April 1989

MWRA
Combined Sewer Overflow
Receiving Water
Monitoring Plan

Massachusetts Water
Resources Authority

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Boston Harbor and Its Tributary Rivers

by

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Miscellaneous Technical Report
Environmental Quality Department
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MWRA CSO Monitoring Plan

I. Introduction: Goals of MWRA Combined Sewer Overflow monitoring program.

Through its CSO monitoring program the MWRA aims to

1) Determine effects of CSO on the aquatic environment;

2) Coordinate the monitoring programs of the communities and the MWRA;

3) Coordinate different programs within the MWRA, including Sewerage, TRAC and Harbor Studies to satisfy NPDES permit requirements;

4) Integrate with beach, harbor and sludge abatement monitoring, including work done by other agencies.

In order to facilitate an integrated monitoring program, the MWRA proposes to perform CSO receiving water environmental effects monitoring for water subject to discharges from MWRA and member community CSOs. This monitoring plan is phased, and will focus first on measurments of microbial pollutants in the water column and sediments. Microbial indicators will be employed to identify and monitor individual CSOs or groups of CSOs as sources of pollution. The second phase of monitoring will continue to follow these microbial pollutants in the water column and, in addition, will focus on sediments identified as CSO-impacted during the first phase. These sediments will be sampled for microbial indicators and pathogens, toxic metals, and organic pollutants in the zone(s) of impact.

The environmental effects monitoring will be complemented by discharge monitoring, to be performed both by the MWRA and the member communities.

The background, rationale and details of this monitoring plan are described below.

II. Background data

A. Sample areas. The CSO areas include different aquatic regimes (freshwater and marine water). These CSO receiving waters can be divided into nine areas, shown on Figure 1:

1. Charles River (between Watertown Dam and New Charles River Dam). There are no CSOs upstream of the Watertown Dam.
2. Mystic River
3. Chelsea River
4. Inner Harbor
5. Dorchester Bay
6. Constitution Beach
7. Harbor Islands/Quincy Bay. (There are no CSOs at Quincy Beaches, Quincy Bay is presumably affected by Moon Head.)
8. Alewife Brook
9. Neponset River

These areas are of interest because they are used for recreation and shellfishing and/or are grossly polluted.

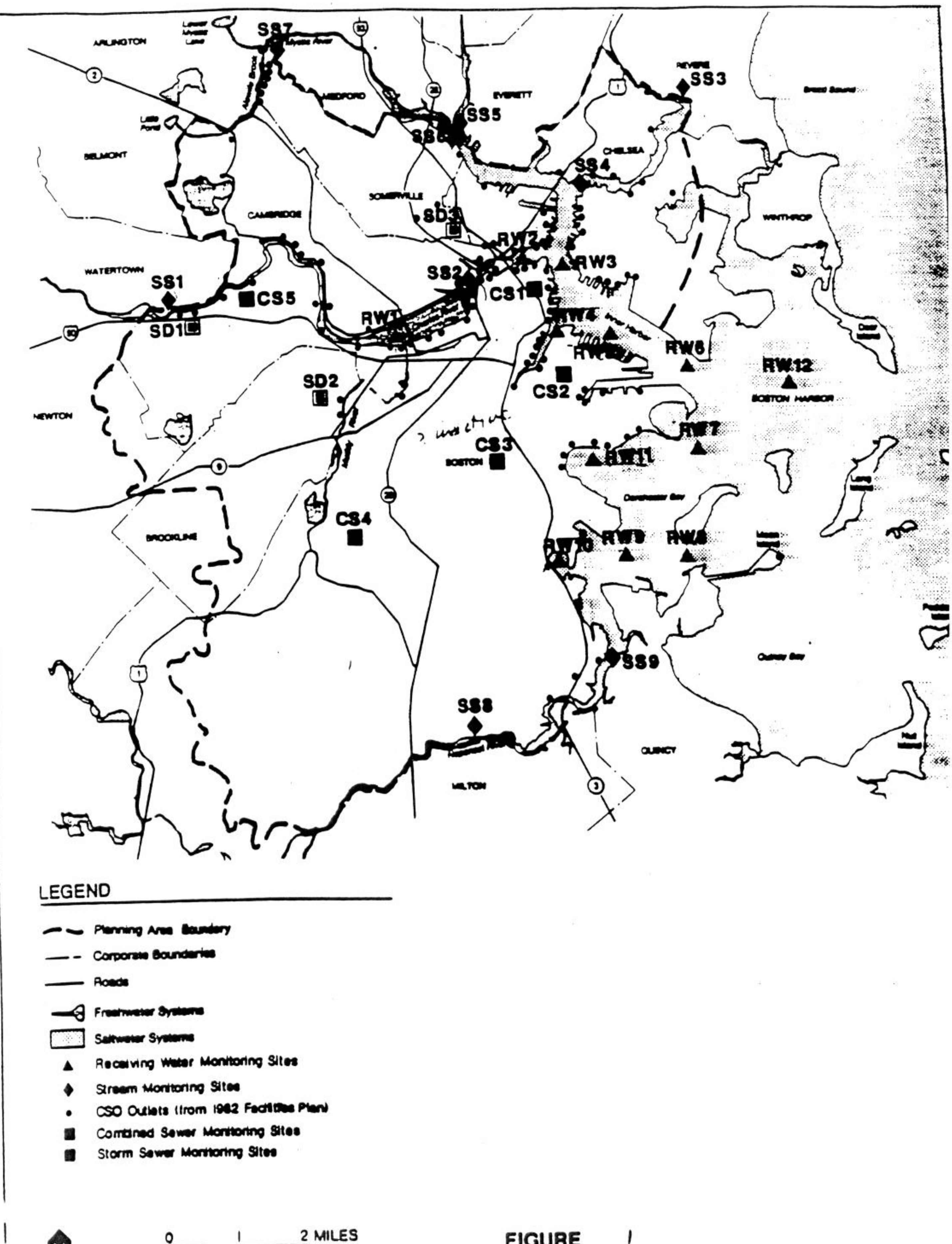


FIGURE 1

CSO MONITORING PROGRAM

B. Summary of receiving water data. The MWRA monitoring plan is based on data collected in the receiving waters during several investigations, including the 1988 MWRA CSO Facilities Plan, DEQE sampling, MDC beach monitoring, and other monitoring and scientific studies.

1) Microbiological data.

a. Charles River and Inner Harbor. The most recent microbiological data for CSO receiving waters were collected by CH2M Hill for the MWRA CSO Facilities Plan, during the summer and fall of 1988. Several indicator bacteria (total coliforms, fecal coliforms, Enterococcus, E. coli) in the water were enumerated after storms and during dry weather. Fig. 1 shows the CH2M Hill sampling stations. Samples were taken at in the Charles River at the Watertown Dam (SS1--upstream of all CSOs), near the Stony Brook conduit (RW1) and at the new Charles River Dam, river side (SS2). This sample transect was continued into the Inner Harbor: stations were located at the new Charles River Dam, harbor side (RW2); at the confluence of the Mystic River and the Inner Harbor (RW3); at Fort Point Channel (RW4); at Boston Inner Harbor between Commonwealth Pier and Logan Airport (RW5); and at Boston Harbor between Fort Independence and Logan Airport (RW6).

Figs. 2 and 3 show water column fecal coliform counts obtained one and four days after a storm, averaged over three storms, plotted along this Charles River/Inner Harbor transect. Fig. 4 shows the ranges of three measurements of fecal coliform counts in dry weather plotted along the same transect.

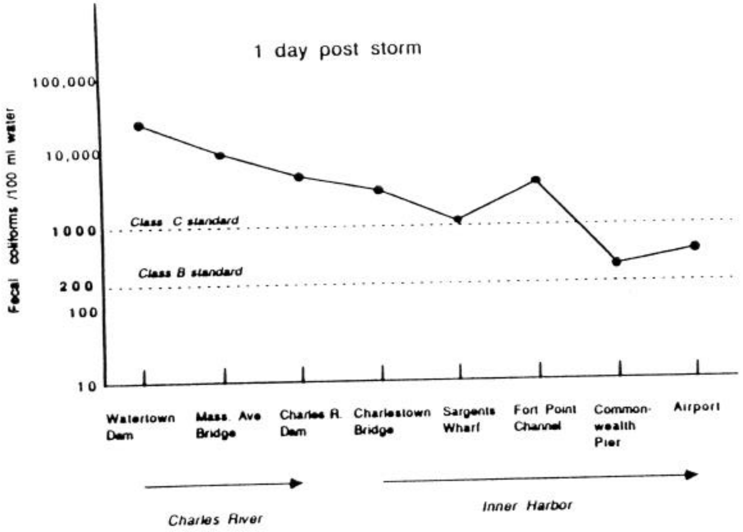


Fig 2. Fecal coliform counts in Charles River and Inner Harbor, first day after storm, averaged over 3 storms.

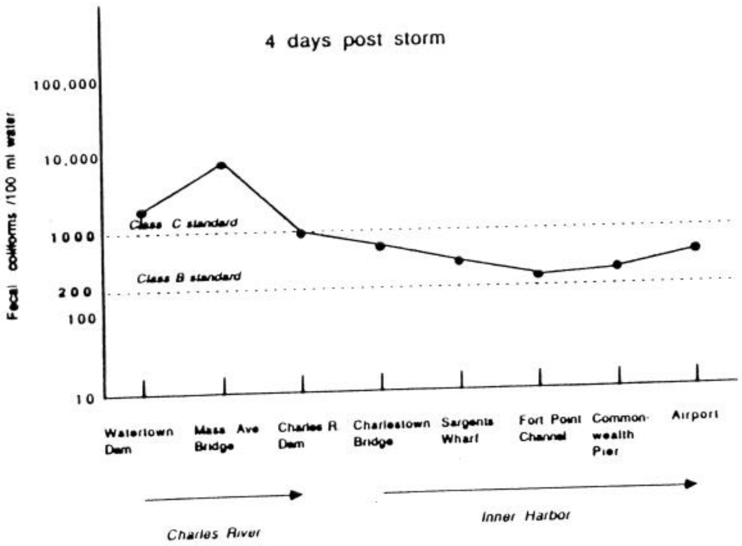


Fig. 3 Fecal coliform counts in Charles River and Inner Harbor, fourth day after storm, averaged over 3 storms.

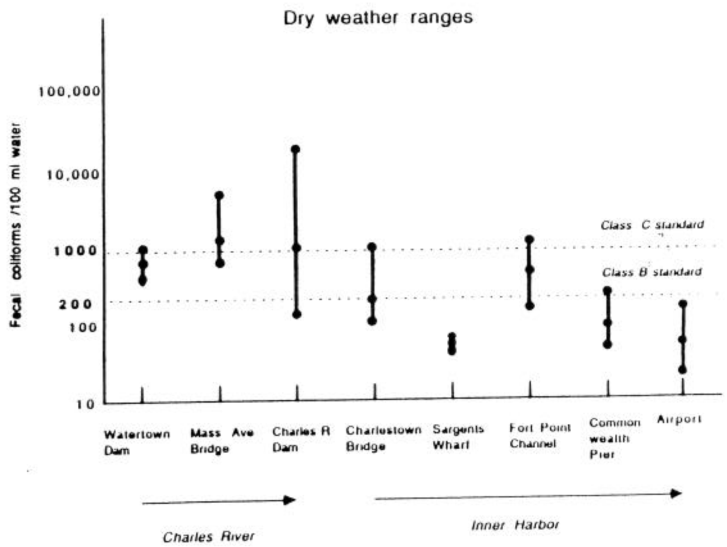


Fig. 4

The Charles River basin is a class "C" water body, and the Inner Harbor is class "SC". Counts of fecal coliforms above 1,000/100ml in these waters violate Massachusetts water quality standards. On Figs. 2 through 4, this 1,000/100 ml level and the class B 200 colony/100 ml standard are indicated by a dashed line. These data show that water quality standards were regularly violated in the Charles River (Stations SS1, RW1, SS2) during both wet and dry weather. Water quality violations occurred both in CSO receiving waters and upstream of any CSOs, at SS1.

In the Inner Harbor, stations RW2 through RW6, fecal coliform counts decreased compared to the Charles River. The Fort Point Channel station was an exception to this trend. Counts at Fort Point Channel ranged from approximately 1,000 to 10,000 per 100 ml until 4 days after a storm, when counts decreased to the dry weather range of approximately 100 to 1500 per ml. Water quality violations in the Inner Harbor and in the Charles occurred in both wet and dry weather; but the overall trend was for higher counts and more violations in wet weather.

b. Dorchester Bay beaches. A summary of fecal coliform counts in Dorchester Bay obtained during the CSO Facilities Plan is presented in Table 1A. Dorchester Bay is classsified as "SB" water, intended for swimming. Fecal coliform counts over 200/100 ml violate Massachusetts water quality standards. All Dorchester Bay stations sampled were subject to violations of fecal coliform standards during wet weather, but were within standards during dry weather. Table 1B shows the

Table 1A

Fecal Coliforms[Geometric Mean/100 ml and (Range)] in Dorchester Bay in Wet and Dry Weather.[a]

Data from MWRA CSOFP Monitoring

	Day After Storm.				All Post Storm Combined	Dry
	1	2	3	4		
RW-7	91 (50-150)	37 (<5-200)	316 (<50-900)	260 (100-500)	129 (<5-900)	11 (<5-50)
RW-8	280 (220-400)	37 (<20-50)	219 (<50-1400)	136 (<50-1000)	132 (<50-1400)	6 (<5-10)
RW-9	208 (100-450)	72 (<50-100)	50 (<50-50)	96 (50-350)	97 (<50-450)	5 (<5-5)
RW-10	96 (50-340)	287 (150-1500)	130 (<50-1450)	174 (<50-2100)	157 (50-2100)	18 (<50-50)
RW-11	50 (<10-50)	29 (<10-<50)	50 (<50-50)	131 (<50-300)	56 (<10-350)	5 (<5-5)
All Stations	126 (<10-450)	67 (<5-1500)	125 (<50-1450)	150 (<50-2100)	111 (<5-2100)	8 (<5-50)

a Most geometric means for each day post storm and dry weather are based upon 3 samples, a few are based upon 2 or 4 samples. The recorded detection limits were used to calculate the geometric means for samples recorded as "<".

Table 1B

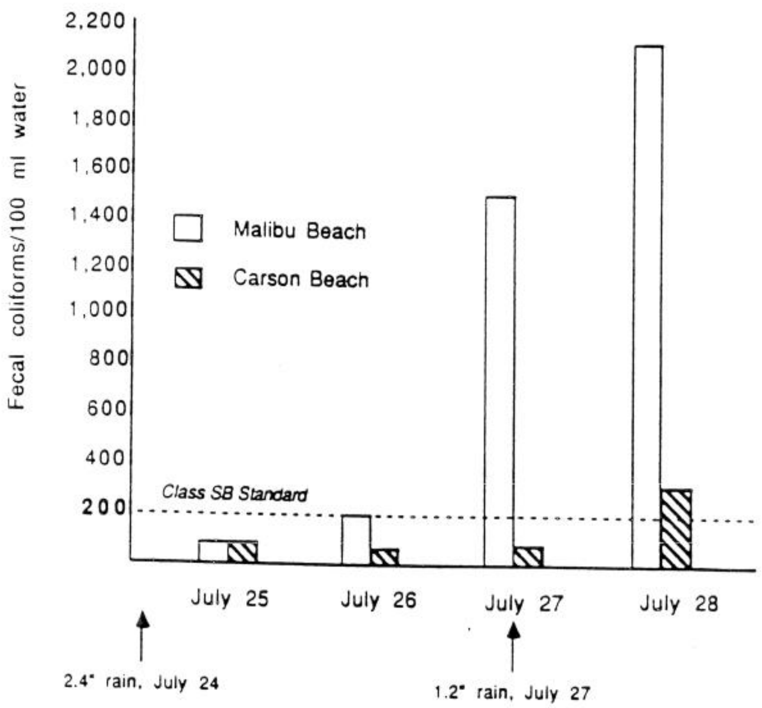
1987 & 1988 MDC Beach Sampling Summary, Beaches Adjacent to CSOs

	1987		1988	
	Weeks > 200/Weeks Sampled	% Time "Closed"	Weeks > 200/Weeks Sampled	% Time "Closed"
Constitution @ North Site	4/14	29	3/11	27
@ Bathhouse	2/14	14	2/11	18
@ South Site	3/14	21	1/11	9
Pleasure Bay @ Broadway	1/14	7	0/11	0
Carson Beach @ M Street	1/14	7	1/11	9
@ I Street	4/14	29	1/11	9
@ Bathhouse	5/14	36	0/11	0
Malibu Beach @ Bathhouse	2/14	14	1/11	9
Tenean Beach @ North Site	1/12	8	2/11	18
@ Middle Site	1/12	8	3/11	27
@ South Site	2/12	17	2/11	18

percent of time during a swimming season the Constitution Beach and Dorchester Bay beaches were closed in 1987 and 1988. All but two beaches were closed for at least one week during the summer of 1988, and Tenean Beach on Dorchester Bay was closed for 3 weeks during the 11 week swimming season. The effect of wet weather on fecal coliform counts at two different Boston swimming beaches is shown in Fig. 5.

Fecal coliforms in other rivers tributary to Boston Harbor are shown in Table 2. Coliform counts in the Chelsea River, Alewife Brook, and the Neponset River exceed allowable counts both in wet and dry weather.

Fig. 5.



Increase in fecal coliforms near two Dorchester Bay beaches after rain.

Table 2

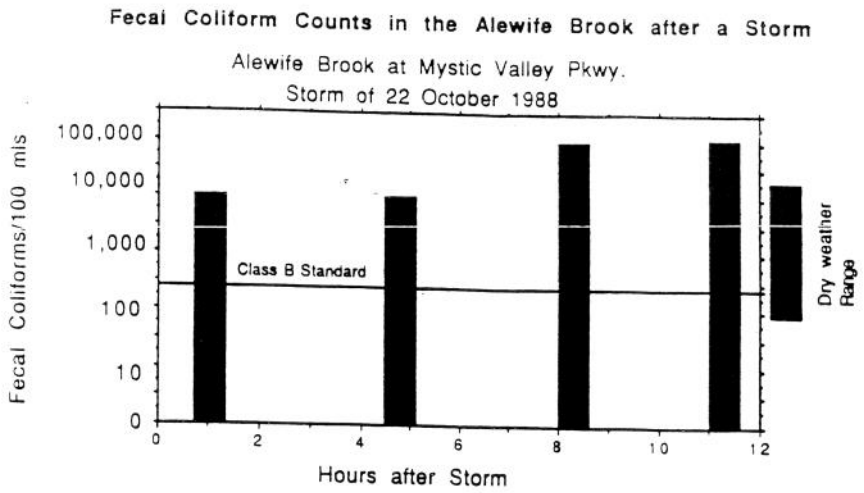
Fecal Coliforms in Boston Harbor Tributaries

Geometric Means/100 mls (Range)

		Wet	Dry
Chelsea River	SS-3	21,147 (800-170,000)	4,094 (600-26,000)
	SS-4	798 (50-4,100)	45 (10-100)
Alewife Brook, Mystic River	SS-5	1,800 (400-12,000)	142 (60-400)
	SS-6	342 (70-1,400)	84 (30-200)
	SS-7	48,962 (8,000-270,000)	1,706 (110-11,000)
Neponset River	SS-8	6,087 (800-70,000)	1,828 (500-4,700)
	SS-9	4,900 (300-80,000)	94 (50-240)

Fecal coliform counts in Alewife Brook during dry weather and after a storm are shown in Figure 6.

Fig. 6



2) **Organic pollutant data.** The CSO Facilities Plan study included extensive analysis of receiving water samples for organic pollutants (CH2M Hill Quality Assurance Project Plan, May 17, 1988). The priority pollutants analyzed included 37 volatile organic acids, 66 base/neutral/acid extractables, and 27 PCBs and pesticides. Out of 48 receiving water samples (at sites RW1-RW12) analyzed for these compounds, the only compound detected at levels approaching the "lowest reported chronic toxicity level" was bis 2-ethylhexylphthalate (7 out of 48 samples showed concentrations at or above 3 ug/L). All concentrations of this compound in the receiving water were 2-3 orders of magnitude below reported acute toxicity levels. No pesticides or PCBs were detected in any receiving water samples. Several volatile organic compounds and acid/base/neutral extractable compounds were detected, but at concentrations 2-3 orders of magnitude below reported acute and chronic toxicity levels.

3) **Metals.**

a. **Charles River.** Data for total metals concentrations found in the Charles River water column are shown in Table 3.

Table 3. Total metals concentrations in Charles River water.

Station	Storm	Date	Conc.(Total)	IDL[1]	EPA criteria (Dissol.) acute	EPA criteria (Dissol.) chronic
			ug/L			
			Silver		1.2	none
SS1	1	19-May-88	ND[2]	0.81		
	3	24-Jul-88	1.2			
	5	22-Oct-88	ND	0.8		
	D	29-Jun-88	ND	0.8		
RW1	1	19-May-88	ND	0.81		
	3	25-Jul-88	ND	4.0		
	4	30-Aug-88	ND	0.8		
	5	23-Oct-88	ND	0.8		
	D	28-Jun-88	ND	1.0		
SS2	1	20-May-88	2.7			
	3	24-Jul-88	1.2			
	5	22-Oct-88	ND	0.8		
	D	29-Jun-88	0.9			
			Arsenic		360.0	190.0
SS1	1	19-May-88	ND	50.0		
	3	25-Jul-88	3.4			
	4	30-Aug-88	2.7			
	5	23-Oct-88	ND	2.4		
	D	28-Jun-88	1.9			
RW1	1	19-May-88	ND	50.0		
	3	25-Jul-88	3.4			
	4	30-Aug-88	2.7			
	5	23-Oct-88	ND	2.4		
	D	28-Jun-88	1.9			
SS2	1	20-May-88	ND	50.0		
	3	24-Jul-88	ND	2.4		
	5	22-Oct-88	ND	2.4		
	D	29-Jun-88	1.5			

Table 3 continued

Station	Storm	Date	Conc.(Total)	IDL[1]	EPA criteria (Dissol.) acute	EPA criteria (Dissol.) chronic
			ug/L			
			Cadmium		1.8-3.9	0.66
SS1	1	19-May-88	ND	1.5		
	3	24-Jul-88	ND	4.3		
	5	22-Oct-88	0.95			
	D	29-Jul-88	5.7			
RW1	1	19-May-88	ND	1.5		
	3	25-Jul-88	ND	4.3		
	4	30-Aug-88	ND	4.3		
	5	23-Oct-88	ND	3.1		
	D	28-Jun-88	ND	4.3		
SS2	1	20-May-88	1.6			
	3	24-Jul-88	ND	4.3		
	5	22-Oct-88	3.0			
	D	29-Jun-88	ND	4.3		
			Chromium		**16.0**	**11.0**
SS1	1	19-May-88	ND	5.2		
	3	24-Jul-88	ND	8.3		
	5	22-Oct-88	ND	8.0		
	D	29-Jun-88	13.5			
RW1	1	19-May-88	ND	5.2		
	3	25-Jul-88	ND	8.3		
	4	30-Aug-88	ND	8.3		
	D	28-Jun-88	12.4			
SS2	1	20-May-88	9.3			
	3	24-Jul-88	ND	8.3		
	5	22-Oct-88	ND	8.0		
	D	29-Jun-88	ND	8.3		

Table 3 continued

Station	Storm	Date	Conc.(Total)	IDL[1]	EPA criteria (Dissol.) acute	chronic
			ug/L			
			Copper		9.2	6.5
SS1	1	19-May-88	7.3			
	3	24-Jul-88	7.0			
	5	22-Oct-88	13.4			
	D	29-Jun-88	81.3			
RW1	1	19-May-88	6.8			
	3	25-Jul-88	6.5			
	4	30-Aug-88	ND	4.8		
	5	23-Oct-88	9.1			
	D	28-Jun-88	13.8			
SS2	1	20-May-88	5.8			
	3	24-Jul-88	14.2			
	5	22-Oct-88	6.6			
	D	29-Jun-88	11.2			
			Mercury		2.4	0.12
SS1	1	19-May-88	ND	0.2		
	3	24-Jul-88	1.2			
	5	22-Oct-88	0.3			
	D	29-Jun-88	ND	0.2		
RW1	1	19-May-88	0.4			
	3	25-Jul-88	0.3			
	4	30-Aug-88	ND	0.2		
	D	28-Jun-88	0.2			
SS2	1	20-May-88	ND	0.2		
	3	24-Jul-88	0.9			
	5	22-Oct-88	0.4			
	D	29-Jun-88	ND	0.2		

Table 3 continued

Station	Storm	Date	Conc. (Total)	IDL[1]	EPA criteria (Dissol.) acute	EPA criteria (Dissol.) chronic
			ug/L			
			Nickel		**1100.0**	**56.0**
SS1	1	19-May-88	ND	13.3		
	3	24-Jul-88	ND	9.4		
	5	22-Oct-88	ND	15.7		
	D	29-Jun-88	255.0			
RW1	1	19-May-88	ND	13.3		
	3	25-Jul-88	ND	9.4		
	4	30-Aug-88	ND	9.4		
	5	23-Oct-88	ND	15.7		
	D	28-Jun-88	ND	9.4		
SS2	1	20-May-88	ND	13.3		
	3	24-Jul-88	ND	9.4		
	5	22-Oct-88	ND	15.7		
	D	29-Jun-88	ND	9.4		
			Lead		34.0	1.3
SS1	1	19-May-88	14.4			
	3	24-Jul-88	70.1			
	5	22-Oct-88	27.6			
	D	29-Jun-88	7.1			
RW2	1	19-May-88	23.6			
	3	25-Jul-88	6.8			
	4	30-Aug-88	7.6			
	5	23-Oct-88	4.0			
	D	28-Jun-88	12.4			
SS2	1	20-May-88	7.2			
	3	24-Jul-88	9.8			
	5	22-Oct-88	3.5			
	D	29-Jun-88	19.6			

Table 3 continued

Station	Storm	Date	Conc. (Total)	IDL[1]	EPA criteria (Dissol.) acute	EPA criteria (Dissol.) chronic
			ug/L			
			Zinc		**180.0**	**47.0**
SS1	1	19-May-88	31.2			
	3	24-Jul-88	36.1			
	5	22-Oct-88	95.8			
	D	29-Jun-88	82.2			
RW1	1	19-May-88	95.8			
	3	25-Jul-88	16.6			
	4	30-Aug-88	ND	11.4		
	5	23-Oct-88	20.2			
	D	28-Jun-88	36.9			
SS2	1	20-May-88	21.1			
	3	24-Jul-88	36.4			
	5	22-Oct-88	94.4			
	D	29-Jun-88	71.0			

[1]IDL, Instrument Detection Limit
[2]ND, Not detected

Generally, metals concentrations in the Charles were below EPA criteria, although it is difficult to make strict comparisons because the criteria are based on dissolved metals concentrations, while total metals were measured. The EPA criteria for acute toxicity were apparently exceeded in some samples for silver, cadmium, copper and lead. Table 4 shows the median concentrations obtained for trace metals in the Charles

Table 4

Wet and Dry Weather Trace Metals Levels (ug/l) in the Charles River Basin

Data from the MWRA CSOFP Field Monitoring Project

	Ag[a]	As	Cd	Cr	Cr^{6+}	Cu	Hg	Ni	Pb	Zn
Medians, Wet Weather[b]										
SS-1	0.8	2.6	1.5	8.0	5.0	7.3	0.3	13.3	27.6	36.1
RW-1	0.8	3.1	3.7	8.1	5.0	6.6	0.4	9.4	7.2	18.4
SS-2	1.2	2.4	3.0	8.3	5.0	11.2	0.4	13.3	7.2	36.4
Dry Weather										
SS-1	0.8	1.8	5.7	13.5	5.0	81.3	0.2	255.0	7.1	82.2
RW-1	1.0	1.9	4.3	12.4	5.0	13.8	0.2	9.4	12.4	36.9
SS-2	0.9	1.5	4.3	8.3	5.0	11.2	0.2	9.4	19.6	71.0

a The values reported here assume the detection limit for all samples reported as nondetected.

b Medians at RW-1 are based upon 4 storm samples. Medians at SS-1 and SS-2 are based upon 3 storm samples. Dry weather values are based upon a single sample.

River. Of the nine metals examined, only cadmium and copper showed a central tendancy of concentrations exceeding EPA criteria. For both these metals, concentrations in dry weather were equal to or greater than concentrations in wet weather, and concentrations at SS1 (upstream of any CSOs) were sometimes greater than at stations affected by CSO.

b. Metals in Boston Harbor. Table 5 shows a summary of metals data collected in Massachusetts Bay and Boston Harbor during the MWRA Secondary Treatment Facilities Plan (1988), and by Wallace et al. (1987). Copper was the only metal found in concentrations exceeding EPA criteria. Table 6 shows data for copper concentrations in Boston Harbor collected during the CSO Facilities Plan.

Table 5

Trace Metal Water Quality Data, Boston Harbor and Nearby Waters

Concentrations are in ug/l except where otherwise noted.

Metal	Aquarium Report MWRA Average Mass Bay	Nut Isl	FP V, Appendix X. Deer Island Piling	Light	EPA Toxicity Criterion (Saline) Acute	Chronic
Cd	0.03	0.03	0.05	0.05	43.0	9.3
Cr	0.95	1.63	1.46	1.65	1100.0	50.0
Cu	0.42	1.11	1.60	1.66	2.9	---
Hg(ng/l)	< 8.90	< 6.40	< 7.10	< 7.00	2,100.0	25.0
Ni	0.41	0.54	0.64	0.63	14.	7.1
Pb	0.09	0.41	0.41	0.42	140.	5.6
Zn	0.69	1.68	2.95	2.87	170.	58.0

Wallace et al. 1987
High tide total metals data
Mean (Standard Deviation)

Metal	Inner Harbor	North Harbor	South Harbor
Cd	0.06 (0.031)	0.08 (0.010)	0.07 (0.012)
Cr	---	---	---
Cu	9.71 (4.10)	3.09 (1.10)	2.85 (1.05)
Hg(ng/l)	---	---	---
Ni	1.49 (0.51)	1.10 (0.46)	0.87 (0.28)
Pb	0.71 (0.24)	0.58 (0.26)	0.65 (0.41)
Zn	6.29 (1.48)	3.90 (1.23)	3.56 (1.24)

Table 6. Boston Harbor copper concentrations, 1988 CSOFP

Location	Mean wet weather ug/L	Mean dry weather
Inner Harbor	5.4	8.9
Fort Point Channel	5.1	4.8
Outer Harbor	7.4	8.4

Except at Fort Point Channel, the mean dry weather concentrations of copper were greater than the mean wet weather concentrations.

4) Acute toxicity of CSO effluent. Tests for acute toxicity of CSO effluent on Mysidopsis bahia and Cyprindon variegatus showed no acute toxicity.

5) Conventional pollution measures.

a. Total suspended solids. Mean TSS for the three Charles River stations for wet and dry weather are shown in Table 7.

Table 7. Total suspended solids in the Charles River, 1988 CSOFP.

Station	Mean wet weather mg/L	Mean dry weather
SS1	45	38
RW1	12	12
SS2	7	14

The only station where mean TSS in wet weather was greater than in dry weather was SS1, upstream of the CSOs.

b. Dissolved oxygen. Mean levels of dissolved oxygen at each site are presented in Table 8, with violations of the Massachusetts 5mg/L minimum standard noted.

Table 8. Dissolved oxygen in the Charles River, 1988 CSOFP.

Station	n	Mean	Range (mg/L)	No. Samples < 5mg/L	DO values < 5mg/L
SS1	15	6.8	3.0-9.0	1	3.0
RW1	18	6.1	0.46-8.8	2	0.46, 4.6
SS2	13	5.8	3.6-8.7	5	3.6, 3.6, 3.9, 4.2, 4.4

Violations of the dissolved oxygen criterion occurred in the Charles River, both upstream of the CSO-impacted waters, and in CSO impacted waters. The most severely affected area was SS2, at the Charles River Dam, with 5 of 13 samples (38%) showing violations of the DO criterion.

Table 9 presents the results of dissolved oxygen measurements in Boston Harbor during the 1988 CSOFP.

Table 9. Dissolved oxygen concentrations in Boston Harbor, 1988 CSOFP data.

Station	Mean DO (mg/L)	No. samples < 5mg/L	Total samples	% violations
Inner Harbor				
RW2	5.4	7	17	41%
RW3	6.0	3	15	20%
RW4	5.9	6	17	35%
RW5	6.5	0	14	0%
RW6	6.7	0	16	0%
Outer Harbor				
RW7	6.8	0	15	0%
RW8	7.0	0	14	0%
RW9	6.3	1	15	6%
RW10	6.6	1	19	5%
RW11	8.0	0	16	0%
RW12	7.1	0	16	0%

Low levels of dissolved oxygen occurred most frequently in the Inner Harbor, at the Fort Point Channel station and upstream. In the Outer Harbor, the lowest mean levels of DO and two violations of DO standards occurred in the southern part of Dorchester Bay, at RW9 and RW10.

III. Discussion of data and rationale for monitoring plan.

A. Pollution by indicator microorganisms and pathogens. Violations of the fecal coliform standards occurred at all the stations sampled for the 1988 CSOFP; bearing out previous observations of beach monitoring data (MDC 1987), shellfish bed monitoring data, and DWPC data. Generally, the worst violations are associated with wet weather, which would be expected if CSO discharges were a cause of bacterial pollution. The effect of a rainstorm on bacterial pollution of these receiving waters could typically be detected four days after the event, and even after four days most receiving waters had still not returned to background dry weather levels. In Dorchester Bay, violations of bacterial standards were virtually always associated with wet weather. However, in the Charles River (and in the other tributaries) and in the Inner Harbor, coliform counts were elevated even during dry weather. Understanding the relationships among rainfall, CSO discharge, and bacterial pollution is further complicated by the observation of high coliform counts at SS1 in the Charles River, upstream of any CSOs.

Violation of microbial water quality standards in the CSO planning area is severe, but the relative contribution of CSO discharges to these violations needs further clarification, especially in the Charles River and the Inner Harbor. This is clearly an important problem, because the presence of pathogenic microorganisms and their indicators have immediate and conspicuous impacts: pollution of beaches, shellfish beds and potential exposure of the public to unacceptably high risks of contracting infectious diseases (Koff et al. 1967; Cabelli 1982.). The presence of pathogens and their indicators in the water column is of clear importance for public health, and continued monitoring will be necessary to determine the effect of CSO discharges on microbial pollution levels. These measurements will help assess how water quality might be improved by planned CSO facilities.

B. Toxics. Combined sewer overflows are potentially an important source of toxic materials, including organic compounds and trace metals, in the receiving waters. However, trying to assess the potential toxic effects of CSO discharge by measuring concentrations of these materials in the receiving water may not be the most effective monitoring strategy, for the following reasons. The CSOFP measurements of toxics show that 1) CSO effluent shows no acute toxicity; 2) organic priority pollutants are almost never detected in the receiving waters, and when detected are orders of magnitude below EPA acute toxic criteria; and 3) except for copper, and at some sites, cadmium, toxic metals levels generally do not violate water quality criteria. Metals levels in the receiving waters are as high, or higher, in dry weather as in wet weather (Tables 3, 4 and 5); and in the Charles River metals concentrations at SS1, upstream of CSOs, are as high or higher than CSO-impacted waters. Although CSO discharges may be an important contributor of toxics to the aquatic environment, the data indicate that the acute, wet weather effect in the water column is transient, and/or not above background levels. For Boston Harbor and its tributary rivers, measuring toxics in the water column is probably not the best way to assess the impact of any CSO toxic discharges on the aquatic environment. One efficient and cost-effective way to estimate and monitor the overall toxics contribution of CSO discharges will be to measure toxics concentrations in the sewer pipes and treatment plant influent, and calculate the approximate loads to the receiving waters based on flows, as described below.

This method of assessing toxics in CSO, while providing a reference measure, does not address the difficult problem of measuring what may be sporadic, unpredictable and highly variable discharges of toxics from the 80+ different combined sewers. The logistics of collecting CS effluent samples make such measurements very expensive. However, significant toxic discharges into the aquatic environment are likely to leave their signatures in the sediment; and the most important environmental effect of CSO toxic discharges in the CSOFP area is probably on the sediments (Matson et al. 1978; Gilbert et al. 1972; Hall 1986; Shiaris and Jambard-Sweet 1986; Gallagher 1989). Effects of CSO discharges on sediment have already been described for the Fox Point CS (Shiaris et al. 1987, Gallagher and Grassle 1989). Therefore, monitoring toxics in CSO discharges should focus on describing zones of CSO impact in sediments and monitoring impacted areas for the presence of accumulations of toxic organic compounds and metals.

C. Other pollution indicators. Table 7 illustrates the difficulty in interpreting measurements of total suspended solids in receiving waters as an indication of CSO discharges. Greater amounts of suspended solids were found in dry weather than in wet weather, except at SS1, the station not affected by CSO. Similarly, it would be very difficult to interpret receiving water data when trying to evaluate the relative effect of CSOs in contributing to levels of BOD, nutrients, and other conventional pollutants. There are abundant sources of all these other pollutants, including the atmosphere, street runoff, land runoff, etc. Again, as for toxics, the best way to assess the CSO contribution of these conventional pollutants will be to measure their concentrations in the pipes, and calculate loads based on flows. The most important adverse environmental effect of nutrient pollution is to decrease dissolved oxygen. Dissolved oxygen can be measured directly in the water column.

D. Other parameters. Although dissolved oxygen, temperature, salinity and pH of natural waters are general measures of the condition of the environment and often not directly attributable to individual CSO discharges, it is important to measure these variables because they interact with other pollution indicators, e.g. microorganisms and metals. In addition, these parameters may indicate chronic effects of CSO discharges in a general way, e.g. low dissolved oxygen in the Inner Harbor (Table 9).

E. Summary of rationale. Past monitoring data and the CSOFP data show that violation of microbial water quality standards in Bsoton Harbor and its tributary rivers is chronic and egregious. People who consume shellfish taken from Boston Harbor, swim at Harbor beaches, or who use the Charles Basin for sailing and windsurfing may be exposed, through the water, to unacceptably high risks of contracting infectious diseases. The public has an interest in knowing the extent to which CSOs contribute to this problem, and if planned CSO facilities will result in improved water quality. Documentation of the effect of CSO abatement on microbial pollution will be important.

Bacteria are both pollutants and pollution indicators. Measuring bacteria in the sediments adjacent to CSOs may be the most simple and practical way to identify a CSO (or group of CSOs) as a source of pollution (Shiaris et al. 1987), and to delineate its zone of impact on the bottom.

The failure to find demonstrably higher levels of toxic metals in the receiving waters during wet weather than in dry weather, and the absence of toxic levels of organic priority pollutants in the water column, imply that continued monitoring of the water column for toxic effects of CSO would have very limited use. The finding of no acute toxicity of CSO effluent implies that no acute toxic effects would be expected in the effluent plume or zone of initial dilution. In this study area, any toxics introduced into the aquatic environment by CSO discharges will probably have the greatest effect on the sediment. Therefore, environmental monitoring of toxics should be focused on sediments, rather than the water column.

Several conventional pollutants, including suspended solids, BOD, and nutrients, would be extremely difficult to attribute to sources which discharge only sporadically, as do CSOs, by measurements in the water column. There are many sources of these pollutants, and their effects on the environment are complex, often seasonal, long term, and not localized. In order to measure an effect of CSO discharge on the environment in terms of these parameters, by water column monitoring, it would be necessary to distinguish effects among all contributing sources as well as natural environmental variation. The most direct way to measure the contribution of CSOs of these conventional pollutants in a body of water will be to measure their concentrations in the pipes, and calculate the loads based on flows. Measurements of dissolved oxygen in the water column will provide an environmental indication of the overall severity of nutrient pollution.

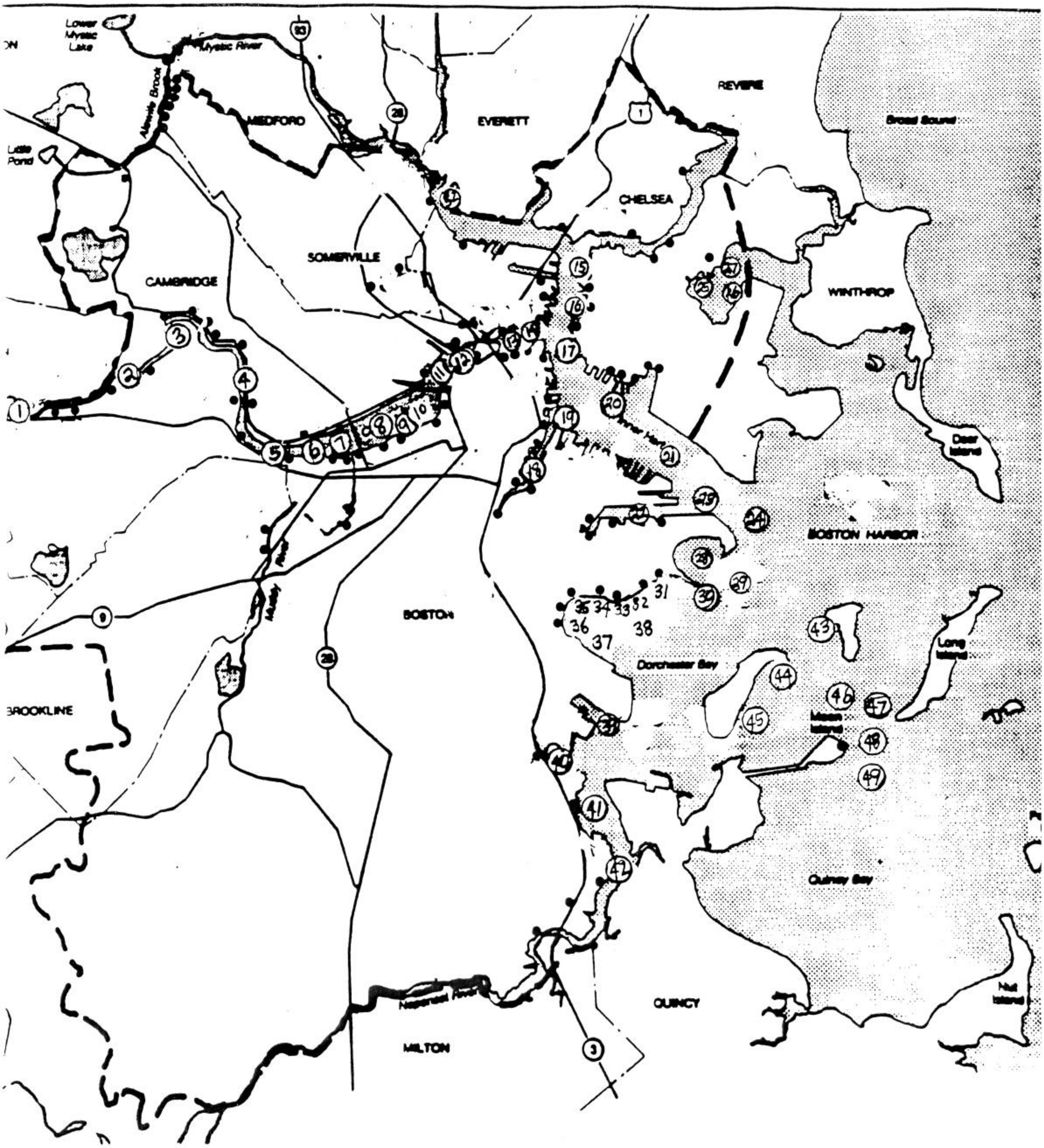
IV. MWRA CSO monitoring plan

A. Environmental effects monitoring. In addition to satisfying NPDES permit requirements, MWRA CSO monitoring has a two-fold purpose. The first is to establish the present environmental effects of CSO discharges on their respective receiving waters. Understanding these effects will help establish priorities in planning CSO facilities. Second, MWRA will be gathering baseline data which will permit evaluation of the effects of upgrading the Deer Island pumping capability, and eventually to measure the effects of CSO control facilities.

The MWRA monitoring program will be based on sound principles of environmental effects monitoring (Green, 1979). The sampling will be designed to test clearly formulated null hypotheses; control and impacted areas will be sampled; and preliminary studies will be carried out to establish measurement and environmental variablity, appropriate methodologies, and the applicability of statistical tests.

For example, a null hypothesis to be tested will be "CSO No. 201 does not contribute significantly to fecal coliform violations in the Charles River." To determine whether a CSO has an effect, samples must collected in an unimpacted (e.g. upstream) area (control) and in an area likely to be impacted upon by that CSO.

1. Sample stations. The sampling stations illustrated in Fig. 5 have been chosen to bracket individual CSOs or groups of CSOs, and to include control sites.



Area Boundary

Boundaries

Fig. 5

Proposed, CSO, sampling stations

Legend for Fig. 5. Tentative Sampling stations for CSO receiving waters.

Station no.	Site
Charles River	
1	Watertown Dam, upstream of BOS-31
2	Downstream of BOS-33
3	Upstream near CAM-5
4	Downstream of CAM-11
5	Upstream of MWR-010
6	Between MWR-010 and MWR-201
7	Downstream of MWR-201
8	Between MWR-023 and MWR-019
9	Between MWR-019 and MWR-020
10	At MWR-022
11	At BOS-049
12	At MWR-203
Inner Harbor	
13	Upstream of BOS-52
14	Downstream of BOS-52
15	Mystic River
16	Mystic River
17	Inner Harbor
18	Fort Point Channel
19	Fort Point Channel
20	Inner Harbor
21	Inner Harbor
22	Reserve Channel
23	Inner Harbor
24	Mouth of Inner Harbor
Constitution Beach	
25, 26, 27	
Dorchester Bay	
28	Inside Pleasure Bay
29	Outside Pleasure Bay
30	Outside Pleasure Bay
31-37	Carson Beach, includes BOS-81, BOS-82, BOS-83, BOS-84, BOS-85, BOS-86, BOS-87
38	Dorchester Bay
39	Fox Point CSO Facility BOS-89
40	Malibu Beach BOS-88
41	Tenean Beach BOS-90
42	Neponset estuary BOS-93
53	Neponset River estuary, upstream of BOS-95
54	Neponset River estuary, downstream of BOS-95
55	Neponset River at Adams Street Bridge, above dam

Legend for Figure 5 continued

43-49 Harbor Islands, Quincy Bay, Moon Island BOS-125

Alewife Brook/Mystic River
56-71 (15 sites still to be selected)

MWRA 205
52

Control sites (unaffected by CSO) to be monitored throughout season

28 Pleasure Bay
50 Calf Island Beach
51 Lovells Island Beach
72 Quincy Bay (class SA water)
73 Broad Sound off Winthrop (class SA water)

Reference sites to be monitored throughout the season

1 Charles River
9 Charles River

Downstream of confluence of Alewife Brook and Mystic River

Upstream of Amelia Earhart Dam

15 Mystic River
17 Inner Harbor
19 Fort Point Channel
24 Mouth of Inner Harbor
55 Neponset River at Adams Street above dam
41 Tenean Beach
33 Carson Beach
39 Fox Point
40 Malibu Beach

All these sample areas will be more precisely defined in the detailed monitoring plan.

2. **Parameters.** Fecal coliforms will be enumerated and pH will be measured in water samples. Enterococcus will also be counted in saline waters. Dissolved oxygen, temperature, and salinity will be measured at each station for every sample, at the surface and near the bottom. The depth at which the sample was collected will be recorded. Other environmental data including rainfall intensity, volume and duration; windspeed and direction, and tidal conditions will be recorded. Fecal coliforms and Clostridium perfringens spores will be enumerated in sediment samples during the first season's sampling effort. (As an adjunct to this work, MWRA Harbor Studies Department will initiate monitoring for pathogens, including viruses (enteroviruses and hepatitis A by gene probe technology) in the CSO receiving waters.

3. **Sampling schedule.** Sampling will begin in April, 1989. During the first phase of environmental sampling, water samples will be collected on as close to a daily basis as practicable (3-4) samples/week at all the stations in a given sample area, e.g. the Charles River. (Sample areas are described in section II of this document.) Samples will be collected in both wet and dry weather. After sampling a given area for three weeks, another area will be studied, until all the areas have been sampled. The rounds of sampling will be continued as long as weather permits.

Reference and control areas will be sampled every two weeks, including wet and dry weather.

The water sampling described above should provide enough information to select several CSO outfalls, which are associated with high bacteria counts, for sediment sampling. The results of the water sampling will also help to select control areas for sediment sampling.

4. Second phase of monitoring. (1990) After locations of "hot spots" and control areas indicated by microbial indicators have been determined in sediments, transects will be set up to sample these areas for toxic metals and priority pollutants. MWRA anticipates being able to sample transects adjacent to 3-4 CSOs for metals, organic pollutants, pathogens (e.g. Salmonella) and indicator organisms (fecal coliforms and Clostridium perfringens). These transects will be sampled on a quarterly basis.

5. Methods. One of the purposes of the preliminary monitoring will be to determine environmental, sampling, and laboratory variation. This information will enable us to determine numbers of replicate samples necessary, and numbers of duplicate laboratory tests necessary to measure variation within and among sites. This information is necessary in order to document environmental effects in a statistically valid way. Using the variation we measure in sampling and in the laboratory, we will design a sampling protocol appropriate for the application of statistical analysis, e.g. ANOVA (Sokal and Rohlf 1981).

A second objective will be to choose efficient and reproducible methods for enumerating fecal coliforms, Enterococcus, and eventually Salmonella in natural waters and sediments. A membrane filtration technique, either Standard Methods 909 C (ref), or the newer hydrophobic grid membrane filtration technique (HGMF) will be employed for enumerating fecal coliforms in water samples. Likewise, Enterococcus will be enumerated on mEnterococcus agar either by standard membrane filtration or HGMF. Fecal coliforms and Enterococcus in sediment will be enumerated either by the MF methods described in Shiaris et al. (1987), by HGMF methods or by an MPN method. As results of the preliminary work become available, a standard operating procedure, including quality assurance will be developed for laboratory and sampling methods.

Clostridium perfringens spores in sediment samples will be enumerated by the membrane filter method of Bisson and Cabelli (1979). Salmonella will be enumerated either by gene-probe methodolgy (Gene-Trak Systems), by HGMF, or by conventional enrichment and selective media methods.

B. Discharge monitoring.

1. Modeling. The CSO Facilities Plan includes a model which will predict overflow conditions, including when overflows will occur, where they will occur, and the amount of discharge, and the effect on the receiving waters. This model will help MWRA to estimate flows entering the receiving waters, and thus the pollutant loadings for toxics and conventional pollutants. MWRA monitoring for bacterial indicators will help to verify the model predictions.

2. Flowmeters. Install flowmeters where possible in CSO outfall pipes, to measure quantity and frequency of discharges. Where possible, CSO pipes will be physically inspected to verify if discharges do take place, and to determine if apparently inactive CSOs (e.g. 018 through 022) have not discharged.

3. Treatment plant influent monitoring. MWRA will regularly measure levels of toxic pollutants in sewer pipes and at the treatment plant. The MWRA toxics reduction and control program is initiating a pilot program of intensive monitoring of copper and oil in sewer pipes. In combination with CSO flow monitoring, these measurements will enable MWRA to ascertain inputs of nutrients, BOD, and TSS into the receiving waters via CSO discharges.

V. Reporting results. Results of the monitoring program will be reported to the EPA and MDWPC on a monthly basis, and will include results of fecal coliform counts, dissolved oxygen, temperature and salinity in the water column, the estimated volume of discharges, and the corresponding loads introduced into the receiving waters by these discharges. As data become available for sediment monitoring, these data will be reported on a quarterly basis.

This preliminary program will include frequent periodic reassessments, enabling MWRA to choose the most informative parameters and sites to study and to determine environmental, sampling, and measurenent variability, all of which must be known in order to detect environmental effects.

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