8.1	.	165
	22	4868	6	0	20.8	42,000	31.5	7.3	0	130
	22	4867	6	39	16.9	38,900	28.9	8.0	0	85
	24	4870	6	0	18.8	39,200	29.0	9.3	0	150
	24	4869	6	40	16.7	38,900	28.8	8.6	0	55
	27	4859	6	0	20.9	35,900	24.9	9.0	120	65
	44	4875	6	0	17.5	39,000	29.4	8.6	0	20
	44	4874	6	21	16.7	38,800	29.0	8.4	0	610
	52	4857	6	0	21.1	37,900	26.5	5.4	595	205
	52	4856	6	12	20.4	40,100	26.0	4.3	510	150
	75	4853	6	0	20.4	39,100	27.1	4.2	210	10
	91	4871	6	0	19.4	40,000	29.8	7.5	55	20
	92	4872	6	0	19.7	40,000	29.9	7.7	20	10
	93	4873	6	0	19.5	40,000	29.9	7.6	5	0
29-Aug	11	4885	9	0	25.6	680	0.1	9.3	160	0
	14	4884	5	0	21.2	36,200	23.1	6.9	85	30
	14	4883	5	38	17.2	38,800	29.5	6.3	5	5
	15	4881	5	0	21.5	39,800	27.8	7.6	35	25
	18	4878	6	0	21.2	41,500	28.4	7.1	155	125
	18	4877	6	25	17.8	40,000	29.5	5.5	45	110
	19	4887	6	0	21.3	38,800	27.0	7.8	40	10
	19	4886	6	29	17.2	38,800	29.8	6.6	220	30
	21	4889	6	0	20.3	40,000	28.6	8.2	45	30
	21	4888	6	34	16.9	38,900	30.0	7.4	335	90
	22	4891	6	0	22.5	43,000	29.5	6.5	0	40
	22	4890	6	39	16.8	38,800	30.0	7.1	125	60
	24	4893	6	0	19.5	40,100	29.5	9.3	5	25
	24	4892	6	40	17.3	38,800	29.3	7.5	320	165
	27	4882	5	0	21.5	39,400	27.9	9.4	55	10
	44	4898	6	0	19.9	40,200	29.3	9.5	0	90
	44	4897	6	21	16.7	38,700	29.5	7.5	335	125
	52	4880	5	0	21.1	39,000	23.5	5.3	500	60
	52	4879	5	10	20.6	40,800	29.2	3.2	500	185
	75	4876	5	0	21.8	41,800	28.2	5.2	1,170	80
	91	4894	6	0	21.2	41,000	28.9	8.2	0	0
	92	4895	6	0	21.1	41,000	28.9	8.2	5	0
	98	4896	6	0	21.1	41,100	29.0	8.0	0	5
30-Aug	11	4908	9	0	24.9	670	0.1	7.6	220	170
	14	4907	5	0	21.1	35,100	21.0	8.1	95	190
	14	4906	5	35	17.1	38,500	28.9	6.7	15	380
	15	4904	5	0	22	38,500	26.2	8.2	10	5
	18	4901	5	0	21.1	41,200	28.6	5.7	165	720
	18	4900	5	19	18	38,900	28.5	4.7	85	2,280
	19	4910	5	0	21	40,000	27.9	8.5	40	385
	19	4909	5	29	17.4	38,300	28.3	7.1	40	300
	21	4912	5	0	19.9	32,900	29.2	8.9	10	225

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
30-Aug	21	4911	5	36	16.9	38,400	28.9	8.1	60	115
	22	4914	5	0	22.9	43,100	29.5	7.3	0	100
	22	4913	5	39	16.7	38,400	28.9	7.7	70	175
	24	4916	5	0	19.5	39,400	28.2	10.1	0	160
	24	4915	5	36	16.8	38,400	29.1	8.3	15	110
	27	4905	5	0	21.5	35,600	24.4	8.5	50	85
	44	4921	5	0	19.3	39,400	28.6	10.2	0	55
	44	4920	5	18	16.8	38,200	29.0	8.4	50	40
	52	4903	5	0	21.7	33,900	23.2	5.7	270	30
	52	4902	5	6	20.9	40,700	28.5	4.2	175	70
	75	4899	5	0	22.3	40,200	27.2	2.5	630	540
	91	4917	5	0	21.4	40,900	28.4	8.6	5	245
	92	4918	5	0	20.8	40,500	28.5	9.1	10	120
	98	4919	5	0	21.3	41,200	28.8	8.6	0	135
03-Sep	1	4940	9	0	21.8	242	0.0	6.5	320	425
	10	4927	9	0	23.3	590	0.0	7.7	60	30
	10	4926	9	23	13.2	27,500	21.8	0.6	10	0
	11	4925	9	0	23.2	720	0.5	7.5	60	140
	11	4924	9	22	20.3	25,800	16.5	3.6	145	650
	14	4923	3	0	18.6	38,900	28.2	6.8	5	40
	14	4922	3	34	17	38,500	29.2	6.1	0	0
	2	4939	9	0	21.7	241	0.0	6.7	4,200	1,390
	3	4938	9	0	23	239	0.0	7.0	245	180
	4	4937	9	0	23.2	249	0.0	7.9	85	105
	5	4936	9	0	23	250	0.0	8.1	95	50
	6	4935	9	0	22.5	269	0.0	6.9	185	255
	6	4934	9	9	21.7	370	0.0	5.0	1,140	225
	7	4933	9	0	22.3	372	0.0	6.1	1,685	230
	7	4932	9	11	22.3	372	0.0	6.2	1,530	225
	8	4931	9	0	22.9	495	0.0	8.0	150	40
	8	4930	9	13	22.5	462	0.2	6.1	450	55
	9	4929	9	0	22.8	510	0.0	8.2	80	40
	9	4928	9	17	20.7	20,000	14.0	0.5	120	30
04-Sep	1	4957	9	0	22.3	252	0.0	7.4	310	175
	10	4946	9	0	23	590	0.0	8.1	25	380
	10	4945	9	26	13.5	27,400	22.2	0.3	0	5
	11	4944	9	0	22.9	730	0.2	8.6	20	935
	11	4943	9	21	20.9	22,500	14.5	3.9	30	135
	14	4942	3	0	19	38,800	28.3	7.0	5	345
	14	4941	3	37	17	38,200	29.1	6.4	10	25
	2	4956	9	0	21.6	256	0.0	7.2	3,200	225
	3	4955	9	0	24	252	0.0	9.1	590	160
	4	4954	9	0	22.9	249	0.0	7.9	560	15
	5	4953	9	0	22.5	258	0.0	7.3	420	75
	6	4952	9	0	22.2	308	0.0	6.3	875	265
	6	4951	9	10	21.8	359	0.0	5.5	1,200	310
	7	4950	9	0	22.1	359	0.0	6.8	1,425	315
	7	4949	9	16	22	359	0.0	6.6	1,390	350
	8	4959	9	0	22.8	570	0.0	8.2	1,495	35
	8	4958	9	18	22.2	5,000	1.5	0.1	205	15
	9	4948	9	0	22.4	550	0.0	8.4	70	595
	9	4947	9	20	20.6	19,000	13.7	0.2	10	5

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
05-Sep	1	4981	9	0	21.5	227	0.0	.	6,550	7,550
	10	4968	9	0	24.1	600	0.0	.	50	100
	10	4967	9	23	20.4	11,000	10.0	.	0	550
	11	4966	9	0	23.1	800	0.0	.	100	150
	11	4965	9	25	20.5	24,000	17.1	.	50	550
	14	4964	2	0	19.5	39,000	27.2	6.0	.	1,500
	14	4963	2	37	17.1	38,300	29.1	5.8	.	1,160
	2	4980	9	0	22.1	261	0.0	.	9,350	2,100
	3	4979	9	0	22	251	0.0	.	50	200
	4	4978	9	0	22.1	250	0.0	.	150	50
	42	4962	2	0	19.1	35,900	26.1	6.4	150	150
	5	4977	9	0	22.1	251	0.0	.	2,150	8,350
	54	4961	1	0	20	34,800	24.1	.	295	9,750
	55	4960	9	0	20.8	312	0.0	6.5	8,150	12,900
	6	4976	9	0	22.1	261	0.0	.	1,750	900
	6	4975	9	10	22.1	310	0.0	.	1,500	2,450
	7	4974	9	0	22.2	409	0.0	.	950	2,500
	7	4973	9	11	22	461	0.0	.	900	2,200
	8	4972	9	0	22.1	510	0.0	.	150	150
	8	4971	9	10	22	540	0.0	.	300	0
	9	4970	9	0	22	610	0.0	.	150	0
	9	4969	9	20	20	6,000	4.1	.	50	50
06-Sep	1	5000	9	0	20.1	215	0.0	7.0	1,200	3,800
	10	4987	9	0	22.4	620	0.0	7.5	120	120
	10	4986	9	26	13.6	27,100	21.8	1.1	0	0
	11	4985	9	0	22.1	790	0.2	7.3	20	110
	11	4984	9	21	20.8	19,800	13.1	1.1	550	3,500
	14	4983	2	0	19	36,300	26.3	6.2	840	255
	14	4982	2	42	16.6	37,600	29.1	6.2	270	60
	2	4999	9	0	20.7	197	0.0	5.6	8,250	7,050
	3	4998	9	0	21.2	247	0.0	6.6	1,500	790
	4	4997	9	0	21.3	246	0.0	6.6	1,443	510
	5	4996	9	0	21.5	245	0.0	6.6	777	563
	6	4994	9	10	21.7	373	0.0	5.0	2,300	1,830
	6	4995	9	10	21.9	255	0.0	5.4	800	2,407
	7	4993	9	0	21.7	370	0.0	6.0	5,400	2,200
	7	4992	9	11	21.5	387	0.0	6.5	5,800	2,650
	8	4991	9	0	22.2	490	0.0	6.5	2,127	1,600
	8	4990	9	17	22	1,840	1.0	1.0	1,210	1,153
	9	4989	9	0	21.9	580	0.0	6.9	440	510
	9	4988	9	22	20.6	20,200	13.8	0.8	327	50
09-Sep	1	5019	9	0	21.1	241	0.0	6.8	325	420
	10	5006	9	0	22.5	520	0.0	7.6	395	.
	10	5005	9	28	14	24,500	19.0	0.9	0	0
	11	5004	9	0	22.5	690	0.0	7.3	105	10
	11	5003	9	21	20	24,100	17.0	0.9	130	50
	14	5002	6	0	19.3	33,000	25.1	4.9	70	20
	14	5001	6	40	17.3	37,800	28.0	4.5	10	5
	2	5018	9	0	22.4	259	0.0	8.0	11,800	325
	3	5017	9	0	21.5	240	0.0	7.8	1,715	35
	4	5016	9	0	22	210	0.0	6.8	295	55
	5	5015	9	0	22.4	248	0.0	7.7	125	95
	6	5014	9	0	22.6	282	0.0	7.8	290	85
	6	5013	9	10	22.4	260	0.0	6.3	290	160
	7	5012	9	0	23.4	431	0.0	6.2	855	265

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
09-Sep	7	5011	9	15	22.5	500	0.0	1.7	1,240	30
	8	5010	9	0	24.9	448	0.0	8.4	1,030	80
	8	5009	9	21	22.5	9,100	6.0	1.1	5,300	1,165
	9	5008	9	0	23	470	0.0	8.0	655	.
	9	5007	9	21	20	19,000	13.1	1.0	15	0
10-Sep	1	5038	9	0	21.5	249	0.0	7.2	300	365
	10	5025	9	0	22.3	550	0.0	6.3	410	245
	10	5024	9	30	14.6	24,500	19.9	1.6	270	95
	11	5023	9	0	22.1	680	0.0	6.2	245	245
	11	5022	9	22	20.1	29,900	16.5	1.5	150	155
	14	5021	6	0	19.6	33,400	23.8	5.5	80	70
	14	5020	6	38	17.6	37,500	27.5	4.9	5	170
	2	5037	9	0	22	257	0.0	8.1	8,950	1,170
	3	5036	9	0	23.4	264	0.0	9.9	700	290
	4	5035	9	0	22	222	0.0	8.4	135	160
	5	5034	9	0	22.4	239	0.0	9.6	140	105
	6	5033	9	0	22.1	244	0.0	7.8	145	183
	6	5032	9	10	21.6	365	0.0	2.3	250	175
	7	5031	9	0	22.5	365	0.0	7.0	775	160
	7	5030	9	16	21.6	510	0.0	1.5	950	380
	8	5029	9	0	22.3	490	0.0	7.5	850	200
	8	5028	9	18	23.1	8,100	5.0	1.6	1,300	745
	9	5027	9	0	22.3	455	0.0	7.5	890	125
	9	5026	9	22	21.1	18,800	13.0	1.8	770	675
11-Sep	1	5057	9	0	21.9	261	0.0	7.0	310	355
	10	5044	9	0	22.7	600	0.0	6.7	235	0
	10	5043	9	27	13.7	26,200	21.0	1.0	30	0
	11	5042	9	0	22.4	710	0.0	7.4	140	15
	11	5041	9	22	19.9	23,500	16.0	0.6	145	865
	14	5040	5	0	19.5	37,500	27.0	5.5	70	0
	14	5039	5	37	17.7	38,200	28.9	4.9	30	70
	2	5056	9	0	22.1	258	0.0	8.8	2,800	455
	3	5055	9	0	22.2	264	0.0	8.5	540	90
	4	5054	9	0	22.4	251	0.0	9.0	450	140
	5	5053	9	0	22	251	0.0	8.6	440	180
	6	5052	9	0	21.9	320	0.0	6.7	1,350	520
	6	5051	9	10	21.5	570	0.0	3.4	5,400	960
	7	5050	9	0	22.2	510	0.0	6.8	755	20
	7	5049	9	18	21.8	880	0.0	3.9	1,450	600
	8	5048	9	0	22.3	520	0.0	7.2	520	10
	8	5047	9	18	21.1	9,100	2.5	1.1	835	255
	9	5046	9	0	22	530	0.0	7.0	490	20
	9	5045	9	23	19.6	18,800	13.0	0.5	260	10
12-Sep	1	5076	9	0	21	252	0.0	.	410	460
	10	5063	9	0	21.9	610	0.0	.	85	0
	10	5062	9	31	13.4	26,900	20.8	.	25	0
	11	5061	9	0	22	790	0.2	.	55	0
	11	5060	9	22	20.2	21,200	14.2	.	85	20
	14	5059	5	0	18.8	37,500	26.9	5.7	80	0
	14	5058	5	37	17.3	37,800	28.9	5.7	35	110
	2	5075	9	0	21.8	262	0.0	.	2,300	340
	3	5074	9	0	21.6	258	0.0	.	225	135
	4	5073	9	0	21.6	260	0.0	.	645	125
	5	5072	9	0	21.6	280	0.0	.	400	110

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
12-Sep	6	5071	9	0	21.3	310	0.0	.	1,170	490
	6	5070	9	10	20.8	410	0.0	.	1,255	145
	7	5069	9	0	22	570	0.0	.	455	175
	7	5068	9	11	21.2	450	0.0	.	1,245	240
	8	5067	9	0	21.8	530	0.0	.	735	225
	8	5066	9	15	21.4	520	0.0	.	2,050	785
	9	5065	9	0	22	580	0.1	.	320	0
	9	5064	9	22	21.2	19,900	13.2	.	40	0
13-Sep	1	5095	9	0	20.2	250	0.0	8.7	115	310
	10	5082	9	0	22.3	600	0.0	9.2	50	5
	10	5081	9	31	14.2	27,000	21.5	1.0	40	0
	11	5080	9	0	22	120	0.5	8.2	30	10
	11	5079	9	24	20.3	20,000	14.0	0.9	70	35
	14	5078	5	0	18.1	35,000	26.0	6.2	65	110
	14	5077	5	36	17.2	37,000	28.0	6.1	25	615
	2	5094	9	0	21	260	0.0	10.6	2,450	395
	3	5093	9	0	21.5	260	0.0	9.5	335	150
	4	5092	9	0	21.1	255	0.0	10.3	570	170
	5	5091	9	0	21.3	260	0.0	11.1	145	55
	6	5090	9	0	21.2	300	0.0	10.3	660	215
	6	5089	9	10	20.4	300	0.0	8.3	715	355
	7	5088	9	0	21.4	500	0.0	6.9	720	165
	7	5087	9	15	20.6	450	0.0	6.7	815	75
	8	5086	9	0	22	550	0.0	9.6	295	5
	8	5085	9	14	20.8	500	0.0	8.2	1,575	535
	9	5084	9	0	22.3	600	0.0	10.7	170	30
	9	5083	9	20	21.8	8,000	5.0	0.8	420	120
16-Sep	1	5112	9	0	20.5	269	0.0	7.4	985	750
	10	5101	9	0	21.4	710	0.1	7.3	195	20
	10	5100	9	32	13.5	21,000	21.0	0.6	50	5
	11	5099	9	0	21.2	810	0.3	6.8	260	65
	11	5098	9	25	20.1	20,500	14.2	0.4	845	5,950
	14	5097	3	0	18.7	36,100	26.6	5.6	55	105
	14	5096	3	37	16.6	36,900	28.5	6.0	175	145
	2	5111	9	0	20.1	265	0.0	6.6	6,950	1,270
	3	5110	9	0	20.5	269	0.0	7.7	2,100	285
	4	5109	9	0	21.1	265	0.0	7.4	835	160
	5	5108	9	0	21.2	267	0.0	7.6	710	850
	6	5107	9	0	20.9	267	0.0	6.5	355	670
	6	5106	9	10	20.4	379	0.0	4.1	2,900	1,405
	7	5114	9	0	21	470	0.0	6.4	2,650	365
	7	5113	9	17	20.8	610	0.0	6.5	680	90
	8	5105	9	0	21.2	590	0.0	6.3	550	20
	8	5104	9	19	21.6	7,500	2.9	1.5	785	500
	9	5103	9	0	21.6	590	0.0	6.3	390	40
	9	5102	9	23	20	20,100	13.9	2.0	410	430
17-Sep	1	5133	9	0	22.8	277	0.0	6.9	780	285
	10	5120	9	0	22.5	650	0.0	8.4	655	30
	10	5119	9	31	15.2	26,900	20.9	0.3	10	0
	11	5118	9	0	22.9	950	0.2	8.1	325	115
	11	5117	9	22	20.5	21,200	14.5	0.4	230	130
	14	5116	3	0	19.6	37,500	27.2	5.5	100	175
	14	5115	3	38	16.4	36,500	27.8	5.8	175	1,090
	2	5132	9	0	21.9	270	0.0	6.6	5,250	620

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
17-Sep	3	5131	9	0	21.5	272	0.0	7.4	1,405	250
	4	5130	9	0	25.2	292	0.0	7.5	4,550	1,180
	5	5129	9	0	23.4	281	0.0	6.8	1,200	60
	6	5128	9	0	21.7	402	0.0	5.9	17,500	1,295
	6	5127	9	10	21	610	0.0	0.5	6,400	2,235
	7	5125	9	0	21.3	590	0.0	5.0	2,950	760
	7	5126	9	0	21.7	475	0.0	5.9	2,750	725
	8	5124	9	0	22.1	510	0.0	6.2	3,000	900
	8	5123	9	16	21.2	7,900	6.0	0.3	1,370	300
	9	5122	9	0	22	500	0.0	8.1	845	40
	9	5121	9	23	20.5	17,100	12.9	0.2	770	50
18-Sep	1	5152	9	0	23.2	285	0.0	6.1	725	210
	10	5139	9	0	23	630	0.1	8.2	465	30
	10	5138	9	31	14.2	21,300	21.0	0.4	930	10
	11	5137	9	0	23.2	810	0.2	8.4	185	25
	11	5136	9	23	19.9	21,200	14.0	0.3	100	185
	14	5135	3	0	19.2	37,000	27.2	5.6	35	30
	14	5134	3	39	15.9	36,100	28.3	5.8	15	150
	2	5151	9	0	22.9	278	0.0	7.0	3,200	140
	3	5150	9	0	22.2	272	0.0	7.7	620	205
	4	5149	9	0	22.9	304	0.0	7.5	1,495	225
	5	5148	9	0	23.6	331	0.0	9.0	1,455	85
	6	5147	9	0	22.9	422	0.0	7.5	1,180	95
	6	5146	9	10	21.7	600	0.0	5.4	940	180
	7	5145	9	0	22.5	570	0.0	7.2	1,670	210
	7	5144	9	12	21.9	600	0.0	6.4	1,135	245
	8	5143	9	0	22.8	600	0.0	8.4	1,220	235
	8	5142	9	15	21.7	600	0.0	5.9	1,690	440
	9	5141	9	0	22.7	610	0.0	7.8	995	360
	9	5140	9	20	20.3	18,900	12.6	0.4	650	160
19-Sep	1	5171	9	0	23.3	299	0.0	6.5	185	160
	10	5158	9	0	22.6	700	0.0	7.0	665	100
	10	5157	9	29	13.6	25,000	20.9	0.1	105	10
	11	5156	9	0	23.2	320	0.2	8.2	165	145
	11	5155	9	22	20.2	21,000	14.2	0.3	305	680
	14	5154	2	0	19.7	37,800	27.2	6.1	0	10
	14	5153	2	40	16.1	35,800	28.0	5.2	10	500
	2	5170	9	0	22.9	289	0.0	7.3	2,280	690
	3	5169	9	0	23.3	290	0.0	9.7	520	180
	4	5168	9	0	22.9	328	0.0	8.0	605	260
	5	5167	9	0	23.1	387	0.0	8.3	505	90
	6	5166	9	0	22.8	410	0.0	7.1	645	150
	6	5165	9	10	21.6	580	0.0	2.0	1,385	1,190
	7	5164	9	0	23	580	0.0	7.9	1,280	995
	7	5163	9	12	21.4	820	0.0	1.4	1,200	765
	8	5162	9	0	22.9	620	0.0	7.7	1,545	690
	8	5161	9	18	22.3	890	0.0	4.6	1,730	825
	9	5160	9	0	22.9	650	0.0	7.2	940	130
	9	5159	9	18	20.3	19,000	13.0	0.2	490	130
20-Sep	1	5190	9	0	17.9	161	0.0	8.0	9,700	16,200
	10	5177	9	0	21.7	660	0.0	6.8	445	120
	10	5176	9	29	13.8	25,100	20.2	0.2	110	15
	11	5175	9	0	21.7	830	0.0	7.0	740	1,010
	11	5174	9	22	20.4	14,500	9.5	0.3	1,340	4,200

Table A.03 Continued

Date	Site	Samnum	Tide	DS	Temp	Cond	Salin	DO	F. colif.	Entero.
20-Sep	14	5173	2	0	18.2	31,000	22.6	6.1	1,855	1,230
	14	5172	2	41	15.1	35,300	28.1	5.8	50	520
	2	5189	9	0	18.9	150	0.0	6.4	18,150	24,500
	3	5188	9	0	20.5	247	0.0	5.9	10,800	8,850
	4	5187	9	0	20.6	261	0.0	6.6	2,300	10,250
	5	5186	9	0	20.3	260	0.0	6.9	1,845	3,550
	6	5185	9	0	20.8	270	0.0	6.4	3,200	3,300
	6	5184	9	10	20.7	290	0.0	6.4	2,400	5,100
	7	5183	9	0	21	500	0.0	4.3	9,200	6,550
	7	5182	9	11	20.7	420	0.0	4.2	16,450	10,650
	8	5181	9	0	21.7	550	0.0	5.2	8,400	10,550
	8	5180	9	19	21.2	6,900	4.0	0.8	4,850	3,450
	9	5179	9	0	21.4	650	0.0	6.7	535	95
	9	5178	9	24	19.8	19,200	13.5	0.1	575	25

B. Appendix: Analytical Techniques

B.1 Data Sources

B.1.a Monitoring Program

Field

Field observations and measurements were immediately entered into waterproof field notebooks. Unique sample numbers, which were assigned to each sample prior to sampling, were preprinted onto the sample labels, the field notebooks, and the Lab Data Sheets. Field data were transcribed daily from the field notebooks onto the data sheets in the laboratory. Daily checks were made to ensure transcription accuracy. Full field notebooks were stored in the laboratory.

Laboratory

Bacterial counts were entered onto lab data sheets in the laboratory. On a monthly basis the data sheets were photocopied, and the copies stored in MWRA's Charlestown Navy Yard offices. The originals were filed at the laboratory.

B.1.b Rainfall and System Loads

Rainfall

We obtained National Weather Service daily rainfall records for the period October 1, 1990, to November 31, 1991.

MWRA Treatment Plant Flows

We obtained daily flow and effluent fecal coliform measurements for October 1, 1990, to November 31, 1991, from treatment plant logs for the Deer Island POTW.

B.2 Data Entry and Validation

B.2.a Monitoring Program Data

Entry

We developed a screen entry template for dBASE III+ (Ashton-Tate, Torrance, CA) that mimics the lab data sheets. Data entry was performed at the laboratory. Key-punched data were checked against the lab data sheets by lab personnel after each session. Files were backed up daily to both fixed and floppy disks. These files were transferred on a monthly basis to the fixed disk of a separate PC at the Charlestown Navy Yard.

Validation

The data were entered twice into identical dBASE tables. The first keypunching was performed by lab personnel, the second by a professional data entry consultant. We input ASCII versions of these files to a program which electronically compared every field of each record in one file to the corresponding field in the second file. The program flagged inconsistencies between the two files, which indicated data entry error in one file or the other. The inconsistent fields were checked against the data sheets to identify and correct errors.

Once the errors identified by the file-checking program were corrected, we consulted industrial quality control tables (ASQC 1981) to determine the proper numbers of samples for further checking. A pseudo-random number generator was used to generate sample numbers for this check, and the Acceptable Quality Limit (AQL) was set at 1 percent. All fields in the randomly selected records were then checked against the corresponding data sheets. This means that a data file meeting the acceptance criteria in the ASQC tables, as the 1990 field monitoring data did, contains a maximum of 1 percent of **records** (samples) with one or more erroneous **fields** (variables).

B.2.b Rainfall and Sewage Flows

Daily rainfall and treatment plant flows were entered onto LOTUS 123 (LOTUS Development Corp., Cambridge, MA) spreadsheets. Rainfall and flow data were validated as described in the previous CSO receiving water report (MWRA 1991e). Supplemental variables calculated within LOTUS 123 were checked manually to ensure that the formulae used were correctly implemented.

B.2.c File Storage

Monitoring Data

Backup copies of the raw data files were maintained in two separate locations. These files were erased as data were validated and appended to the databases. The validated database files were maintained on a separate subdirectory on fixed disk, and on a floppy disk backup. No alterations except for addition of new validated data were permitted to these copies of the files. All analyses and transformations were performed upon copies of the files.

Other Files

Validated copies of all other data files were maintained on separate subdirectories on a fixed disk, backed up to floppy disk. As with the monitoring data, all analyses and transformations were performed on copies of the files.

B.2.d File Transformations and Applications

Data analysis and graphics presentation required passage of the data through several different applications on different platforms. Following such transformations data were printed out, and all the fields in roughly 5% of the records were checked against the originals to ensure that errors were not added in the file manipulations.

Several different software packages were used for data analysis and the preparation of summary tables and figures. In cases where similar analyses were run using different packages, the results were checked against each other for consistency.

Monitoring Program Data

The following variables calculated from the field monitoring data were used extensively in the data analyses:

- **REGION** Sample data were aggregated into the regions using SPSSX SELECT IF statements. We sampled several stations (e.g., station 44) while monitoring more than one region, so data from those stations were assigned to different regions by date ranges.

- **LGFC, LGME** The fecal coliform and *Enterococcus* data were log-normally distributed. Since the parametric statistics used in the analyses assume normally distributed data (Sokal and Rohlf 1981), $\log_{10}(x+1)$ transformations were computed for both the fecal coliform (LGFC) and the *Enterococcus* (LGME) data within SPSSX. Frequency distributions of log-transformed counts did not violate the assumptions of normality.

- **CURRENT** The tidal information coded in the TIDE variable was further grouped into a current variable whose value equalled "1" for the ebb tide, and "2" for flood tides. The rare occasion where tide was coded as high slack (TIDE = 1) or low slack (TIDE = 4) were arbitrarily coded as flood and ebb, respectively.

Rainfall and System Loads

- **Rainfall** Several supplemental variables were computed from Logan Airport data in order to further test for effects of rainfall. These variables and the formulae used to derive them are detailed in Table 2.03. In brief, the supplemental variables tested for delayed and/or additive effects of rainfall over several days.

- **Treatment Plant and CSO Facilities** For the Deer Island Treatment Plant, the effluent fecal coliform loading was calculated from the flow and effluent coliform counts (Table 2.03).

B.3.b Analyses

Analyses are described in approximately the order in which we carried them out. Several analyses which are not specifically referenced in the body of the report, but which form the basis for later analyses, are included here. The names of the specific SPSSX procedures used are provided.

freedom. Thus, the 95% CIs may slightly underestimate the true confidence intervals, especially for categories with fewer than 5 records. After the 95% confidence intervals were calculated, the log mean and the CIs were back-transformed to give the geometric means and confidence intervals for each category

(e.g., Geom. mean = $10^{\log \text{mean}}-1$).

Regression and Correlation

Regression and correlation analyses were run for each year on the entire data set using the SPSSX procedures PLOT, which constructs simple scattergrams of pairs of variables with linear regression statistics; PEARSON CORR, which calculates Pearson product-moment correlation coefficients; and NONPAR CORR, which as used calculates Spearman rank-order correlation coefficients.

Replicates

In order to determine the extent of variation in replicate field samples and duplicate laboratory filtrations, regressions and scatterplots were constructed for both raw and log-transformed bacterial counts. Each year's complete monitoring data set was used in the regressions of lab duplicates, which were run on every sample. A subset of the monitoring data for which the variable **REP** equalled "Y" was used in the regressions of field replicate samples.

Indicators

Linear regressions and scattergrams were run on the entire data set on the raw and log-transformed fecal coliforms against the raw and log-transformed *Enterococcus* counts, to investigate the relationship between the two indicators.

Indicators vs. Other Variables

Pearson correlation analyses were run for each season's data on all possible pairs of variables from the following data list:

Fecal Coliform	Log(x+1) Fecal Coliform
Enterococcus	Log(x+1) *Enterococcus*
Dissolved Oxygen	Salinity
Water Temperature	All Logan rain variables
All sewage flow and load variables	

B. Appendix B

Stepwise Multiple Regressions

Multiple regressions were only performed on a group of stations from northern Dorchester Bay.

These regressions were Type II, in that we were not attempting to build predictive equations for use in further work, but rather were attempting to explain the variance in the bacterial indicator data based upon the other variables (Sokal and Rohlf 1981). The regressions were run with the SPSSX procedure REGRESSION, using the STEPWISE subcommand. The analyses used the SPSSX default operating parameters (p to enter of 0.05, p to remove 0.10 (SPSS 1986).

In some of the multiple regressions two or more rainfall variables entered the equations as significant predictors of bacterial indicator levels. When two rain variables containing different information entered (e.g., three-day summed rain and single-day rain 5 days before sampling), the results were accepted as potentially valid. If, as occasionally happened, the second rain predictor entered with a negative correlation with residual indicator counts, the regression was terminated prior to the entry of the second predictor.

As mentioned in the correlation section the rainfall and sewage variables contained single values for each date, while the field monitoring data (e.g., salinity, DO, indicators) were measured at 10-20 stations per date. Because of this, significance levels for these variables in the equations of greater than 0.005 were disregarded. In practice, the significance levels seen when sewage or rainfall variables entered the equations as primary predictors were nearly always less than 0.001.

Since we expected the various regions in the harbor to behave differently based on the results of the correlation analyses, the regressions were only run on the data from each region, not on the entire data set. Regressions were run at the individual station level where the sample size was sufficient. In regions with both surface and bottom data for most stations, regressions were run separately on surface and bottom data. Deer Island effluent coliforms and coliform loadings showed nonsignificant correlations with indicator counts measured, while Deer Island flows showed high correlations with indicators measured in the field. The treatment plant flows were included in regressions as a measure of system loading rather than as a direct influence on indicator levels themselves.

B. Appendix B

Figure B.01. SPSSX Output from Sample Command File (Table B.01).

```
3-Jul-90  SPSS-X RELEASE 3.1 FOR VAX/VMS     Page  1

  1 0 SET WIDTH 80
  2 GET FILE = 'CSODATA3.SYS'
File DUB3:[HARBOR_STUDIES1.SPSS]CSODATA3.SYS;
   Created:  9-APR-90 16:45:36 - 71 variables

  3 SELECT IF(REGION EQ 'INNERH')
  4 SELECT IF(DPTHSAM EQ 0)
  5 SORT CASES BY STATION
 SIZE OF FILE TO BE SORTED:     216 CASES OF    568 BYTES EACH.
 SORT COMPLETED SUCCESSFULLY.  FILE SIZE:      240 BLOCKS.
Preceding task required 2.44 seconds CPU time;  4.48 seconds elapsed.

   6  TITLE  'Correlations, Salinity vs Fecal Coliforms and Enterococcus'
  7  SUBTITLE 'Whole Inner Harbor'
  8  PEARSON CORR SALIN WITH LGFC LGME
PEARSON CORR problem requires 144 bytes of workspace.

3-Jul-90 Correlations, Salinity vs Fecal Coliforms and Enterococcus    Page  2
 11:54:40  Whole Inner Harbor

PEARSON CORRELATION COEFFICIENTS
        LGFC     LGME
 SALIN      -.5580   -.4439
        ( 199)   ( 199)
        P=.000   P=.000

 (COEFFICIENT / (CASES) / 1-TAILED SIG)

 " . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED
-----------------------------------------------------------------
 3-Jul-90 Correlations, Salinity vs Fecal Coliforms and Enterococcus    Page  3
 11:54:40  Whole Inner Harbor

0Preceding task required .38 seconds CPU time;  .75 seconds elapsed.

  9  SPLIT FILE BY STATION
  10  SUBTITLE 'Inner Harbor Split by STATION'
  11  PEARSON CORR SALIN WITH LGFC LGME
PEARSON CORR problem requires 144 bytes of workspace.
 3-Jul-90 Correlations, Salinity vs Fecal Coliforms and Enterococcus    Page  4
 11:54:40  Inner Harbor Split by STATION

PEARSON CORRELATION COEFFICIENTS
 STATION:   13
        LGFC     LGME
 SALIN      -.2093   -.2256
        ( 14)    ( 14)
        P=.236   P=.219
-----------------------------------------------------------------
 STATION:   14
        LGFC     LGME
 SALIN      -.4072   -.0680
        ( 14)    ( 14)
        P=.074   P=.409
-----------------------------------------------------------------
```

2 Pages of output truncated

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