Combined work/quality assurance project plan (CWQAPP) for benthic monitoring: 2002-2005

Massachusetts Water Resources Authority

Environmental Quality Department
Report ENQUAD ms-076

Citation:

Williams IP, NJ Maciolek, JD Boyle, DT Dahlen, E Baptiste Carpenter. 2002. **Combined work/quality assurance plan for benthic monitoring: 2002-2005.** MWRA Environmental Quality Department Miscellaneous Report Number ms-076. Massachusetts Water Resources Authority, Boston, MA. 109 pp.

COMBINED WORK QUALITY ASSURANCE PROJECT PLAN
FOR
BENTHIC MONITORING

for

Benthic Monitoring: 2002 – 2005

Tasks 17-20
MWRA Harbor and Outfall Monitoring Project
Contract No. S366

Submitted to

Massachusetts Water Resources Authority
Environmental Quality Department
100 First Avenue
Charlestown Navy Yard
Boston, MA 02129
(617) 242-6000

Prepared by

Isabelle P. Williams, ENSR
Nancy J. Maciolek, ENSR
Jeanine D. Boyle, Battelle
Deirdre T. Dahlen, Battelle
Ellen Baptiste Carpenter, Battelle

Submitted by

Battelle Duxbury Operations
397 Washington Street
Duxbury, MA 02332
(781) 934-0571

May 2002

Report No. ms-076

COMBINED WORK QUALITY ASSURANCE PROJECT PLAN
(CWQAPP)

for

BENTHIC MONITORING: 2002 – 2005

Tasks 17-20
MWRA Harbor and Outfall Monitoring Project

CONCURRENCES AND APPROVALS

Ms. Ellen Baptiste Carpenter Battelle Project Manager	Date
Dr. Carlton D. Hunt Battelle Technical Director	Date
Ms. Rosanna Buhl Battelle Project QA Officer	Date
Dr. James A. Blake Benthic Area Task Manager	Date
Dr. Michael Mickelson MWRA Project Manager	Date
Mr. Kenneth E. Keay MWRA Benthic Monitoring Project Area Manager	Date
Ms. Wendy Leo MWRA EM & MS Manager	Date

CONTENTS

TABLES

FIGURES

APPENDICES

1.0 PROJECT NAME

MWRA Harbor and Outfall Monitoring Project
Tasks 17–20
Benthic (Sea-Floor) Monitoring, 2002–2005

2.0 PROJECT REQUESTED BY

Massachusetts Water Resources Authority

3.0 DATE OF REQUEST

November 28, 2001

4.0 DATE OF PROJECT INITIATION

November 28, 2001

5.0 PROJECT MANAGEMENT

Dr. Andrea Rex	MWRA Director of Environmental Quality Department
Dr. Michael Mickelson	MWRA Harbor and Outfall Monitoring Project Manager
Mr. Ken Keay	MWRA Harbor and Outfall Monitoring Deputy Project Manager and Benthic (Sea-Floor) Monitoring Project Area Manager
Ms. Ellen Baptiste-Carpenter	Battelle Harbor and Outfall Monitoring Project Manager
Dr. Carlton Hunt	Battelle Harbor and Outfall Monitoring Project Technical Director
Ms. Jeanine Boyle	Battelle Harbor and Outfall Monitoring Deputy Project Manager
Mr. Wayne Trulli	Battelle Harbor and Outfall Monitoring Field Manager
Ms. Deidre Dahlen	Battelle Harbor and Outfall Monitoring Laboratory Manager
Ms. Ellen Baptiste-Carpenter	Battelle Harbor and Outfall Monitoring Database Manager
Dr. James A. Blake	Benthic Area Task Manager

6.0 QUALITY ASSURANCE (QA) MANAGEMENT

Ms. Wendy Leo	MWRA EM & MS Manager
Ms. Rosanna Buhl	Battelle Project QA Officer
Ms. Debbie McGrath	ENSR QA Officer

7.0 PROJECT DESCRIPTION

The Benthic (Sea-Floor) Monitoring component of the MWRA Harbor and Outfall Monitoring (HOM) program addresses three main concerns: eutrophication, contaminants, and particulate inputs. Eutrophication, which may occur from the transfer of nutrient loads to the Massachusetts Bay outfall, may depress oxygen levels in benthic habitats. Such hypoxia could have profound impacts on the benthos (Diaz and Rosenberg, 1995). Toxic contaminants introduced into the environment may accumulate in depositional areas. Sediments not only represent a long-term sink for chemical contaminants, but are also sources of nutrients, toxic chemicals, and pathogenic microbes to the overlying water column (Salomons *et al.*, 1987; Brown and Neff, 1993). Excess sediment and organic particles discharged from an outfall, which is not expected from the MWRA outfall, can smother benthic habitats under certain circumstances. Such disturbances to benthic sediments frequently result in characteristic and well-documented changes in the communities that inhabit them (Pearson and Rosenberg, 1978). Therefore, benthic community structure and function can be used to indicate the overall condition of the receiving water environment. Moreover, analysis of synoptic sediment samples for benthic community parameters and for concentrations of chemical contaminants, nutrients, and organic matter often make it possible to attribute changes in benthic faunal community characteristics to particular chemical constituents of the effluent or, in some cases, to other sources of disturbance (NRC, 1990).

The benthic monitoring tasks of the Harbor and Outfall Monitoring Project will support the collection of data on the benthic macrofauna and flora, and the physical properties and levels of organic matter, nutrients, sewage indicators, and potentially toxic contaminants in the sediments in which the macrofauna reside. These measurements are made over a wide geographic area influenced by many natural and anthropogenic factors including past and current discharge of effluents from MWRA wastewater outfalls. These benthic monitoring studies provide valuable information on the temporal responses of Boston Harbor benthic communities to changes in MWRA wastewater treatment practices and are expected to provide evidence of response at the outfall in Massachusetts Bay. Certain of these measurements have been developed into monitoring thresholds designed to provide evidence of important changes in the benthic environment that may be related to the discharge from the outfall.

7.1 Objective and Scope

The scope of the benthic task includes (1) monitoring the recovery of the benthic communities in Boston Harbor and (2) obtaining data on the communities and sediment quality at sites in Massachusetts Bay and Cape Cod Bay between 2000 and 2005.

The principal aim of the Harbor studies is documentation of continuing recovery of benthic communities in areas of Boston Harbor in response to decreases in wastewater discharges, for example, reductions in combined sewer overflow (CSO) releases. Recent reports have indicated that some infaunal community changes are consistent with those expected with habitat improvements (Kropp *et al*., 2000a; Kropp *et al*., 2001). The Harbor recovery monitoring includes evaluation of local and area-wide changes in the Boston Harbor system that have resulted from (1) improvements in wastewater treatment practices (*e.g.*, cessation of sludge discharge and conversion from primary to full secondary treatment), (2) diversion of effluent to the new ocean outfall, and (3) improvements to (CSO) control systems.

Outfall studies include monitoring the response of benthic communities in Massachusetts and Cape Cod Bays to effluent discharge that began in September 2000. This monitoring program focuses most intensely on nearfield sites in western Massachusetts Bay (0–8 km from the outfall), where changes in water and sediment quality were predicted to occur following initiation of the discharge. Farfield areas (typically >8 km from the outfall), which serve primarily as reference areas for the nearfield, are also

examined as part of the monitoring studies. Such sites can become monitoring stations if the discharge is shown to affect sites distance from the diffuser.

The objectives of the benthic monitoring program are addressed in four tasks that involve sampling in the Boston Harbor, Massachusetts Bay, and Cape Cod Bay. Included are sediment sampling in the Harbor and Bays; hard-bottom sampling near the outfall; analysis of sedimentary physical characteristics, organic matter content, sewage tracer levels, and chemical contaminant concentrations; and soft- and hard-bottom benthic community structure. The present status and variability of the benthic environmental quality within the Harbor and Massachusetts Bays system will be evaluated by examination of the interrelationships among these parameters. Particular importance will be placed on the rapid evaluation of benthic data with respect to monitoring thresholds described in the Contingency and Outfall Monitoring Plans (MWRA 1997a; b; MWRA 2001), the Procedures for Calculation and Testing of Contingency Plan thresholds (MWRA, in prep) and MWRA Standard Operating Procedures (Appendix A).

Task 17. Harbor Benthic Surveys — include traditional sediment grab-sampling to collect samples for characterization of the physical, chemical (TOC), and biological status of surficial sediments at eight stations throughout Boston Harbor (Kropp and Boyle, 2001); an extensive reconnaissance survey using sediment profile images (SPI) (Kropp *et al*., 2001); and a focused contaminant survey to detect effects of CSOs on local sediment quality (Lefkovitz *et al*., 2000).

Task 18. Outfall Benthic Surveys — include nearfield and farfield soft-bottom surveys using traditional grab-sampling methods; SPI sampling in the nearfield that is designed to provide a rapid evaluation of those sedimentary habitats; and a nearfield benthic ROV (remotely operated vehicle) survey to provide semi-quantitative data about hard-bottom community responses in the vicinity of the outfall (Hilbig, *et al*., 1996; Kropp *et al*., 2000a; Kropp, *et al*., 2000b; Kropp *et al*., 2001). A special study will gather additional sediment-chemistry data, three times a year, to investigate possible short-term impacts of the new outfall discharge on concentrations of sediment contaminants and their interrelationships with possible changes in sedimentary organic carbon in depositional environments in the nearfield. Summer outfall benthic data will be evaluated for possible triggering of monitoring thresholds.

Task 19. Chemical Analysis of Sediments— includes the use of advanced analytical methods to determine potentially toxic metal and organic chemical contaminants of major concern in the sediments in Boston Harbor and the Bays. Sewage tracers, total organic matter, and grain size for the sediment samples collected under Tasks 17 and 18 will be analyzed (Kropp and Boyle 2001, Lefkovitz 2000).

Task 20. Analysis of Benthic Fauna — includes the determination of the benthic soft- and hard-bottom community structure. Benthic fauna recovered from sediment grab samples collected under Tasks 17 and 18 will be identified and counted. Results are evaluated statistically to characterize benthic community structure and to make temporal and spatial comparisons of community parameters within the Harbor and Bays ecosystems. Soft-bottom habitats will be examined through the analysis of SPI photographs. Hard-bottom communities (faunal and floral) will be evaluated through analysis of photographs and corresponding videotape for possible responses to the effluent discharge from the outfall (Kropp *et al* 2000b, Kropp *et al* 2001). A reference collection of all soft-bottom taxa (identified and unidentified specimens) collected will be stored, maintained, and compiled throughout the project (Kropp and Boyle 2001).

7.2 Data Usage

The benthic monitoring provides data that will be used to:

- Evaluate response against contingency plan thresholds
- Determine ecologically meaningful changes with statistical rigor and evaluate these changes as possible responses of benthic communities to cessation of discharges in Boston Harbor or to the continuation of treated wastewater discharges through the outfall diffuser
- Continue to develop an understanding of the dynamics and status of the ecosystems
- Correlate changes in benthic community parameters to changes in sediment concentrations of organic matter, sewage tracers, and potentially toxic chemical contaminants.

Critical to this component of the monitoring program is the use of statistical and numerical methods to evaluate benthic habitat and community changes and that can separate likely causes.

7.3 Technical Approach

7.3.1 Boston Harbor Studies

The Harbor Benthic Surveys provide the benthic samples and other data required to document long-term improvement of sediment quality and resulting recovery of the benthic communities in Boston Harbor following the cessation of sludge and effluent discharge into the Harbor. Information from an extensive reconnaissance survey using SPI supplements traditional infaunal data to provide a large-scale picture of benthic conditions in the Harbor. This greater spatial coverage is particularly important because conditions are expected to improve over a broader expanse of the Harbor since secondary treatment was implemented in 1999 and effluent discharge was diverted to the new outfall in September 2000. Harbor surveys also provide the samples necessary for monitoring contamination of sediments near CSO discharges in support of MWRA's CSO monitoring study.

During the Harbor traditional surveys (Task 17.1), conducted in April and August, soft-sediment grab samples will be collected from eight locations (Table 1, Figure 1). These traditional stations were selected after consideration of historic sampling sites and Harbor circulation patterns (Kelly and Kropp, 1992). Samples from these traditional stations will be analyzed for selected physical sediment parameters and sewage tracers (Task 19), and for benthic infaunal community parameters (Task 20).

To provide greater geographic coverage for the study of benthic community recovery, a Harbor reconnaissance survey (Task 17.2) will be conducted during August of each year. Sediment profile images (SPI) will be obtained at 60 reconnaissance stations (Table 1; Figure 1).

The CSO study (Task 17.3), to be conducted in August 2002, is a continuation of the MWRA's CSO studies conducted in 1990, 1994, and 1998 (Durell, 1995; Lefkovitz, *et al*., 2000). The CSO sediment studies provide information on improvements in sediment quality in Boston Harbor after CSO upgrades. Sediments will be collected from 13 of the 14 sites in Boston Harbor, including T01, T02, T07, and T08, sampled in the 1998 survey (Lefkovitz, *et al*., 2000), as well as T03, T04, T05A, and T06. The 14th station sampled in 1998, Station DB13, is 0.01'W of T04 but will be considered as equivalent to Station T04; the 2002 target coordinates will be those of Station T04 (Table 1). Thus, sediments from all eight traditional stations will be sampled allowing comparison with sediment contaminant concentrations determined for all eight stations in 1997 (Blake, *et al*., 1998). The 17 sediment samples collected for the CSO study will be analyzed for selected contaminants and the results compared to those obtained during

Table 1. Target Locations for Harbor Traditional, Reconnaissance, and CSO Survey Stations.

Station	Latitude	Longitude	Depth (m)
Traditional Stations (all will be included in the CSO survey)			
T01	42°20.95′N	70°57.81′W	4.9
T02	42°20.57′N	71°00.12′W	6.8
T03	42°19.81′N	70°57.72′W	8.7
T04*	42°18.60′N	71°02.49′W	3.2
T05A	42°20.38′N	70°57.64′W	17.5
T06	42°17.61′N	70°56.66′W	6.6
T07	42°17.36′N	70°58.71′W	5.9
T08	42°17.12′N	70°54.75′W	11.3
Reconnaissance Stations			
R02	42°20.66′N	70°57.69′W	13.8
R03	42°21.18′N	70°58.37′W	4.5
R04	42°21.52′N	70°58.78′W	7.2
R05	42°21.38′N	70°58.68′W	5.7
R06	42°19.91′N	70°57.12′W	10.9
R07	42°20.85′N	70°58.53′W	5.6
R08	42°20.66′N	70°59.50′W	2.6
R09	42°20.80′N	71°00.98′W	11.6
R10	42°21.32′N	71°02.20′W	12.8
R11	42°19.28′N	70°58.48′W	7.3
R12	42°19.10′N	70°58.47′W	6.1
R13	42°19.03′N	70°58.84′W	6.7
R14	42°19.25′N	71°00.77′W	10.0
R15	42°18.92′N	71°01.15′W	3.2
R16	42°18.95′N	70°57.68′W	8.0
R17	42°18.29′N	70°58.63′W	8.1
R18	42°17.33′N	70°57.67′W	8.0
R19	42°16.92′N	70°56.27′W	9.2
R20	42°19.49′N	70°56.10′W	11.2
R21	42°18.53′N	70°56.78′W	8.7
R22	42°18.02′N	70°56.37′W	9.4
R23	42°17.63′N	70°57.00′W	10.8
R24	42°17.78′N	70°57.51′W	7.4
R25	42°17.48′N	70°55.72′W	7.3
R26	42°16.13′N	70°55.80′W	7
R27	42°16.83′N	70°54.98′W	6
R28	42°16.90′N	70°54.52′W	7

Table 1. (continued)

Station	Latitude	Longitude	Depth (m)
R29	42°17.38′N	70°55.25′W	11
R30	42°17.43′N	70°54.25′W	5
R31	42°18.05′N	70°55.03′W	10
R32	42°17.68′N	70°53.82′W	5
R33	42°17.65′N	70°59.67′W	5
R34	42°17.33′N	71°00.42′W	4
R35	42°17.05′N	70°59.28′W	6
R36	42°16.53′N	70°59.20′W	5
R37	42°17.93′N	70°59.08′W	6
R38	42°17.08′N	70°57.83′W	7
R39	42°17.73′N	70°58.22′W	8
R40	42°19.73′N	71°01.45′W	2
R41	42°18.67′N	71°01.50′W	4
R42	42°19.18′N	71°01.50′W	2
R43	42°18.40′N	71°00.13′W	3
R44	42°20.62′N	71°00.13′W	9.3
R45	42°19.70′N	70°58.05′W	6.8
R46	42°17.46′N	70°55.33′W	10.5
R47	42°20.67′N	70°58.72′W	6.5
R48	42°17.61′N	70°59.27′W	5.9
R49	42°16.39′N	70°54.49′W	6.1
R50	42°16.50′N	70°53.92′W	6.1
R51	42°15.80′N	70°56.53 ′W	5.3
R52	42°15.71′N	70°56.09′W	5.2
R53	42°16.15′N	70°56.27′W	6
Remaining CSO Stations			
DB01	42°19.48′N	71°02.75′W	3.0
DB03	42°19.30′N	71°00.86′W	5.0
DB04	42°19.68′N	71°02.22′W	4.0
DB06	42°19.39′N	71°02.25′W	2.0
DB10	42°17.50′N	71°02.33′W	2.0
DB12	42°18.97′N	71°01.29′W	5.0
DB13* (will not be sampled)	42°18.60′N	71°02.50′W	3.2
DB14	42°17.92′N	71°02.73′W	2
C019 (1998 station location)	42°21.55′N	71°02.71′W	7.9
SWEX3	42°19.76′N	70°59.56′W	8.0

*For the CSO survey, Station T04 and DB13 will be considered as equivalent. Target coordinates will be those for Station T04.

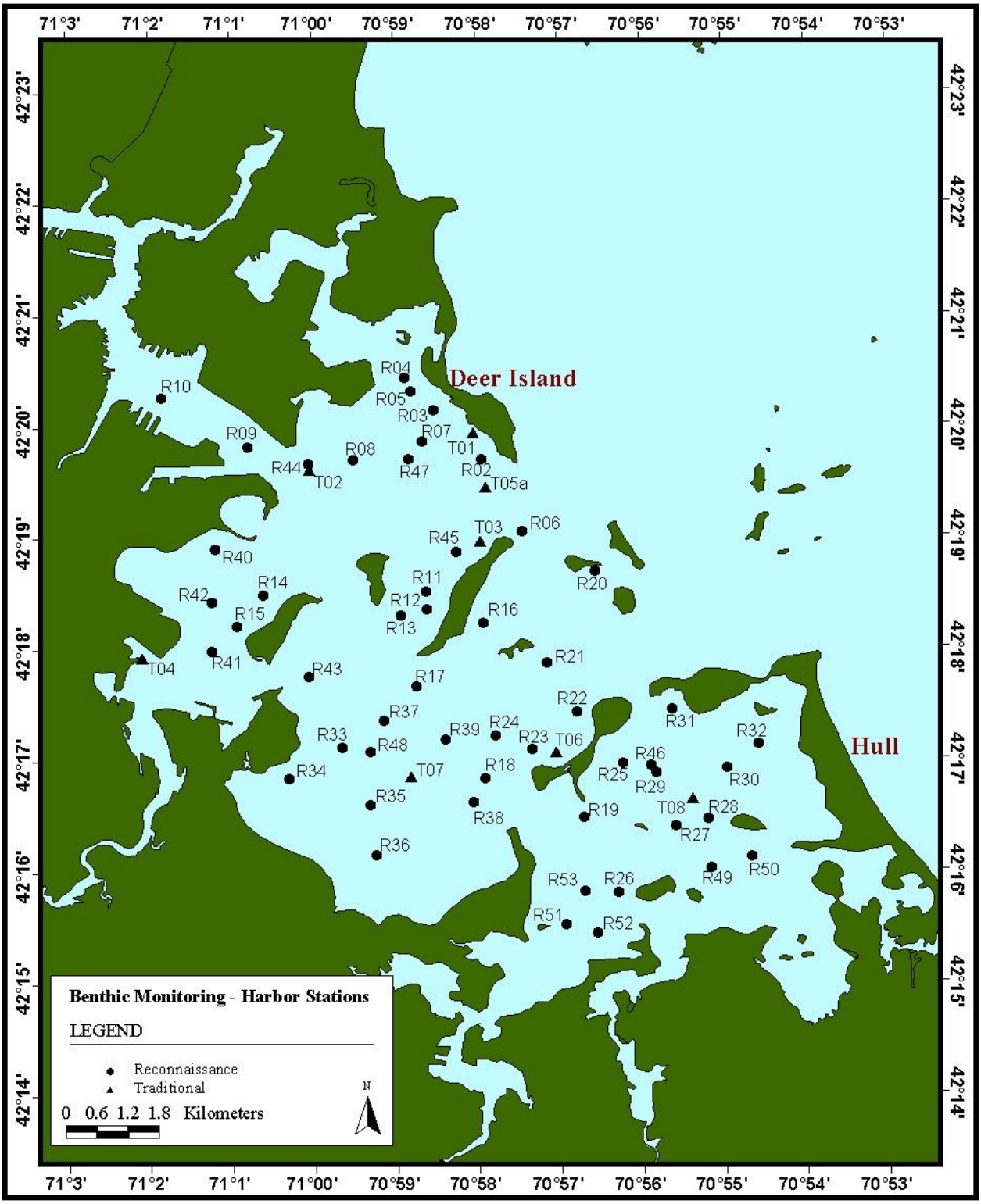

Figure 1. Locations of Boston Harbor Traditional and Reconnaissance Stations.

the previous three CSO studies and the 1997 Harbor contaminant study. A synthesis report on the CSO study will be submitted to MWRA in July 2003.

Details of the field sampling and laboratory methods to be used in the Harbor benthic studies (including the CSO studies) are provided in Section 12.

7.3.2 Outfall Studies

The Outfall Benthic Surveys provide quantitative measurements of benthic community structure and patterns of contaminant concentrations in the sediments of Massachusetts and Cape Cod Bays. Baseline data was collected yearly in August from 1992–2000, and in September 2000. After effluent discharge into Massachusetts Bay began, the focus of the program changed to an evaluation of the effects of the discharge on the ecosystems of both Bays. Outfall surveys conducted under this task will provide the data required for a quantitative assessment of the effects of discharged effluent on sediment chemistry (Task 19) and benthic infaunal communities (Task 20). The objectives of the monitoring program in the post-discharge phase are (1) to satisfy National Pollutant Discharge Elimination System (NPDES) permit requirements, (2) to test whether or not any discharge-related impacts are within the limits predicted by the Supplemental Environmental Impact Study (SEIS)(EPA, 1988), and (3) to determine if changes in the system exceed Contingency Plan thresholds (MWRA 1997a,b; MWRA 2001; Appendix A).

Technical Overview — The nearfield benthic surveys, conducted in August of each year (Task 18.1), are designed to provide spatial coverage and local detail of faunal communities inhabiting depositional environments within about 8 km of the diffuser. Samples for sediment chemistry and benthic infauna will be collected at the 20 nearfield stations and three farfield stations (Table 2; Figure 2). Inclusion of the three farfield stations in this task allows analysis of the faunal samples collected at those stations to be accelerated during laboratory activities conducted under Task 20.

The Nearfield Contaminant Special Study Surveys (NCSS) (Task 18.2) examine the possible short-term impacts of the outfall discharge on the concentration of contaminants in the sediments and the relationship of any such contamination with changes in organic carbon concentration in the depositional sediments near the outfall. Four nearfield depositional sites (FF10, NF08, NF22 and NF24) were selected for this study after consideration of grain size composition (>50% sand/silt), stability of grain size composition over the period monitored, and historical high TOC relative to other stations nearby (>1% TOC). The NCSS was initiated in October 1998. Pre-discharge baseline surveys also were conducted in August 1999 and August 2000 as part of the nearfield benthic surveys. The first post-discharge survey occurred in November 2000. Surveys were conducted three times in 2001, in February, August and October, and are scheduled to recur on the same timetable through 2005.

Nearfield sediment profile image surveys (Task 18.3), conducted in August each year at 20 nearfield and 3 farfield stations (Table 2 in Kropp and Boyle 2001), give an area-wide, qualitative/ semi-quantitative assessment of sediment quality and benthic community status that can be integrated with the results of the quantitative surveys to determine sedimentary conditions near the outfall. Furthermore, these surveys provide rapid comparison of benthic conditions to a Contingency Plan threshold for depth of sediment RPD. Sediment profile imagery (35-mm slides) allows a faster evaluation of the benthos to be made than can be accomplished through traditional faunal analyses. Rapid analysis of the SPI data will be accomplished with a digital video camera arranged to view the same sediment profile as the 35-mm film camera. At least three photographic images will be collected for analysis from each station.

Because of the relative sparseness of depositional habitats in the nearfield and in the vicinity of the diffusers, an ongoing study of hard-bottom habitats supplements the soft-bottom studies. Nearfield hard-

Table 2. Target Locations for Outfall Survey Stations.

Station	Latitude	Longitude	Depth (m)
Nearfield Stations			
NF02	42°20.31′N	70°49.69′W	26
NF04	42°24.93′N	70°48.39′W	34
NF05	42°25.62′N	70°50.03′W	36
NF07	42°24.60′N	70°48.89′W	32
NF08[+]	42°24.00′N	70°51.81′W	28
NF09	42°23.99′N	70°50.69′W	29
NF10	42°23.57′N	70°50.29′W	32.9
NF12	42°23.40′N	70°49.83′W	34.9
NF13	42°23.40′N	70°49.35′W	33.8
NF14	42°23.20′N	70°49.36′W	34.1
NF15	42°22.93′N	70°49.67′W	32.7
NF16	42°22.70′N	70°50.26′W	31.1
NF17	42°22.88′N	70°48.89′W	30.6
NF18	42°23.80′N	70°49.31′W	33.3
NF19	42°22.30′N	70°48.30′W	33.2
NF20	42°22.69′N	70°50.69′W	28.9
NF21	42°24.16′N	70°50.19′W	30
NF22[+]	42°20.87′N	70°48.90′W	30
NF23	42°23.86′N	70°48.10′W	36
NF24[+]	42°22.83′N	70°48.10′W	37
Farfield Stations			
FF01A	42°33.84′N	70°40.55′W	35
FF04	42°17.30′N	70°25.50′W	90
FF05	42°08.00′N	70°25.35′W	65
FF06	41°53.90′N	70°24.20′W	35
FF07	41°57.50′N	70°16.00′W	39
FF09	42°18.75′N	70°39.40′W	50
FF10[+]*	42°24.84′N	70°52.72′W	28.7
FF11	42°39.50′N	70°30.00′W	88.4
FF12*	42°23.40′N	70°53.98′W	23.5
FF13*	42°19.19′N	70°49.38′W	20.7
FF14	42°25.00′N	70°39.29′W	73.3

[+]Nearfield Contaminant Special Study Stations.
*Farfield Stations FF10, FF12, and FF13 are analyzed with the nearfield stations.

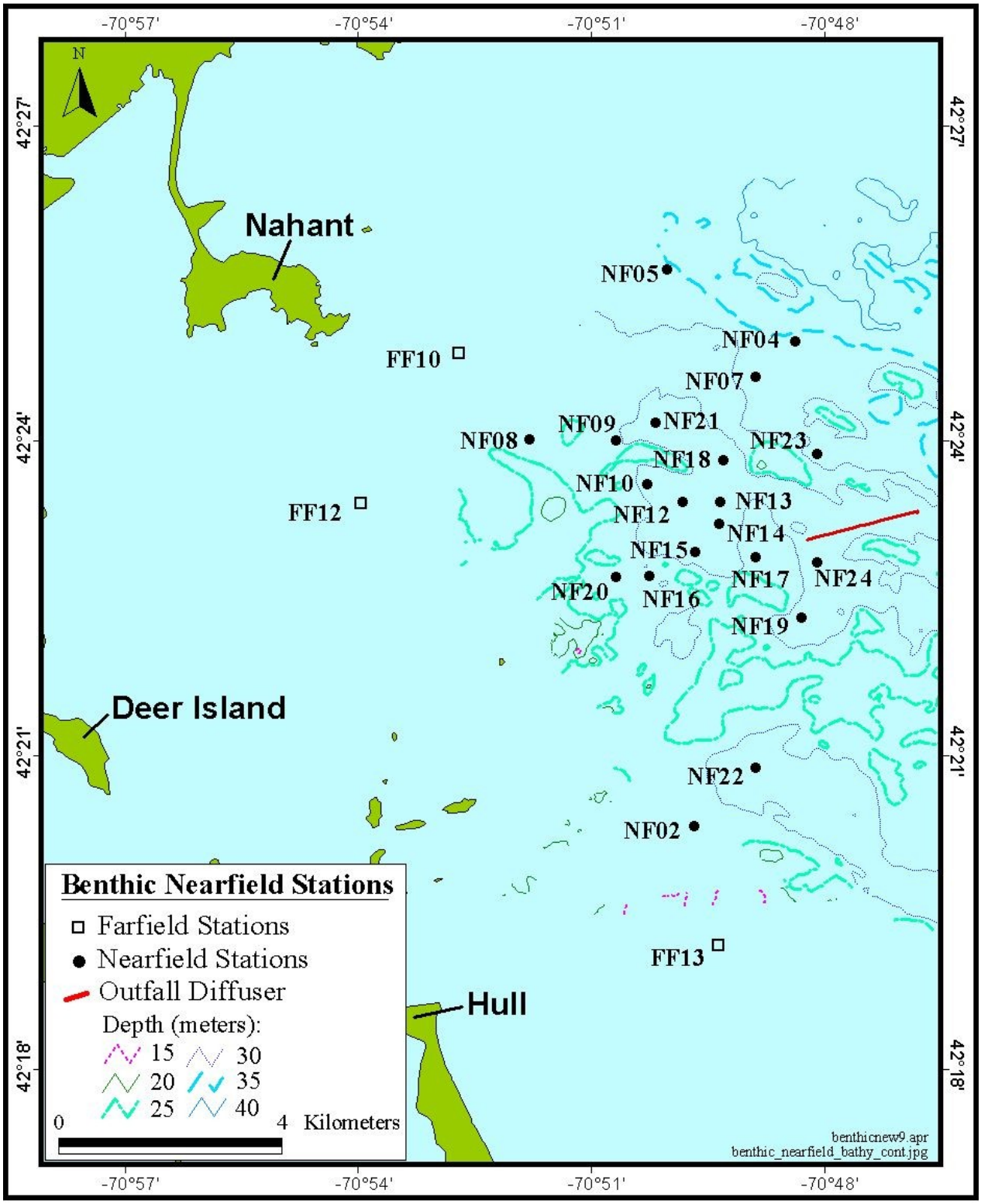

Figure 2. Locations of Nearfield Benthic Stations (including FF10, FF12 and FF13).

bottom surveys (Task 18.4) will take place in June each year. Videotape footage and 35-mm slides will be taken at 20 waypoints/stations along 6 transects and 3 solitary waypoints, one of which is Diffuser #44 (Table 3, Figure 3). Twenty minutes of video and 36 still photographs of the bottom will be taken at each station.

Table 3. Target Locations for Hard-bottom Survey Transects.

Transect	Waypoint/ Station	Latitude	Longitude	Depth (m)
T1	1	42°23.606'N	70°48.201'W	25
T1	2	42°23.625'N	70°48.324'W	24
T1	3	42°23.741'N	70°48.532'W	22
T1	4	42°23.815'N	70°48.743'W	20
T1	5	42°23.869'N	70°48.978'W	27
T2	1	42°23.634'N	70°47.833'W	26
T2	2	42°23.570'N	70°47.688'W	27
T2	3	42°23.525'N	70°47.410'W	26
T2	4	42°23.457'N	70°47.265'W	32
T2	5 = Diffuser #2	42°23.331'N	70°46.807'W	34
T4	1	42°23.046'N	70°46.502'W	31
T4	2	42°23.012'N	70°46.960'W	29
T4	3	42°22.877'N	70°47.580'W	30
T4/T6	1	42°22.948'N	70°47.220'W	23
T6	1	42°22.993'N	70°47.712'W	30
T6	2	42°22.855'N	70°47.082'W	27
T7	1	42°24.565'N	70°47.015'W	23
T7	2	42°24.570'N	70°46.920'W	24
T8	1	42°21.602'N	70°48.920'W	23
T8	2	42°21.823'N	70°48.465'W	23
T9	1	42°24.170'N	70°47.768'W	24
T10	1	42°22.680'N	70°48.852'W	26
Diffuser # 44		42°23.116'N	70°47.931'W	33

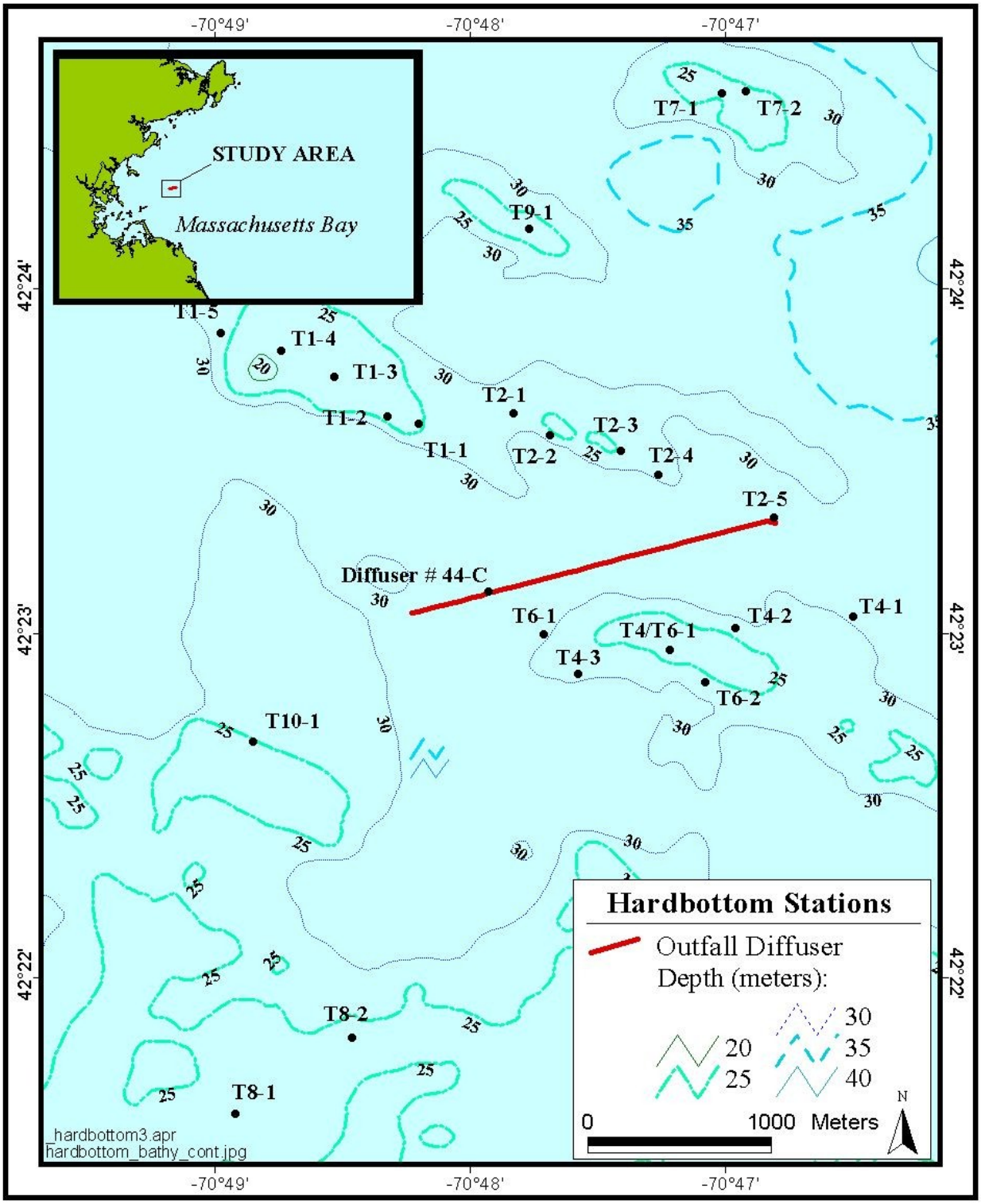

Figure 3. Locations of Hard-bottom Survey Stations.

Farfield benthic surveys, conducted in August each year (Task 18.5), contribute reference and early-warning data on soft-bottom habitats in Massachusetts and Cape Cod Bays. Grab samples will be collected at eight stations (Table 2, Figure 4) for infaunal and chemical analyses. Some sampling within the Stellwagen Bank National Marine Sanctuary is required. Appropriate permits will be obtained.

Details of field sampling and laboratory methods to be used in the Outfall studies are given in Section 12.

Contingency Plan Thresholds — The MWRA (1997a) developed a Contingency Plan that specifies numerical or qualitative thresholds that may suggest that environmental conditions in the Bay are changing or might be likely to change. The Plan provides a mechanism to confirm that a threshold has been exceeded, to determine the causes and significance of the event, and to identify the action necessary to return the trigger parameter to a level below the threshold (if the change resulted from effluent discharge). Sediment thresholds have been established for depth of the redox potential discontinuity (RPD), sediment contaminant concentrations, benthic community diversity and relative abundance of opportunistic species (MWRA, 1997a,b; MWRA, in prep; and Appendix A).

Battelle's requirement under HOM4 in regard to threshold testing is the following:

- Maintain threshold, threshold_baseline and threshold_test tables in the local (Battelle Duxbury Operations) copy of the EM&MS
- Import new threshold and threshold_baseline tables if MWRA makes changes
- Maintain the current version of threshold test scripts as provided by MWRA
- Run the current version of the threshold test script on newly loaded data as appropriate
- Maintain a record of all threshold runs in local copy of the threshold_test table
- Report running of threshold tests in the monthly progress report
- Report results of threshold tests in the data report.

7.4 Monitoring Parameters and Collection Frequency

A summary of the numbers of stations to be visited and the types and numbers of field samples to be collected in Boston Harbor and in Massachusetts and Cape Cod Bays during this project is given in Table 4. The numbers of samples are listed separately for each survey and for all benthic surveys within a subtask.

The parameters to be measured during the various Benthic (Sea-Floor) Monitoring tasks can be characterized as macrobiological, sedimentological (habitat properties and contaminant levels), and microbiological. Macrobiological parameters, based primarily on the species-level identifications, include community measures such as abundance (or percent cover), numbers of species, and diversity. Some sediment habitat properties are measured during the SPI studies (Table 5) and include information about sediment geophysical properties and the general nature of the infaunal community. Sediment grain-size distribution is determined visually during the SPI analyses and through the laboratory analysis of subsamples taken from grab samples. Sediment contaminant parameters include several types of organic contaminants (PAHs, PCBs, and pesticides) and metals. Microbiological parameters focus on concentrations of sewage tracer organisms including *Clostridium perfringens*, fecal coliform bacteria, and *Enterococcus*. The latter two microbiological parameters are determined only for CSO study samples. A detailed presentation of the parameters to be measured is presented in the text and tables comprising Section 12.

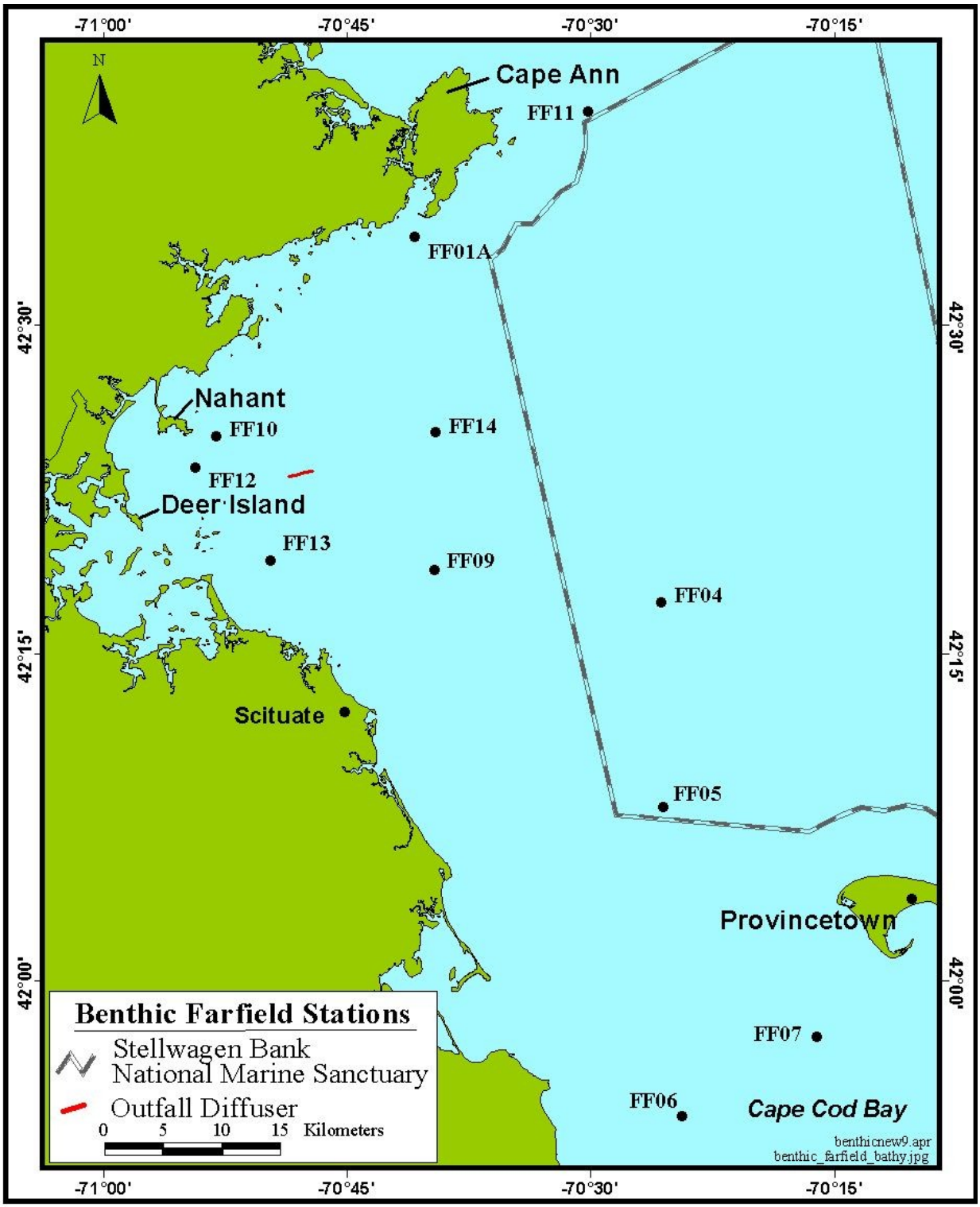

Figure 4. Locations of Farfield Benthic Stations (FF10, FF12, and FF13 will be analyzed with the nearfield samples).

Table 4. Number of Samples Collected on Each Survey, and in Total, by Task.

	Task 17 Harbor Surveys					Task 18 Outfall Surveys									
	17.1		17.2		17.3	18.1*		18.2		18.3		18.4		18.5	
	Survey	*Total*	*Survey*	*Total*	*Total*	*Survey*	*Total*	*Survey*	*Total*	*Survey*	*Total*	*Survey*	*Total*	*Survey*	*Total*
Infauna	24	192	—	—	—	35	140	—	—	—	—	—	—	24	96
Sediment Chemistry Polynuclear Aromatic hydrocarbons (PAHs) Polychlorinated biphenyls (PCBs) Linear alkyl benzenes (LABs) Metals Coprostanol	—	—	—	—	51	35	140	12	96	—	—	—	—	16	6
Ancillary Parameters Total Organic Carbon (TOC) Grain Size *C. perfringens*	8	56	—	—	51	35	140	12	96	—	—	—	—	16	64
Enterococcus	—	—	—	—	51	—	—	—	—	—	—	—	—	—	—
Fecal Coliform	—	—	—	—	51	—	—	—	—	—	—	—	—	—	—
Sediment Profile Images (SPI)	—	—	180	720	—	—	—	—	—	69	276	—	—	—	—
Hard-bottom Slides Video (min)	—	—	—	—	—	—	—	—	—	—	—	828 460	3312 1840	—	—

* Nearfield surveys include Stations FF10, FF12, and FF13.

Table 5. Parameters Measured from Sediment Profile Images.

Parameter	Units	Method	Description
Sediment Grain Size	Modal phi interval	V	An estimate of sediment types present. Determined from comparison of image to images of known grain size
Prism Penetration	cm	CA	A geotechnical estimate of sediment compaction. Average of maximum and minimum distance from sediment surface to bottom of prism window
Sediment Surface Relief	cm	CA	An estimate of small-scale bed roughness. Maximum depth of penetration minus minimum
Apparent Reduction-oxidation Potential Discontinuity Depth (from color change in sediment)	cm	CA	Estimate of depth to which sediments are oxidized. Area of aerobic sediment divided by width of digitized image
Thickness of Sediment Layers	cm, cm^2	CA	Measure thickness above original sediment surface and delineate area
Methane/Nitrogen Gas Voids	Number, cm, cm^2	V, CA	Count, measure depth from sediment surface, and area
Epifauna	Number	V	Count, identify
Tube Density	Number, cm^2	V, CA	Count
Tube Type Burrow Structures Pelletal Layer Bacterial Mats	 — cm, cm^2 —	 V V, CA V,	 Identify Measure thickness, area Determine presence and color
Infauna Visible Infauna Feeding Voids Successional Stage	 Number Number, cm, cm^2 —	 V V, CA V	 Count, identify Count, measure depth from sediment surface, and area Identify
Organism Sediment Index	—	CA	Derived from RPD, Successional Stage, Voids (Rhoads and Germano, 1986)

V: Visual measurement or estimate
CA: Computer analysis

8.0 PROJECT FISCAL INFORMATION

This project will be carried out under the terms of Harbor and Outfall Monitoring Contract S366 between the MWRA and Battelle Duxbury Operations.

9.0 SCHEDULE OF ACTIVITIES AND DELIVERABLES

Benthic (Sea-Floor) Monitoring activities will span the period from the date of project initiation (November 7, 2001) until July 2006 when the last annual synthesis report is due. Activities include field sampling and laboratory analyses, with deliverables consisting of survey plans, survey reports, data reports accompanied by data exports, and synthesis reports (prepared under Task 33). Schedules for these activities and deliverables are outlined in Tables 6 and 7.

10.0 PROJECT ORGANIZATION

The Benthic (Sea-Floor) Monitoring tasks will be accomplished through the coordinated efforts of several organizations. Figure 5 presents the Project Management structure and the major tasks necessary to complete the scope of work. Each task element has been assigned a separate subaccount with budget and milestones for tracking costs against progress. Battelle's Project Management Plan describes the management policies that will be applied to all HOM 4 activities (Battelle, 2002a).

Dr. Andrea Rex is the MWRA Director of Environmental Quality Department. Dr. Michael Mickelson is the MWRA Project Manager. Mr. Ken Keay is the MWRA Deputy Project Manager and is the Project Area Manager for the Benthic (Sea-Floor) Monitoring. They will be informed of all matters pertaining to work described in this CWQAPP. Ms. Wendy Leo is the MWRA EM&MS Database Manager.

Ms. Ellen Baptiste Carpenter is the Battelle Project Manager and is responsible for ensuring that products and services that meet MWRA's expectations are delivered in a timely and cost-effective manner, and for the overall performance of this project. She is also Battelle's Database Manager for this project. Dr. Carlton Hunt is the Battelle Technical Director and is responsible for ensuring that data collection and interpretation are scientifically defensible and for responding to technical challenges as they arise. Ms. Jeanine Boyle is the Battelle Deputy Project Manager. The Battelle Quality Assurance Officer for the project is Ms. Rosanna Buhl. For this task, Ms. Buhl is responsible for reviewing data reports and QA Statements submitted by subcontractors for quality completeness and adherence to the CWQAPP. She is also responsible for reviewing the CSO synthesis report (Task 33.7) and the chemistry sections of the Harbor (33.6) and Outfall (33.5) synthesis reports. Mr. Wayne Trulli is the Battelle Field Manager responsible for the overall field program. Mr. Chris Gagnon is the Deputy Field Manager and is responsible for all day-to-day field activities conducted by Battelle for the project. Ms. Deirdre Dahlen, Battelle's Laboratory Manager, is responsible for overseeing all laboratory activities in the contract. Key contacts at each of the supporting laboratories are shown in Figure 5. Addresses, telephone (and fax) numbers, and Internet addresses, as well as specific project roles and responsibilities, are presented in the HOM 4 Program Management Plan (Battelle, 2002a).

Technical oversight for the Benthic (Sea-Floor) Monitoring will be provided by a team of Senior Scientists gathered together by Battelle and ENSR. Battelle will have overall responsibility for sediment chemistry under the direction of Dr. Carlton Hunt (Battelle), Ms. Lisa Lefkovitz and Ms. Deirdre Dahlen (Battelle). ENSR will be responsible for the biological aspects of benthic monitoring with Dr. James A. Blake having overall responsibility for the ENSR components. Dr. Blake will be supported by Dr. Nancy Maciolek (ENSR), Ms. Isabelle Williams (ENSR), Dr. Eugene Gallagher (U Mass, Boston), and Dr. Robert Diaz (Diaz and Daughters) for Benthic Ecology; Dr. Robert Diaz (Diaz & Daughters) for

Sediment Profile Imagery; and Dr. Barbara Hecker (Hecker Environmental) for Hard-bottom community analysis. The ENSR Quality Assurance officer is Ms. Debbie McGrath. She will be responsible for ensuring that the audits and reviews required in the Project Management Plan (Battelle, 2002) are conducted. Ms. McGrath will also have reiew responsibility for the Outfall (33.5) and Harbor (33.6) synthesis reports. The contacts for the supporting laboratories are shown in Figure 5.

Table 6. Overview of Harbor and Outfall Surveys and Associated Deliverables.

Survey Date	Survey	Survey Plan	Due Date Summary Report	Draft Survey Report *
February 2002	Nearfield Contaminant Special Study (Task 18.2)	January 2002		March 2002
April 2002	Harbor Traditional (Task 17.1)	March 2002		May 2002
June 2002	Nearfield Hard-bottom Survey (Task 18.4)	May 2002		July 2002
August 2002	Harbor Traditional/Reconnaissance/ Nearfield Contaminant Special Study and Soft-Bottom Outfall Survey (Tasks 17.1,17.2,18.1,18.5)	July 2002	August 2002 (Task 18.1 only)	September 2002
August 2002	CSO Sediment Survey (Task 17.3)	July 2002		September 2002
August 2002	Nearfield Sediment Image Profile Survey (Task 18.3)	July 2002	August 2002	September 2002
October 2002	Nearfield Contaminant Special Study (Task 18.2)	September 2002		November 2002
February 2003	Nearfield Contaminant Special Study (Task 18.2)	January 2003		March 2003
April 2003	Harbor Traditional Survey (Task 17.1)	March 2003		May 2003
June 2003	Nearfield Hard-bottom Survey (Task 18.4)	May 2003		July 2003
August 2003	Harbor Traditional/Reconnaissance/ Nearfield Contaminant Special Study and Soft-Bottom Outfall Survey (Tasks 17.1,17.2,18.1,18.5)	July 2003	August 2003 (Task 18.1 only)	September 2003
August 2003	Nearfield Sediment Profile Image Survey (Task 18.3)	July 2003	August 2003	September 2003
October 2003	Nearfield Contaminant Special Study (Task 18.2)	September 2003		November 2003
February 2004	Nearfield Contaminant Special Study (Task 18.2)	January 2004		March 2004
April 2004	Harbor Traditional Survey (Task 17.1)	March 2004		May 2004
June 2004	Nearfield Hard-bottom Survey (Task 18.4)	May 2004		July 2004
August 2004	Harbor Traditional/Reconnaissance/ Nearfield Contaminant Special Study and Soft-Bottom Outfall Survey (Tasks 17.1,17.2,18.1,18.5)	July 2004	August 2004 (Task 18.1 only)	September 2004
August 2004	Nearfield Sediment Profile Image Survey (Task 18.3)	July 2004	August 2004	September 2004
October 2004	Nearfield Contaminant Special Study (Task 18.2)	September 2004		November 2004

Table 6. (continued)

Survey Date	Survey	Survey Plan	Due Date Summary Report	Draft Survey Report *
February 2005	Nearfield Contaminant Special Study (Task 18.2)	January 2005		March 2005
April 2005	Harbor Traditional Survey (Task 17.1)	March 2005		May 2005
June 2005	Nearfield Hard-bottom Survey (Task 18.4)	May 2005		July 2005
August 2005	Harbor Traditional/Reconnaissance/ Nearfield Contaminant Special Study and Soft-Bottom Outfall Survey (Tasks 17.1,17.2,18.1,18.2,18.5)	July 2005	August 2005 (Task 18.1 only)	September 2005
August 2005	Nearfield Sediment Profile Image Survey (Task 18.3)	July 2005	August 2005	September 2005
October 2005	Nearfield Contaminant Special Study (Task 18.2)	September 2005		November 2005

* Final Survey Reports due 2 weeks from receipt of MWRA's comments on the draft report.

Table 7. Overview of Data and Synthesis Reports.

Survey Date (2002)	Deliverable	Draft Report Due Date
February 2002	Nearfield Contaminant Special Study Data Report (Task 19.4)	15 June 2002
April 2002	Harbor Sediment Chemistry Data Report (Task 19.1)	15 July 2002
	April Harbor Faunal Sorting Completion Letter Report (Task 20.2)	15 July 2002
	April Harbor Faunal Data Report (Task 20.2)	15 September 2002
June 2002	Nearfield Hard-bottom Reconnaissance Data Report (Task 20.8)	15 December 2002
August 2002	August Harbor Faunal Sorting Completion Letter Report (Task 20.2)	15 January 2003
	August Harbor Faunal Data Report (Task 20.2)	15 March 2003
	August Nearfield Faunal Sorting Completion Letter Report (Task 20.3)	60 days after survey completion
	Nearfield Faunal Data Report (Task 20.3)	Later of 30 November 2002 or 105 days after survey completion
	August Farfield Faunal Sorting Completion Letter Report (Task 20.4)	15 October 2002
	Farfield Faunal Data Report (Task 20.4)	January 15 2003
	Nearfield Sediment Chemistry Data Report (Task 19.3)	Earlier of 15 November 2002 or 75 days after survey completion
	Farfield Sediment Chemistry Data Report (Task 19.5)	15 December 2002
	CSO Sediment Survey Data Report (Task 19.2)	15 December 2002
	Harbor Sediment Profile Imaging Survey Data Report (Task 20.6)	15 January 2003
	Nearfield Sediment Profile Imaging Survey Data Report (Task 20.7)	Earlier of 30 October 2002 or 60 days after survey completion
October 2002	Nearfield Contaminant Special Study Data Report (Task 19.4)	15 February 2003
2002 Annual	Outfall Benthic Synthesis Report (Task 33.5)	May 2003
	Reference Collection Status Report (Task 20.1)	June 2003
	Harbor Benthic Synthesis Report (Task 33.6)	July 2003
	CSO Sediment Synthesis Report (Task 33.7)	July 2003

Table 7. (continued)

Survey Date (2003)	Deliverable	Draft Report Due Date
February 2003	Nearfield Contaminant Special Study Data Report (Task 19.4)	15 June 2003
April 2003	Harbor Sediment Chemistry Data Report (Task 19.1)	15 July 2003
	April Harbor Faunal Sorting Completion Letter Report (Task 20.2)	15 July 2003
	April Harbor Faunal Data Report (Task 20.2)	15 September 2003
June 2003	Nearfield Hard-bottom Reconnaissance Data Report (Task 20.8)	15 December 2003
August 2003	August Harbor Faunal Sorting Completion Letter Report (Task 20.2)	15 January 2004
	August Harbor Faunal Data Report (Task 20.2)	15 March 2004
	August Nearfield Faunal Sorting Completion Letter Report (Task 20.3)	60 days after survey completion
	Nearfield Faunal Data Report (Task 20.3)	Later of 30 November 2003 or 105 days after survey completion
	August Farfield Faunal Sorting Completion Letter Report (Task 20.4)	15 October 2003
	Farfield Faunal Data Report (Task 20.4)	15 January 2004
	Harbor Sediment Chemistry Data Report (Task 19.1)	15 November 2003
	Nearfield Sediment Chemistry Data Reports (Task 19.3)	Earlier of 15 November 2003 or 75 days after survey completion
	Farfield Sediment Chemistry Data Reports (Task 19.5)	15 December 2003
	Harbor Sediment Profile Imaging Survey Data Report (Task 20.6)	15 January 2004
	Nearfield Sediment Profile Imaging Survey Data Report (Task 20.7)	Earlier of 30 October 2002 or 60 days after survey completion
October 2003	Nearfield Contaminant Special Study Data Report (Task 19.4)	15 February 2004
2003 Annual	Outfall Benthic Synthesis Report (Task 33.5)	May 2004
	Reference Collection Status Report (Task 20.1)	June 2004
	Harbor Benthic Synthesis Report (Task 33.6)	July 2004

Table 7. (continued)

Survey Date (2004)	Deliverable	Draft Report Due Date
February 2004	Nearfield Contaminant Special Study Data Report (Task 19.4)	15 June 2004
April 2004	Harbor Sediment Chemistry Data Report (Task 19.1)	15 July 2004
	April Harbor Faunal Sorting Completion Letter Report (Task 20.2)	15 July 2004
	April Harbor Faunal Data Report(Task 20.2)	15 September 2004
June 2004	Nearfield Hard-bottom Reconnaissance Data Report (Task 20.8)	15 December 2004
August 2004	August Harbor Faunal Sorting Completion Letter Report (Task 20.2)	15 January 2005
	August Harbor Faunal Data Report (Task 20.2)	15 March 2005
	August Nearfield Faunal Sorting Completion Letter Report (Task 20.3)	60 days after survey completion
	Nearfield Faunal Data Report (Task 20.3)	Later of 30 November 2004 or 105 days after survey completion
	August Farfield Faunal Sorting Completion Letter Report (Task 20.4)	15 October 2004
	Farfield Faunal Data Report (Task 20.4)	15 January 2005
	Harbor Sediment Chemistry Data Report (Task 19.1)	15 November 2004
	Nearfield Sediment Chemistry Data Reports (Task 19.3)	Earlier of 15 November 2004 or 75 days after survey completion
	Farfield Sediment Chemistry Data Reports (Task 19.3, 19.5)	15 December 2004
	Harbor Sediment Profile Imaging Survey Data Report (Task 20.6)	15 January 2005
	Nearfield Sediment Profile Imaging Survey Data Report (Task 20.7)	Earlier of 30 October 2004 or 60 days after survey completion
October 2004	Nearfield Contaminant Special Study Data Report (Task 19.4)	15 February 2005
2004 Annual	Outfall Benthic Synthesis Report (Task 33.5)	May 2005
	Reference Collection Status Report (Task 20.1)	June 2005
	Harbor Benthic Synthesis Report (Task 33.6)	July 2005

Table 7. (continued)

Survey Date (2005)	Deliverable	Draft Report Due Date
February 2005	Nearfield Contaminated Special Study Data Report (Task 19.4)	15 June 2005
April 2005	Harbor Sediment Chemistry Data Report (Task 19.1)	15 July 2005
	April Harbor Faunal Sorting Completion Letter Report (Task 20.2)	15 July 2005
	April Harbor Faunal Data Report (Task 20.2)	15 September 2005
June 2005	Nearfield Hard-bottom Reconnaissance Data Report (Task 20.8)	15 December 2005
August 2005	August Harbor Faunal Sorting Completion Letter Report (Task 20.2)	15 January 2006
	August Harbor Faunal Data Report (Task 20.2)	15 March 2006
	August Nearfield Faunal Sorting Completion Letter Report (Task 20.3)	60 days after survey completion
	Nearfield Faunal Data Report (Task 20.3)	Later of 30 November 2005 or 105 days after survey completion
	August Farfield Faunal Sorting Completion Letter Report (Task 20.4)	15 October 2005
	Farfield Faunal Data Report (Task 20.4)	15 January 2006
	Harbor Sediment Chemistry Data Report (Task 19.1)	15 November 2005
	Nearfield Sediment Chemistry Data Reports (Task 19.3)	Earlier of 15 November 2005 or 75 days after survey completion
	Farfield Sediment Chemistry Data Reports (Task 19.3, 19.5)	15 December 2005
	Harbor Sediment Profile Imaging Survey Data Report (Task 20.6)	15 January 2006
	Nearfield Sediment Profile Imaging Survey Data Report (Task 20.7)	Earlier of 30 October 2005 or 60 days after survey completion
October 2005	Nearfield Contaminant Special Study Data Report (Task 19.4)	15 February 2006
2005 Annual	Outfall Benthic Synthesis Report (Task 33.5)	May 2006
	Reference Collection Status Report (Task 20.1)	June 2006
	Harbor Benthic Synthesis Report (Task 33.6)	July 2006

* Final Reports due 2 weeks after receipt of MWRA's comments on the draft report.

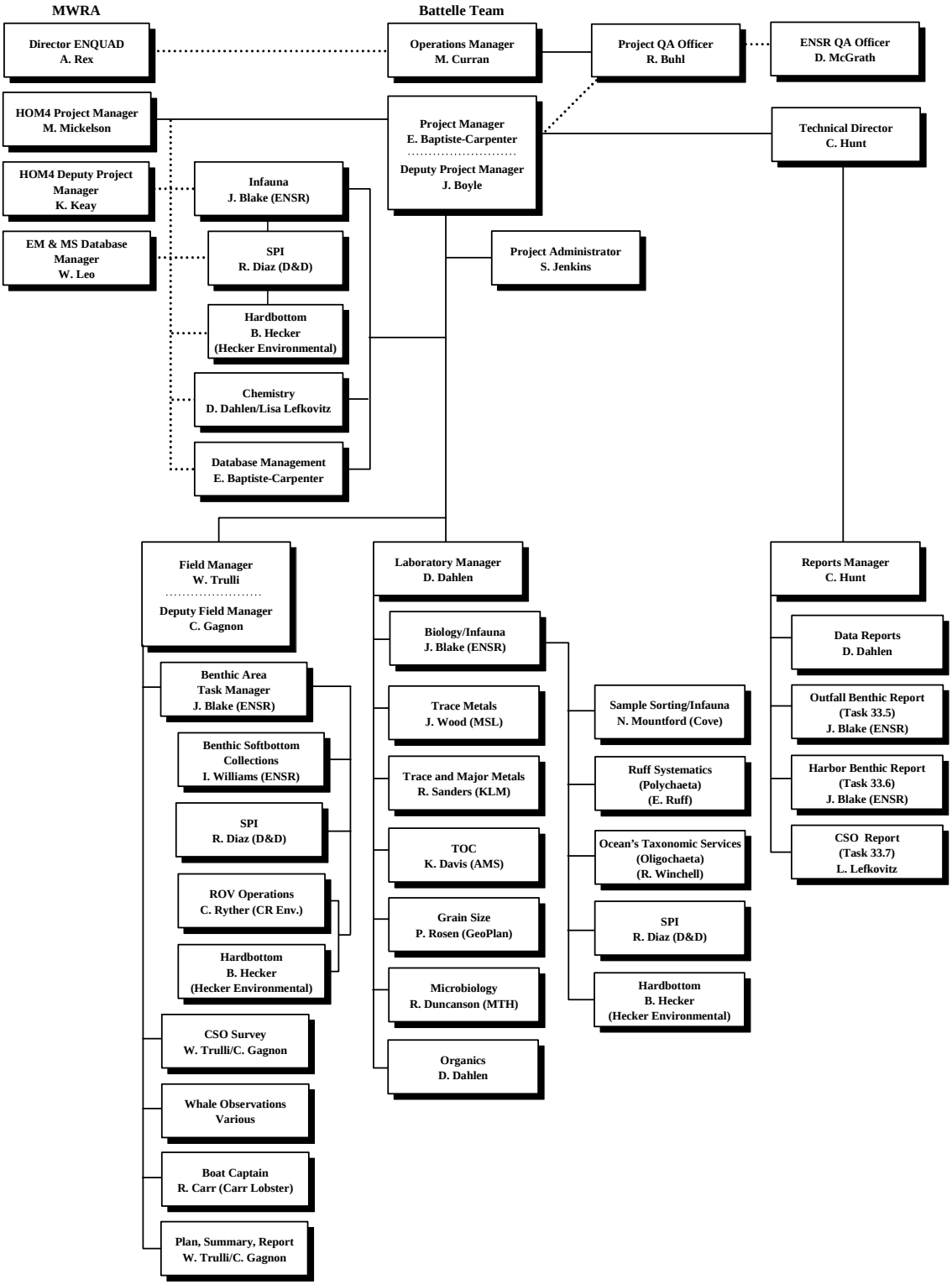

Figure 5. Benthic Monitoring Task Organization.

11.0 DATA QUALITY REQUIREMENTS AND ASSESSMENTS

Requirements for ensuring that the data are fit for their intended use (that is, are of suitable quality) include accuracy, precision, representativeness, comparability, and completeness. When these requirements are met, the final data product is technically defensible. Data elements for this project are discussed in terms of the appropriate characteristics, defined as:

Accuracy: The extent of agreement between a measured value and the true value of interest.
Precision: The extent of mutual agreement among independent, similar, or related measurements.
Representativeness: The extent to which measurements represent true systems.
Comparability: The extent to which data from one study can be compared directly to similar studies.
Completeness: The measure of the amount of data acquired versus the amount of data required to fulfill the statistical criteria for the intended use of the data.

The representativeness and comparability of all the data generated under this CWQAPP depend to some extent upon the selection of the sampling sites. With the exception of 9 of the 14 sites chosen for the CSO Sediment Study, Task 17.3, all soft-bottom stations to be visited during this program will be the same as those listed in Blake and Hilbig 1995 (HOM2) and Kropp and Boyle 2001 (HOM3). Hard-bottom survey sites will be the same as listed in Kropp and Boyle 2001.

Details of how these criteria are met for each component of the Benthic (Sea-Floor) Monitoring tasks are presented in the following sections.

11.1 Field Activities

11.1.1 Navigation

The data quality requirements and assessments for navigational data are described in the water column monitoring CWQAPP (Libby *et al.*, 2002). At each sampling station, the vessel is positioned as close to the target coordinates as possible. Upon arriving at station, the *Event* key is hit to record arrival time. The NavSam© navigation and sampling software collects and stores navigation data, time, and station depth every 2 seconds throughout the sampling event, and assigns a unique identification number to each sample when the sampling instrument hits bottom. The display on the BOSS (Battelle Oceans Sampling System) computer screen is set to show a radius of 30 m around the target station coordinates (six 5-m rings) for all benthic surveys. A station radius of up to 30 m is considered acceptable for benthic sediment sampling.

11.1.2 Grab Sampling

Samples for all benthic sediment infaunal analysis will be collected with a 0.04-m^2 Ted Young-modified Van Veen grab sampler. On surveys where contaminant sample collection is not required, the 0.04 m^2 grab sampler will provide adequate quantities of sediment for grain size, Total Organic Carbon (TOC), and microbiology. Sediment samples for chemical analyses (organic and inorganic) will be collected with a Kynar-coated 0.1-m^2 Ted Young-modified Van Veen grab sampler. Undisturbed samples will be achieved by careful attention to established deployment and recovery procedures. Procedures used by survey crews will cover the following aspects of deployment and recovery:

- thorough wash-down of the grab before each deployment;
- control of penetration by adding or removing weights to the frame and adjusting descent rate;
- slow recovery until grab is free of the bottom;

- inspection for signs of leakage; and
- securing the grab on deck.

Each grab sample will be inspected for signs of disturbance. The following criteria identify ideal characteristics for an acceptable grab sample.

- Sampler is not overfilled with sediment; the jaws must be fully closed and the top of the sediment below the level of the opening doors.
- Overlying water is present and not excessively turbid.
- Sampler is at least half full, indicating that the desired penetration was achieved.

In certain locations, however, slight over-penetration may be accepted at the discretion of the chief scientist. Mild over-penetration may be accepted according to the following standards:

- The sediment surface is intact on at least one side of the grab
- Little or no evidence that the surface sediment has pushed through the grid surface of the grab, *i.e.*, no visible imprint from the screening outside of that grid
- No evidence that sediment has squirted out through the hinge or the edges.

Given the difficulty of obtaining undisturbed sediment in areas with exceptionally thick, anoxic mud, these standards may have to be relaxed further. The chief scientist will make the final decision regarding acceptability of all grabs, and the overall condition of the grab (*i.e.*, "slight over-penetration on one side") will be documented on the station log.

11.1.2.1 Benthic Infauna

Accuracy, Precision, and Representativeness
Because no subsampling will be performed, the accuracy, precision, and representativeness of the sampling will depend upon the factors discussed above under Section 11.1.2.

Comparability
Procedures for washing, sieving, and preserving the samples will be consistent with methods used in previous studies. The use of 300-μm-mesh sieves only, rather than stacked 500-μm and 300-μm-mesh sieves as in 1991 through 1994, will have no impact on the comparability of the samples because the faunal abundances will be compared with the total abundances (300-μm and 500-μm fractions summed) reported through 2001. In addition, samples will be collected only by trained staff under the supervision of a chief scientist with experience in the collection of benthic infaunal samples.

Completeness
All required samples will be collected at all of the stations required for each survey. The entire sample will be sieved and all material retained on the 300-μm-mesh screen will be fixed for analysis.

11.1.2.2 Sediment

Accuracy, Precision, and Representativeness
These qualities are assured by the sampling scheme (see Grab Sampling above) and by ensuring that samples are well homogenized, subsampled according to methods detailed in Section 12, and preserved.

Comparability
Procedures for sampling and subsampling are comparable to those used on previous MWRA surveys and other investigations in Boston Harbor and Massachusetts Bay.

Completeness
All required samples will be collected at all of the stations required for each survey.

11.1.3 Sediment Profile Imagery

The data quality objectives for the field collection of the SPI will be met by following several procedures. Proper assembly and operation of the video/SPI system will ensure that the tape and 35-mm images obtained are clear and of high quality. Real-time monitoring of the video system will permit some degree of evaluation of the potential quality of the 35-mm photographs because the two cameras occupy the same housing and share similar views of the sediment profile. Prior to every field deployment, all video/SPI components are collected and tested for proper operation. Once the video/SPI system is assembled on board the research vessel, a system check is initiated that includes all features of the video/SPI system, from tightening all bolts and video cable connectors to testing the video camera and deck video monitor and recorder. Proper system functioning (penetration of prism, flash from film SPI camera) will be monitored in real time on deck via the video monitor. Any miss-fires or improper film camera operation can then be corrected while on station.

Representativeness will be ensured by sampling at previously sampled locations that were chosen based on similarity of habitat or to allow for wide geographic coverage. Use of a differential global positioning system (DGPS) for navigation will allow re-occupation of previously sampled sites.

The methods used to collect the sediment profile images will be consistent with those used previously in the MWRA HOM program. These documented methods will be followed consistently by trained staff members throughout the program.

To ensure that all required images are collected, the film counter will be checked to confirm that the system was functioning properly after every station or replicate deployment. Any miss-fires or improper camera operation will be corrected while on station. Almost any electronic or mechanical failure of the profile camera can be repaired in the field. Spare parts and a complete back-up camera will be carried on each SPI survey. Images will be collected at all required stations.

11.1.4 Hard-bottom ROV Survey

Accuracy and Precision
The data quality objectives for the field collection of the hard-bottom survey will be met by following several procedures. The real-time viewing of videotapes during the surveys will ensure that the tapes will be of sufficient quality to achieve the objectives of the survey. Only EHG (extra high grade) magnetic videotapes will be used for this project. All equipment will be cleaned and checked thoroughly before deployment.

Hard-bottom transects and waypoints to be taped and photographed are those that were selected by MWRA to be representative of the hard-bottom habitats in the vicinity of the outfall.

The field methods used will be similar to those followed previously. The hard-bottom surveys will follow the same transects as those listed in Kropp and Boyle 2001 to ensure that video and photographic data will be comparable. All transects will be occupied in such a manner that the nature of the epifauna and sedimentary environment in the hard-bottom area can be compared to the previous surveys.

All of the requisite transects (and their waypoints) will be videotaped and photographed. Approximately 20 minutes of video and images from a full roll of film (36 exposure) will be collected at each waypoint. ROV operations will be monitored by real-time viewing of the video during the survey. The videotapes will be checked in the field to ensure the video images are recorded. The still photographs will be developed in the field as they are collected to ensure proper photographic quality and camera functions.

11.2 Laboratory Activities

11.2.1 Infaunal Analysis

Accuracy
Benthic infauna will be identified by experienced taxonomists at ENSR Marine and Coastal Center (Woods Hole, MA), Cove Corporation (Lusby, MD), Ruff Systematics (Puyallup, WA), and Ocean's Taxonomic Services (Plymouth, MA). In cases where different taxonomists identify replicates from the same station, discrepancies in species identifications will be recognized during data entry and reviewed. Taxonomic discrepancies will be addressed by communication among the taxonomists. In the case of questions about organisms in specific taxonomic groups, specimens may be sent to recognized experts for a second opinion on the identification. Standard taxonomic references will be used, and selected specimens of newly found species will be retained as part of an already existing reference collection.

Precision
Sorting technicians will remove all organisms from the samples and separate them into major taxonomic groups. All residual material will be labeled and stored for Quality Control (QC) analysis. Samples will be divided into batches of approximately 10 samples. All samples will be pre-sorted by a junior technician and then 100% re-sorted by an experienced technician. Approximately 10% of the samples from each batch will then be randomly chosen for an independent QC check. If more than 5% of the total organisms in the QC sample have been missed, all remaining samples from that batch will be re-sorted.

Representativeness
Because all of the sample will be analyzed, representativeness will be determined by sampling factors.

Completeness
All samples collected are scheduled for analysis. Because three replicates will be collected at most stations, loss of a sample from a replicated station will still permit data to be obtained for that station. One hundred percent completeness is expected.

Comparability
Methods of analysis will be comparable to those used in previous benthic investigations in Boston Harbor and Massachusetts Bay. Comparability of the identifications will be ensured through the use of standard taxonomic references and by comparison of specimens to a reference collection provided by the MWRA. Taxonomists will be familiar with fauna from this study area or have worked on this project previously. The reference collection will be maintained and, if new species are identified, expanded by ENSR Marine and Coastal Center and turned over to the MWRA, or the MWRA's designee, at the end of the project.

11.2.2 Sediment Chemistry

Data quality objectives for the laboratory program are presented in Table 8 and detailed in the following sections.

Accuracy

Organic Contaminants: Analytical accuracy for organic analyses will be evaluated based on percent recoveries of analytes in National Institute of Standards and Technology (NIST) standard reference materials (SRM), matrix spike (MS) samples, and the surrogate internal standards (SIS) that are added to every sample. In addition, results of procedural blanks will be monitored with each analytical run.

One SRM will be analyzed with each batch of up to 20 samples. The data quality objective for recovery of analytes in SRM samples is ≤35 percent difference (PD) from the certified value and/or the certified range (see Table 8). The percent difference is calculated as follows:

Percent Difference = [(Certified value – SRM sample result) ÷ Certified value)]× 100

One set of matrix spike/ matrix spike duplicate (MS/MSD) samples will be analyzed with each batch of up to 20 sediment samples. The data quality objective for MS and MSD recovery is 50–150%. The percent recovery of analytes in matrix spike and matrix spike duplicate samples is calculated by the following equation:

Percent Recovery =([spiked sample result – unspiked sample result] ÷ spike amount) × 100

One procedural blank will be analyzed with each batch of up to 20 samples. Procedural blanks will be acceptable if the concentrations of any target analyte are less than five times the method detection limit (MDL). Further, provided that concentrations of contaminants are present in the associated samples at levels above ten times blank values, then the impact on data quality due to laboratory contamination is minimal, and the data will not be qualified.

All sediment samples and associated QC samples processed for organic analysis will be spiked with the appropriate SIS before extraction. Quantification of the SIS will be based on the recovery internal standards (RIS) added to the final extract just before instrumental analysis. The acceptable SIS recovery range is 50–150%; one of the PAH surrogate internal standards can be outside this range as long as the others are within the acceptable range. Because samples are quantified relative to the recovery of the SIS that is added before extraction, any loss of analytes during processing is corrected by a comparable loss of the SIS. Therefore, recoveries of less than 50% may be considered acceptable. Each sample showing low recoveries will be individually examined by the laboratory manager and/or task leader to determine the necessity of re-extraction or reanalysis.

Metals: The accuracy of the metals analysis (Ag, Cd, Hg) will be evaluated by analyzing an SRM with each batch of up to 20 samples. In addition, a matrix spike sample and a procedural blank will be run with each batch of up to 20 samples. The goal for the percent recovery of matrix spike samples will be 70–130%. The goal for the recovery of the SRM will be ≤ 20% of the true value. The goal for blank analyses will be < 5 × MDL. As noted above for organics, provided that concentrations of contaminants are present in the associated samples at levels above ten times blank values, then the impact on data quality due to laboratory contamination is minimal, and the data will not be qualified.

The accuracy of the remaining trace and major metals analyses (Al, Fe, Cr, Ni, Pb, Zn, Cu) will be evaluated by analyzing the same United States Geological Survey (USGS) or National Institute of Standards and Technology (NIST) traceable matrix standard at the start and end of each analytical run. The PD for these analyses is ≤20% vs. the certified value.

Table 8. Data Quality Objectives for Sediment Chemistry.

QC Type	Acceptance Criteria	Corrective Action
Procedural Blanks		
Organics Metals (Hg, Cd, Ag) Metals (Al, Fe, Cr, Ni, Pb, Zn, Cu) TOC Grain Size Microbiology: *C. perfringens*, Fecal Coliform *Enterococcus*	<5X MDL <5X MDL NA <0.1 of the lowest sample concentration (total carbon) NA No growth of target or non-target organisms	Results examined by project manager, task leader, or subcontractor lab manager. Reextraction, reanalysis, or justification documented.
Accuracy		
Matrix Spike Organics Metals (Hg, Cd, Ag) Metals (Al, Fe, Cr, Ni, Pb, Zn, Cu) TOC Grain Size Microbiology	 50–150% recovery[a] 70–130% recovery[a] NA NA NA NA	Document, justify deviations
SIS Organics only	 50-150% (40–150% for N-d8)	Document, justify deviations
SRMs Organics Metals (Hg, Cd, Ag) Metals (Al, Fe, Cr, Ni, Pb, Zn, Cu) TOC Grain Size Microbiology	 PD ≤35% vs SRM range[b] PD ≤20% vs SRM certified values PD ≤20% vs SRM certified values ±5% of certified value NA NA	Results examined by project manager, task leader, or subcontractor lab manager. Reextraction, reanalysis, or justification documented.
Precision		
Duplicates Organics (MS/MSD) Metals (Hg, Cd, Ag) (Lab Duplicates) Metals (Al, Fe, Cr, Ni, Pb, Zn, Cu) TOC Grain Size Microbiology (Duplicate Counts of 10% of samples by different analysts) **Triplicate**s Grain Size	 ≤30 R%D ≤25% R%D if value is 5∗MDL ≤25% R%D if value is 5∗MDL ≤25 R%D See triplicates ≤10% difference between counts ≤20% CV if the component is >5% of the sample	 Document, justify deviations Recount to reach consensus Document, justify deviations

[a]MS/MSD concentration must be >5X background values to be used to assess data quality.
[b]For organics SRM: If the detected value falls within the SRM certified range, then PD = 0. If the detected value falls outside the SRM certified range, then the PD is determined against either the upper or lower limit of the range.

Precision

Organic Contaminants: Analytical precision for organic analyses will be determined using the percent recoveries of matrix spike (MS) and matrix spike duplicate (MSD) samples, with the relative percent difference (R%D) between duplicate analyses serving as the measure of precision. The R%D goal for MS/MSD samples is 30%. The R%D is calculated by

$$R\%D = [\ 2\ (D_1 - D_2) \div (D_1 + D_2)] \times 100$$

where D_1 = percent recovery of the first duplicate sample and
D_2 = percent recovery of the second duplicate sample.

Metals (Ag, Cd, Hg): Laboratory duplicates for metals analyses will be performed at a frequency of not fewer than one per 20 samples. The R%D goal for these analyses will be $\leq$25% if the element is greater than 5 times the MDL.

Metals (Al, Fe, Cr, Ni, Pb, Zn, Cu): One sample duplicate will be analyzed with each sample loading. The R%D goal for these analyses will be $\leq$25% if the element is greater than 5 times the MDL.

The laboratory will report the mean value of the laboratory duplicate analysis, for all target compounds, to the database. Mean data will not be v flagged (Table 19).

Representativeness

Representativeness has been addressed primarily in the sample collection design through sampling locations, number of grab samples, and collection of grab samples. Representativeness will also be ensured by proper handling, storage, and analysis of samples, using accepted procedures so that the material analyzed reflects the material collected as accurately as possible.

Completeness

The completeness of analyses will be ensured by comparing the samples received by the laboratory with the samples analyzed. All samples will be analyzed for the parameters listed in Table 9. These analyses will be documented in the laboratory project files. The data quality objective is 95% completion. Completeness will be calculated as:

$$\text{Completeness} = (\text{[Valid data obtained]} \div \text{[Total data planned]}) \times 100$$

Comparability

All data developed for this project will be comparable to previous data generated for the MWRA program. To accomplish this goal, field samplers and subcontractor laboratories will employ modifications of EPA methods and other procedures that are comparable to those used on previous sediment characterization studies (*e.g.*, NOAA 1993; Shea 1993; 1994; Blake and Hilbig 1995, Kropp and Boyle 2001). In addition, these methods are comparable to those being used in other similar sediment studies (*e.g.*, for the MWRA, Massachusetts Bays Program, and NOAA Status and Trends Program). Furthermore, Battelle participates in intercomparison exercises for analysis of PAHs, PCBs, and pesticides in sediment using methods that are similar to those proposed for this task.

Table 9. Sediment Chemistry Analytes and Target Method Detection Limits (MDL).

Analyte	MDL[1]
Physical Sediment Parameters	
Total organic carbon	0.01%
Grain size[2]	0.01%
Sewage Tracers	
Clostridium perfringens	NA
Coprostanol[3]	TBD
Fecal Coliform, *Enterococcus*	NA
Linear alkyl benzenes[4]	
phenol decane	5
phenyl undecane	5
phenyl dodecane	5
phenyl tridecane	5
phenyl tetradecane	5
Metals	
Al Aluminum	2300
Fe Iron	6
Ag Silver	0.063
Cd Cadmium	0.058
Cr Chromium	9
Cu Copper	2
Hg Mercury	0.028
Ni Nickel	2
Pb Lead	2
Zn Zinc	2
Polychlorinated biphenyls[5]	
2,4-Cl_2(8)	0.244
2,2',5-Cl_3(18)	0.107
2,4,4'-Cl_3(28)	0.168
2,2',3,5'-Cl_4(44)	0.132
2,2',5,5'-Cl_4(52)	0.162
2,3',4,4'-Cl_4(66)	0.192
3,3',4,4'-Cl_4(77)	0.242
2,2'4,5,5'-Cl_5(101)	0.139
2,3,3',4,4'-Cl_5(105)	0.0675
2,3',4,4'5-Cl_5(118)	0.105
3,3',4,4',5-Cl_5(126)	0.159
2,2',3,3,4,4'-Cl_6(128)	0.283
2,2',3,4,4',5-Cl_6(138)	0.0836
2,2'4,4',5,5'-Cl_6(153)	0.164
2,2'3,3,4,4',5-Cl_7(170)	0.090
2,2',3,4,4',5,5'-Cl_7(180)	0.0922
2,2',3,4,5,5',6-Cl_7(187)	0.0832
2,2',3,3',4,4',5,6-Cl_8(195)	0.0753
2,2',3,3'4,4',5,5',6-Cl_9(206)	0.0667
Decachlorobiphenyl-Cl_{10}(209)	0.0732
Polynuclear Aromatic Hydrocarbons[5,6] (PAH)	
naphthalene	9.47
C_1-naphthalenes	9.47
C_2-naphthalenes	9.47
C_3-naphthalenes	9.47
acenaphthylene	0.0614
acenaphthene	0.0742
fluorene	0.044
PAH[5,6] (Continued)	
C_1-fluorenes	0.044
C_2-fluorenes	0.044
C_3-fluorenes	0.044
anthracene	0.057
phenanthrene	0.0664
C_1-phenanthrenes/anthracene	0.0664
C_2-phenanthrenes/anthracene	0.0664
C_3-phenanthrenes/anthracene	0.0664
C_4-phenanthrenes/anthracene	0.0664
dibenzothiophene	0.0145
C_1-dibenzothiophenes	0.0145
C_2-dibenzothiophenes	0.0145
C_3-dibenzothiophenes	0.0145
fluoranthene	0.0579
pyrene	0.0621
C_1-fluoranthenes/pyrenes	0.0621
benzo(a)anthracene	0.0623
chrysene	0.0338
C_1-chrysene	0.0338
C_2-chrysene	0.0338
C_3-chrysene	0.0338
C_4-chrysene	0.0338
benzo(b)fluoranthene	0.0898
benzo(k)fluoranthene	0.0704
benzo(a)pyrene	0.0865
dibenzo(a,h)anthracene	0.0693
benzo(g,h,i)perylene	0.0569
indeno(1,2,3-c,d)pyrene	0.0404
perylene	0.059
biphenyl	0.0912
benzo(e)pyrene	0.0327
dibenzofuran	0.251
benzothiazole[3]	1.25
Pesticides[4]	
Hexachlorobenzene	0.156
Lindane	0.0759
Heptachlor	0.135
Aldrin	0.11
Heptachlorepoxide	0.108
alpha-chlordane	0.105
trans-Nonachlor	0.118
Dieldrin	0.085
Endrin	0.0736
Mirex	0.0889
2,4'-DDD	0.112
4,4'-DDD	0.0816
2,4'-DDE	0.257
4,4'-DDE	0.0869
2,4-DDT	0.246
4,4'-DDT	0.0998
DDMU	0.162

[1] μg/g dry weight for metals; ng/g dry weight for organic analytes (PCBs, PAHs, LABs, pesticides)
[2]Detection limit is based on analytical sensitivity of balance and is adjusted for sample size.
[3]MDL will be based on a reporting limit derived from the low calibration standard and adjusted for sample processing volumes/factors.
[4]Detection limits are reporting limits (RL) calculated from the low calibration standard and adjusted for sample processing factors. RL = (conc. in low std × final extract volume × dilution factor) ÷ (sample dry weight). Actual RLs will vary depending upon sample processing factors (*e.g.*, moisture content). Actual RLs will be reported with the data.
[5]MDL concentrations for PAHs, PCBs and Pesticides are based on surrogate corrected data. These MDLs are representative of year 2000 MDL study results. MDLs are updated annually, and are available on request. Batch-specific achieved MDLs will be reported with the data.
[6]MDL concentrations for alkyl homologues are based on the MDL of the unsubstituted, parent compound.

Trace metal data generated during HOM4 will be comparable to those generated previously. The Energy Dispersive X-Ray Fluorescence Spectroscopy (EDXRF) methods that will be used during HOM4 also were used during HOM3. EDXRF methodology is comparable to the methods used under HOM2. Although direct methodological comparisons have not been performed, interlaboratory comparisons conducted by NOAA and the National Research Council of Canada have shown that laboratories that employ EDXRF methods perform as well as, or better than, most laboratories that use other methods (Willie, 1997). This intercomparison showed that the data generated by EDXRF methods for each trace metal tested met the same acceptability criteria as those generated by other methods.

11.2.3 Physicochemical and Microbiological Parameters

Accuracy

Total Organic Carbon: Accuracy of TOC analysis will be evaluated by blanks and SRMs. An acceptable procedural blank must be less than 1/10 of the lowest sample signal (S:N = 10:1)for the batch. SRMs will be analyzed with each batch of samples and must be within 5% of the true value.

Grain Size: Direct measures of accuracy in grain size determination are not possible because there are no standards. Accuracy of laboratory balances at GeoPlan will be maintained by monthly calibration with S class (or equivalent) weights.

Microbiology: The accuracy of measurement of microbiological parameters in sediment samples is not easily quantified, as no standards exist. One procedural blank will be analyzed with each batch of approximately 4–6 samples (8–12 individual assays). The procedural blank will consist of sterile, deionized water and all reagents used during extraction. It will be processed concurrently with a batch of samples. In addition, a filtration blank, consisting of an aliquot of sterile buffered dilution water will be processed through the membrane filtration procedure with each batch of samples. Blanks should have no growth of target or non-target organisms following incubation. Corrective action, such as re-extraction and reanalysis will be taken as necessary, and all corrective actions will be documented.

Precision

Total Organic Carbon: The precision of TOC analysis will be measured by laboratory duplicates run at a frequency of 1 per batch of 20 samples. The R%D objective for duplicate analysis is $\leq$25%. The R%D will be calculated as described above for MS/MSD samples.

Grain Size: The precision of grain size analysis will be evaluated using laboratory triplicates. Triplicate analysis will be run at a frequency of 5%. The goal for these analyses will be a coefficient of deviation (CV) of $\leq$20% for the individual fractions of sand, silt, and clay, if the component is >5% of the sample.

Microbiology: All samples will be extracted and analyzed in duplicate to increase the precision of the analytical result. The goal for duplicate analysis is a coefficient of variation (CV) of $\leq$30%. If the CV of duplicate analyses exceeds 30%, a third analysis is performed. To increase the precision of the number obtained by membrane filtration procedure, each dilution will be filtered in triplicate. For 10% of the assays performed, duplicate counts of the colonies will be conducted by two different analysts with a goal of $\leq$10% difference between counts.

Completeness

Completeness in the laboratory is assured as described in section 11.2.2 for sediment chemistry.

Comparability
Comparability of microbiological and physicochemical determinations will be ensured by using the same methods used previously to analyze MWRA effluent and sludge samples, sediment samples from Boston Harbor and Massachusetts Bay, and samples for other sewage disposal studies.

Representativeness
Sample integrity and representativeness can be ensured through proper sample collection and handling procedures and careful maintenance of acceptable sample storage conditions. In addition, thorough sample homogenization and filtration techniques will be employed, using acceptable methods to ensure that the material analyzed reflects the material collected as accurately as possible.

11.2.4 Sediment Profile Image Analysis

Accuracy
Control of the computer image analysis includes system preparation, actual image analysis, and data reduction. A set of standard instructions is followed in setting up the image processor. These instructions include system warm-up time, video camera to slide distance, light table color check, and cleaning of lens and color filters. Once the system is on and functioning, a standardized scale slide is measured to insure that the linear measurements made on the profile images are accurate.

Precision
Even with the most careful control on development, there may be variation in either the film lots or processing that causes subtle color differences among slides. To correct this problem, the first and last picture taken each field day is of a standard color card (Jobo) with red, green, blue, white, and neutral gray densities. Examination of these color card images allows determination of any variation in color from day to day or film to film. Color variations then can be accounted for during the computer image analysis.

Completeness
Only established and reputable film processing laboratories will be used to develop film. The three best images taken at each station, if usable, will be analyzed.

Comparability
The comparability of the SPI analyses will be ensured by consistent application of QC procedures and by using the same analysts throughout the project whenever possible. The analyses will be comparable to those previously obtained for the MWRA program.

Representativeness
Representativeness is defined by the stations selected in the baseline.

11.2.5 Hard-bottom Video and 35-mm Slide Analysis

Accuracy and Precision
Each slide will be projected and analyzed. Data to be collected for each slide include primary and secondary substrate type, degree of sediment drape, estimated percent cover of crustose pink algae (formerly called *Lithothamnium* spp.), estimated relative abundance of hydroids, spirorbid/barnacle complex, *Ptilota serrata*, and dulse, and counted abundance of other identifiable biota. Organisms will be identified to the lowest possible taxonomic level with the aid of pictorial keys. Taxa that cannot be assigned to a species category will be assigned to general categories (*i.e.*, anemone, fish).

Videotapes will be viewed for the range of substrate characteristics, sediment drape, and habitat relief, and the occurrence of large identifiable taxa at each waypoint. Encrusting, cryptic, or very abundant taxa will not be counted from the videotapes because of reduced visual resolution and time constraints.

Completeness
All usable still photographs and appropriate video images will be analyzed.

Comparability
The methods of collection and analysis of the still and video images are sufficiently similar to previous MWRA hard-bottom studies (Kropp and Boyle 2001) to allow comparisons between the previously collected baseline data and the monitoring data to be collected. The method of analysis of the still photographs is identical to that used in previous MWRA hard-bottom studies and will allow for direct comparisons. The method of analysis for the video images is sufficiently similar to previous studies to allow qualitative comparisons.

Representativeness
Hard-bottom biological assemblages are routinely documented using video and still photographs. For true representativeness, the video footage and still photographs should be randomly located within waypoints to allow for unbiased extrapolation of the data for the area being sampled. Due to various technical constraints of working with an ROV, true randomness is rarely accomplished in hard-bottom studies. The location of the photographic coverage is usually constrained by strength of tidal currents determining the direction in which the ROV can maintain a heading; mobility of the ship during station occupation due to surface currents and wind; bottom visibility (moving in a down current direction frequently causes reduced visibility due to sediment clouds); bottom topography (going over every boulder could keep the ROV too far off bottom); tether length (the ROV could be at the end of the tether before the requisite footage has been collected); and the ROV needing to be a certain distance from the bottom to obtain usable still photographs. Within these constraints, we will try to obtain representative visual images of each area.

The still photographs will be taken as randomly as possible within each video transect to assure that they are representative of the area surveyed. The still photographs will be the primary sample type, and the video footage will be used to supplement them. Due to the more 3-dimensional nature of the video footage, qualitative characterization of habitat relief and habitat and biotic heterogeneity is usually easier from the video footage. Additionally, the video footage covers more area and is thus used to document the occurrence of larger, more sparsely distributed fauna.

12.0 SAMPLING AND ANALYTICAL PROCEDURES

12.1 Navigation

Navigation data from NavSam© will be used for reporting purposes. Refer to the Water Column CWQAPP (Libby *et al*., 2002) for a complete description of navigation procedures.

During the hard-bottom reconnaissance surveys, a DGPS and an ORE International LXT Underwater Positioning System will be used for positioning the vessel and the ROV. The Windows™-based software, HYPACK, will be used to integrate these positioning data and provide real-time navigation, including the position and heading of the vessel and the position of the ROV relative to the vessel.

12.2 Benthic Sample Collection/Shipboard Processing

Field samples collected and analytical methods are summarized in Tables 4 and 10, respectively. The numbers of field samples and the shipboard processing and storage requirements for all samples collected for the Benthic (Sea-Floor) Monitoring tasks are listed in Tables 11 (Harbor benthic surveys) and 12 (Outfall benthic surveys). At all stations, the station coordinates, time, sea state and other weather conditions, and water depth will be recorded by hand onto a field log. Any incidental observations of marine mammals also will be recorded on the log.

12.2.1 Grab Sample Collection

A 0.04-m^2, Ted Young-modified Van Veen grab sampler will be used to collect soft-bottom sediment samples for infaunal analysis. The 0.04-m^2 grab may also be used to collect samples for TOC, grain size and microbiology, as long as sufficient sample volume can be obtained. A Kynar-coated 0.1-m^2 Ted Young-modified Van Veen grab sampler will be used to collect all soft-bottom sediment samples for chemical analyses (organic and inorganic).

Once the survey vessel is on station and coordinates have been verified, the sediment grab will be deployed. When slack in the winch wire indicates the grab is on the bottom, the grab and captured sample will be brought back to the surface. Upon retrieval of the grab, the sample will be inspected for acceptability (see Section 11.1.2). If the sample is unacceptable, the grab will be emptied, rinsed, and redeployed.

If the sample is acceptable, the penetration depth, sediment volume, sediment texture, and depth of the apparent redox potential discontinuity will be visually estimated. The depth of the apparent redox potential discontinuity (RPD) will be estimated, initially, by examining the sediment surface. If the surface of the grab sample is black, with few or no infaunal organisms visible, and produces an odor of hydrogen sulfide then the surface has no measurable RPD layer and is considered to be anoxic. If the surface is oxidized, a clear, plastic ruler marked in millimeters, will be pushed into the sediment and pulled toward the investigator. This action creates a vertical profile that can be examined and allows the RPD to be measured to the nearest millimeter. Alternatively, the same ruler will be used to gently scrape off the surface layers, in millimeter fractions, until the gray to black anoxic sediment layer is exposed. The distance from the surface to the uppermost portion of the gray to black subsurface sediments is the depth of the apparent RPD. Both methods will be used on the MWRA biological sampling cruises to estimate apparent RPD depths. Any sediment adhering to the surface of the ruler will be rinsed back into the grab for processing with the remainder of the sample. The volume of the grab will be estimated by comparing the measured penetration depth with a prepared table of penetration depths versus grab volumes (Table 13). These data will be recorded in the field log.

For the infaunal samples only, after these measurements are taken, the grab will be placed over a bucket, the jaws opened, and the sample emptied into the bucket. Filtered seawater will be used to gently wash the sample into the bucket. Once thoroughly washed (if necessary), the grab will be redeployed until the required numbers of acceptable samples have been obtained for infaunal and/or chemical analysis.

Precautions will be taken during the deployment and retrieval of the grab sampler to prevent contamination of samples between stations. Sampling for infaunal, TOC and grain size determinations require that the grab and associated sampling equipment be washed and rinsed with soap and ambient seawater. Samples taken for *C. perfringens,* fecal coliform and *Enterococcus* analysis require an additional rinse of the grab sampler with ethanol. To remove organic contaminants for samples collected for chemical analyses, the grab and associated sampling equipment must be cleaned with soap and water,

Table 10. Benthic Survey Sample Analyses.

Parameter	Laboratory	Unit of Measurement	Method	Reference
Infaunal Analysis	Cove Corporation; ENSR Marine and Coastal Center	Count/species (# per grab)	ID and Enumeration	Section 12.3.1
Organic Analyses				
Linear Alkylbenzenes (LAB)	Battelle	ng/g dry wt.	GC/MS	Battelle SOP 5-157
Polycyclic Aromatic Hydrocarbons (PAH)	Battelle	ng/g dry wt.	GC/MS	Battelle SOP 5-157
Polychlorinated Biphenyls (PCB)/ Pesticides	Battelle	ng/g dry wt.	GC/ECD	Battelle SOP 5-128
Coprostanol	Battelle	ng/g dry wt.	GC/MS	Battelle SOP 5-157
Metals Analyses				
Major Metals (Al, Fe)	KLM	% dry wt.	EDXRF	KLM Tech. Procedure XRF-01 (formerly 7-40.48)
Trace Metals (Cr, Ni, Pb, Zn, Cu)	KLM	μg/g dry wt.	EDXRF	KLM Tech. Procedure XRF-01 (formerly 7-40.48)
Trace Metals (Ag, Cd, and Hg)	Sequim	μg/g dry wt.	ICP-MS (Ag, Cd) CVAA (Hg)	MSL-I-022 MSL-I-016
Trace Metals (selected - except Hg)	Sequim	μg/g dry wt.	GFAA	MSL-I-029
Ancillary Physicochemical and Microbiological Parameters				
Total Organic Carbon (TOC)	Applied Marine Science	%C by dry weight	Coulometric Carbon Analyzer	SOP AMS-2201
Sediment Grain Size	GeoPlan	% by weight	Stacked sieves on Fritsch Analysette vibrating table and pipette/settling procedures	Folk (1974)
Microbiology: *C. perfringens* Fecal Coliform *Enterococcus*	MTH Environmental	#organisms/g of dry weight sediment	Membrane filtration	Emerson and Cabelli (1982) Saad (1992) EPA/821/R-97/004 Bisson and Cabelli (1979)
Sediment Profile Images	Diaz and Daughters	various (see Table 5)	various	See Section 12.3.4
Hard-bottom	Hecker Environmental	various	various	See Section 12.3.5

Table 11. Field Samples, Processing, and Storage for Boston Harbor Benthic Surveys.

Activity	Task 17.1 Harbor Traditional Survey	Task 17.2 Harbor Reconnaissance Survey (SPI)	Task 17.3 CSO Sediment Survey
Stations	8; T01–T08 (Table 1)	60; T01–T08; R02–R53 (Table 1)	17 [13 from Lefkovitz *et al*., 2000 (all except DB13) plus T03, T04, T05A, and T06]
Weather/sea state/ bottom depth	Record general conditions; record bottom depth (0.5 m)	As for Task 17.1	As for Task 17.1
Marine mammals	Note incidental observations	As for Task 17.1	As for Task 17.1
Sampling: Gear	0.04-m^2 Ted Young-modified Van Veen grab sampler	Sediment profile camera	(0.1 or 0.04-m^2) Kynar coated Ted Young-modified Van Veen grab sampler
Sampling: Measurements	Record penetration (0.5 cm) and sediment volume (0.5 L)	Record prism penetration (0.5 cm)	As for Task 17.1
Sampling: Sediment texture	Describe qualitatively	Not Applicable (NA)	As for Task 17.1
Sampling: RPD depth	Record visual estimate (0.5 cm)	Record visual estimate (0.5 cm)	As for Task 17.1
Faunal Samples: Number	3 each station	3 images at each station	NA
Faunal Samples: Processing	Rinse over 300-µm sieve; fix in 10% buffered formalin	Check counter	NA
Faunal Samples: Storage	Clean, labeled plastic jar Ambient temperature	NA	NA
Chemistry/Microbiology Samples (All): Number	1 each station (Microbiology, TOC, GS only)	NA	3 each station (All Table 9 parameters)
Chemistry Samples (Organics): Processing	NA	NA	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize, and collect ~125 mL subsample
Chemistry Samples (Organics): Storage	NA	NA	Clean, labeled glass jar with Teflon-lined cap; freeze (–20° C); holding time is 1 year to extract (if samples frozen) and 40-d from extraction to analysis
Chemistry Samples (Metals): Processing	NA	NA	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize, and collect ~100 mL subsample

Table 11. (continued)

Activity	Task 17.1 Harbor Traditional Survey	Task 17.2 Harbor Reconnaissance Survey (SPI)	Task 17.3 CSO Sediment Survey
Chemistry Samples (Metals): Storage [2]	NA	NA	Clean, tared and labeled Spex container; freeze (20° C); holding time is 6 months to preparation; Hg holding time is 28-days
Chemistry Samples (Ancillary): Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~ 50 mL subsample for TOC and ~ 100 mL for grain size (if samples are coarse then subsample ~ 200 mL for grain size)	NA	As for Task 17.1
Chemistry Samples (Ancillary): Storage	Clean, labeled glass jar (freeze TOC; refrigerate grain size); holding time for TOC is 28-days; 30-days for grain size	NA	As for Task 17.1
Microbiology Samples: Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~75 mL subsample	NA	As for Task 17.1
Microbiology Samples: Storage	Sterile specimen cup; refrigerate at 1–4° C [1]. Deliver fecal coliform and *Enterococcus* to MTH within 24 h	NA	As for Task 17.1

[1] *Clostridium perfringens* may be stored frozen, but then must not be thawed until analyses are performed.
[2] Sediment received at Battelle MSL will be freeze-dried and blended in a Spex mixer-mill. An aliquot of the freeze-dried, homogeneous material will be shipped directly from Battelle MSL to KLM Analytical for metals (Al, Fe, Cr, Ni, Pb, Zn, and Cu) analysis.

Table 12. Field Samples, Processing and Storage for Outfall Benthic Surveys.

Activity	Task 18.1 Nearfield Benthic Survey	Task 18.2 Nearfield Contaminant Special Study	Task 18.3 Nearfield SPI Survey	Task 18.4 Nearfield Hard-bottom Survey	Task 18.5 Farfield Benthic Survey
Stations	20 nearfield (Table 2); FF10, FF12, FF13	4; located in depositional sites, NF08, NF22, NF24, FF10	20 nearfield (Table 2); FF10, FF12, FF13	23 waypoints on 6 transects; T1, T2, T4, T6, T7, T8, T9, T10; diffuser #44 (Table 3)	8; (Table 2, except FF10, FF12, FF13)
Weather/sea state/ bottom depth	Record general conditions; record bottom depth (0.5 m)	As for Task 18.1	As for Task 18.1	As for Task 18.1	As for Task 18.1
Marine mammals	Note incidental observations	A marine mammal observer is required for the February survey; otherwise as for Task 18.1	As for Task 18.1	As for Task 18.1	As for Task 18.1
Sampling: Gear	Ted Young-modified Van Veen grab sampler	Ted Young-modified Van Veen grab sampler	Digital video camera coupled to 35-mm sediment profile camera	ROV equipped with video and 35-mm cameras	Ted Young-modified Van Veen grab sampler
Sampling: Measurements	Record penetration (0.5 cm) and sediment volume (0.5 L)	As for Task 18.1	Record prism penetration	Record ROV position, depth, heading	As for Task 18.1
Sampling: Sediment texture	Describe qualitatively	As for Task 18.1	Estimate from images (see Section 12.2.3)	Not Applicable (NA)	As for Task 18.1
Sampling: RPD depth	Record visual estimate (0.5 cm)	As for Task 18.1	Estimate from images (see Section 12.2.3)	NA	As for Task 18.1
Faunal Samples: Number	3 each at stations NF12, NF17, NF24, FF10, FF12, FF13, 1 each at remaining stations	NA	3 each station	20 min videotape, 36 still photos per waypoint	3 at each station
Faunal Samples: Processing	Rinse over 300-µm sieve; fix in 10% buffered formalin	NA	Check counter; preview images within 24 h (see Section 12.2.3)	NA	As for Task 18.1
Faunal Samples: Storage	Clean, labeled plastic jar Ambient temperature	NA	NA	NA	As for Task 18.1
Chemistry/ microbiology Samples (All): Number	2 each at stations NF12, NF17, NF24, FF10, FF12, FF13, 1 each at remaining stations. All Table 9 parameters except coprostanol, E*nterococcus* and fecal coliform.	3 at each station All Table 9 parameters except coprostanol, *Enterococcus* and fecal coliform.	NA	NA	2 at each station All Table 9 parameters except coprostanol, *Enterococcus* and fecal coliform.

Table 12. (continued)

Activity	Task 18.1 Nearfield Benthic Survey	Task 18.2 Nearfield Contaminant Special Study	Task 18.3 Nearfield SPI Survey	Task 18.4 Nearfield Hard-bottom Survey	Task 18.5 Farfield Benthic Survey
Chemistry Samples (Organics): Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~125 mL subsample	As for Task 18.1	NA	NA	As for Task 18.1
Chemistry Samples (Organics): Storage	Clean labeled glass jar with Teflon-lined cap; freeze (20° C); holding time is 1 year to extract (if samples are frozen) and 40-days from extraction to analysis	As for Task 18.1	NA	NA	As for Task 18.1
Chemistry Samples (Metals): Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~100 mL subsample	As for Task 18.1	NA	NA	As for Task 18.1
Chemistry Samples (Metals): Storage [2]	Clean tared and labeled Spex container; freeze (20° C); holding time is 6 months to preparation; Hg holding time is 28-days	As for Task 18.1	NA	NA	As for Task 18.1
Chemistry Samples (Ancillary): Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~ 50 mL subsample for TOC and ~ 125 mL for grain size (if samples are coarse then subsample ~ 200 mL for grain size)	As for Task 18.1	NA	NA	As for Task 18.1
Chemistry Samples (Ancillary): Storage	Clean, labeled glass jar (TOC and grain size); freeze (TOC) refrigerate grain size; holding time for TOC is 28-days; 30-days for grain size	As for Task 18.1	NA	NA	As for Task 18.1
Microbiology Samples: Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~75 mL subsample	As for Task 18.1	NA	NA	As for Task 18.1
Microbiology Samples: Storage	Sterile specimen cup; refrigerate at 1–4° C[1]. Deliver fecal coliform and *Enterococcus* to MTH within 24 hours	As for Task 18.1	NA	NA	As for Task 18.1

[1] *Clostridium perfringens* may be stored frozen, but then must not be thawed until analyses are performed.
[2] Sediment received at Battelle MSL will be freeze-dried and blended in a Spex mixer-mill. An aliquot of the freeze-dried, homogeneous material will be shipped directly from Battelle MSL to KLM Analytical for metals (Al, Fe, Cr, Ni, Pb, Zn, and Cu) analysis.

Table 13. Values used to convert grab penetration depth to sediment volume for the 0.04-m^2 Van Veen Grab Sampler

Grab Penetration Depth (cm)	Sediment Volume (L)
3.5–4.0	1.0
5.0	1.5
6.0–6.5	2.0
7.0	2.25
7.5	2.5
8.0	2.75
8.5–9.0	3.0
> 9.5 (over penetration)	3.25

and then rinsed with acetone, and methylene chloride (DCM). On deck, a metal pan is placed under the grab to collect residual acetone and methylene chloride. Any liquid wastes resulting from the latter two rinses will be collected in appropriate containers for return to the laboratory and proper disposal. Before the grab is retrieved, the vessel must be positioned so that the engine exhaust will not contaminate the sample when it has been brought on deck. The numbers of grab samples to be collected at each station for macrofaunal and/or chemical analyses are listed in Tables 11 and 12.

12.2.2 Shipboard Processing of Grab Samples

At Harbor traditional stations and at all outfall stations, grab samples for infaunal analyses will be rinsed with 5-µm filtered seawater through 300-μm mesh sieves. The samples retained on the screens will be transferred to labeled jars and fixed in 10% buffered formalin. Each sample jar will be no more than ½ full of material. The jar will be gently turned around on its side to distribute the formalin evenly throughout the sample. Each sieving technician will initial the survey log to identify his or herself as the siever. Sieves will be washed between samples. The samples will be transferred to 70–80% ethanol as soon as they are received by the sorting laboratory to ensure that mollusks and other organisms with calcareous structures are not damaged by the slightly acidic formalin.

If the grab sample to be used for chemical analyses meets the acceptability criteria, the water overlying the sample will be siphoned from the grab and the surface sediment (0–2 cm) will be collected with a Kynar-coated scoop and transferred to a clean (rinsed with filtered water, acetone, and methylene chloride) glass bowl. The sediment will be thoroughly homogenized before being transferred to appropriate storage containers. About 125 mL of sediment for organic compound analysis will be placed into a clean, wide-mouth glass jar (250 mL) 8 oz with a teflon-lined screw cap. About 75 mL of sample for metals analysis will be placed into a tared, acid-cleaned, plastic, (125 mL) 4 oz Spex jar. Approximately 50- and 125-mL subsamples for TOC and Grain Size will be placed into separate 4 oz, (125 mL) and 8 oz (250 mL) wide-mouth glass jars, respectively. Note that if the sediment is coarse, then approximately 200 mL of wet sediment should be subsampled for grain size analysis. A subsample to be used for *Clostridium perfringens* analysis will be placed into a sterile specimen cup (½ to ¾ full), labeled and refrigerated or frozen until analysis. During the CSO survey, additional subsamples taken for fecal coliform and *Enterococcus* analyses will be placed in separate sterile specimen cups (½ to ¾ full). These samples will be labeled, refrigerated at 1–4°C, and sent to MTH Environmental within 24 hours of collection.

Under the sampling/analysis protocols specified by NOAA for the National Status & Trends Mussel Watch Project, no sediment holding times are specified. The U.S. EPA has suggested some holding times by reference to water sample holding times; for example, EPA document #503/8-91-002 presents the interim final Monitoring Guidance for the National Estuary Program (EPA, 1992). Sediment chemistry samples will be frozen as soon as possible after sampling and will remain frozen until sample processing begins. It is assumed that if the samples are properly handled and remain frozen, their integrity will not be compromised prior to processing. Furthermore, project requirements for submission of data reports preclude the possibility of violation of the above-mentioned holding times suggested by the EPA.

12.2.3 Sediment Profile Image Collection

The sediment profile camera system consists of a camera enclosed in a pressure-resistant housing, a 45° prism, and a mirror that reflects an image of the sediment through the camera lens. A strobe mounted inside the prism is used to illuminate the sediment. Prior to every field deployment, all essential items are gathered and tested for proper operation. The camera/prism system is mounted in a cradle that is secured to a larger frame that ensures that the prism penetrates the sediment at a 90° angle. A winch is used to lower the entire assembly (at a consistent rate) to the seafloor. When the system is on the seabed, the penetration rate of the camera/prism assembly into the sediment is controlled by a hydraulic piston. Contact with the seabed triggers the camera. To permit proper penetration of the sediment by the prism, a brief time delay occurs between contact with the seafloor and the first exposure. The delay ranges from 1 second in soft mud to 15 seconds in hard sand. After the required number of exposures, the camera assembly is returned to the ship and an estimate of the prism penetration depth is made by visually measuring the displacement of a moveable sleeve placed on the camera assembly. A more accurate estimate is obtained during subsequent laboratory analysis of the images.

The profile camera prism will be fitted with a digital video camera so that video and 35-mm cameras have the same view of the sediment profile. The video signal will be sent to the surface via cable so that prism penetration can be monitored and an initial impression of benthic habitat type can be formed. The initial evaluation will be done on the boat in real-time or between stations by an experienced senior scientist (Dr. Robert Diaz). The video signal will be recorded for later detailed evaluation and review.

The real time video image will be monitored on deck and recorded onto Hi8-mm tape. To check for subtle color differences due to lighting variation (prism video lights and ambient light) a standard color card (Jobo) with red, green, blue, white, and neutral gray densities will be placed in front of the prism and recorded for 5–10 seconds between stations. From these color card images, variation in color can be monitored. Color variations then can be accounted for during the computer image analysis. The images are used to complete initial assessment of habitat changes resulting from outfall discharges.
The video will be used to provide a "quick look" analysis within 24 hours of completing the field work. Parameters that will be evaluated in the quick look analysis are

- sediment grain size,
- sediment layering, thickness, and type,
- surface and subsurface fauna and structures,
- approximate prism penetration,
- approximate surface relief,
- approximate color RPD,
- general benthic successional stage, and
- other major, readily discernable patterns.

The results of this rapid review then will be communicated within two business days to MWRA via an e-mail summary of the survey. The combination of video and slide film will ensure accurate and reliable collection of SPI data. The video contributes the real-time assessment component, whereas the 35-mm film provides high-resolution image detail for full image analysis in the laboratory. The 35-mm film also allows direct comparisons with historic profile camera data.

12.2.4 Hard-bottom Videotapes and 35-mm Slides

The annual ROV survey of the nearfield hard bottom environment will examine a series of waypoints along transects. A MiniRover MK II ROV equipped with a Benthos low-light, high-resolution video camera and a Benthos Model 3782 35-mm minicamera with strobe, 150 W halogen lamps, a compass, and a depth gauge will be deployed from the survey vessel to obtain the necessary video and slides. The ROV will travel as close to the bottom as possible so that the clarity of the video and photographs is as good as conditions will allow. Approximately 20 minutes of video footage will be recorded along randomly-selected headings. Along this route, still photographs will be taken as randomly as possible until an entire (36 exposure) roll of 35-mm film has been exposed. At waypoints including an outfall diffuser, approximately 50% of the effort will be devoted toward documenting the diffuser itself and 50% toward documenting the seafloor nearby. The date, time, and water depth will be recorded on the videotapes and will appear on the video monitor during the recording. The time, depth and description of any identifying characteristics will be recorded for each photograph taken at the waypoints. The occurrence of the video taping and 35-mm slide exposure will be recorded as "event" on the NavSam© system. The time that is displayed on the video monitor (and recorded on the tape) will be synchronized with the NavSam© clock. When a still photograph is taken, the event will be marked on the NavSam© system and marked verbally on the videotape. The NavSam© will produce labels that will be attached to each video cartridge. Each roll of film will be processed onboard. Slides will be manually labeled after they are mounted at the lab.

The video footage is compared in real-time to a summary of each waypoint from the previous year. This assures that we are in the same location and would also rapidly highlight any dramatic changes. Any readily observable changes will be communicated to MWRA via e-mail immediately following the cruise. This video comparison component provides real-time qualitative assessment, while the 35-mm slides provide high-resolution for a more detailed analysis. The 35-mm slides also allow for direct comparisons with the historical hard-bottom data.

12.3 Laboratory Processing

Data will be recorded on project-specific data sheets (Appendix B) and entered into the computer application provided by Battelle.

12.3.1 Macrofaunal Analysis

ENSR will ship all grab samples obtained on the Harbor benthic (Task 17) and Outfall benthic (Task 18) surveys for benthic faunal analysis to Cove Corporation in Lusby, Maryland where the organisms will be picked from the samples and sorted into major taxonomic groups. All acceptable grab samples will be processed.

Samples will be fresh-water rinsed over 300-μm-mesh screens to remove any broken-up mud casts and transferred to 70–80% ethanol for sorting and storage. To facilitate the sorting process, all samples will be stained in a saturated alcoholic solution of Rose Bengal at least overnight, but no longer than 48 hours to avoid over staining. After rinsing with clean alcohol, small amounts of the sample will be placed in glass dishes, and all organisms, including anterior fragments of polychaetes, will be removed and sorted,

using a dissecting microscope, to major taxonomic categories such as polychaetes, arthropods, and mollusks.

After samples have been sorted, the organisms will be sent to taxonomists for identification and enumeration. Cove Corporation and ENSR Marine and Coastal Center will each be responsible for approximately half of the samples. Cove Corporation will be responsible for Replicates 1 and 3 from all Boston Harbor stations and Nearfield stations FF10, FF12, FF13, NF12, NF17, and NF24 as well as for Replicates 2 of the eight Farfield stations, for a total of 52 samples. ENSR will be responsible for the remaining 55 samples. Identifications will be made at the lowest practical taxonomic level, usually species. Primary taxonomic responsibilities are as follows:

- Dr. James A. Blake (ENSR)—Polychaetes
- Dr. Nancy Maciolek (ENSR)—Polychaetes
- Mr. Tim Morris (Cove)—Crustaceans and Polychaetes
- Ms. Nancy Mountford (Cove)—Mollusks and Polychaetes
- Mr. Gene Ruff (Ruff Systematics)—Polychaetes
- Mrs. Isabelle P. Williams (ENSR)—Crustaceans, Molluscs, Other
- Mr. Russ Winchell (Ocean's Taxonomic Services)—Oligochaetes

Dr. James A. Blake (ENSR) will provide general oversight of the taxonomy performed for the Benthic (Sea-Floor) Monitoring studies.

12.3.1.1 Reference Collection

MWRA has established a project-specific reference collection. The reference collection is a valuable resource that will be used by project taxonomists to ensure comparability of the taxonomic identifications performed under HOM4 with those made under previous contracts. This collection will be inspected annually to ensure that it is stored properly to reduce the risk of alcohol evaporation and damage, and to ensure that labels are intact and legible. Vials in which the alcohol level is low will be filled with clean alcohol. Any labels showing signs of deterioration will be replaced.

Specimens of any taxon not previously identified during the program will be added to the collection. As part of the maintenance of the reference collection, taxonomists will review any possible inconsistencies between previous identifications and those made during this project. The taxonomic status of species in the collection will be evaluated as relevant systematic revisions appear in the scientific literature. If necessary, recommendations for changes in taxonomic usages will be made to MWRA. The reference collection will be returned to MWRA upon submission of the final reference collection status report in June 2006.

12.3.2 Sediment Chemistry

The physical parameters and chemical analytes are listed in Table 9. Methods for % dry weight determinations are detailed in the sample preparation SOPs.

Organic Chemical Analyses: Battelle will perform all organic sediment chemistry analyses. Sediment samples will be extracted for PAH, LAB, chlorinated pesticides, and PCB by following Battelle SOP 5-192. This modification of EPA Method 3550 incorporates methods developed by Battelle for NOAA's National Status & Trends Mussel Watch Project (Peven and Uhler, 1993). Briefly, approximately 30 g of sediment will be serially extracted with dichloromethane (DCM) and sodium sulfate using shaker table

techniques. Approximately 10-g of the original sample will also be taken for dry weight determination. The sample will be weighed into an extraction vessel and spiked with SIS, solvent will be added, the jar will be shaken for the appropriate amount of time, and the sample will be centrifuged. The extract will be decanted into an Erlenmeyer flask. After each extraction (total of three solvent additions) the filtered solvent will be combined in the flask. The combined extracts will be processed through a 2% deactivated alumina column, concentrated to 900 μL using Kuderna-Danish and nitrogen evaporation techniques. The extract will be split 50:50 for separate cleanup using size-exclusion high-performance liquid chromatography (HPLC); one split will be processed using a PCB/pesticide collection window and the other split will be processed using a PAH/LAB collection window. This procedure will remove common contaminants that interfere with instrumental analysis, including elemental sulfur. The post-HPLC extracts will be concentrated to approximately 0.5 mL under nitrogen and the RIS will be added to quantify extraction efficiency. The final extract for PCB and pesticide analysis will be solvent-exchanged with isooctane prior to analysis.

Sample extracts will be analyzed for PAH and LAB compounds by gas chromatography mass spectrometry (GC/MS) operating in the selected-ion-monitoring (SIM) mode using a 60-m DB5 column (or equivalent) and a Hewlett Packard 5973 detector (or equivalent) (Battelle SOP 5-157). PAH and LAB will be quantified by the method of internal standards, using RISs for quantification; sample data will be surrogate corrected in spreadsheet. Concentrations of LAB compounds will be determined as five separate LAB groups (those with alkyl chains containing 10, 11, 12, 13, and 14 carbon atoms, primary ion-m/*z* 91). LABs will be quantified versus the surrogate internal standard 1-phenylnonane.

Pesticides and PCB congeners will be analyzed and quantified using gas chromatography/electron capture detection (GC/ECD) (Hewlett Packard 5890 Series 2 GC) using a 60-m DB5 column and hydrogen as the carrier gas following Battelle SOP 5-128, including a second column for confirmation. Second column confirmation is <u>not</u> required for samples where target pesticides and PCBs were not detected on the primary column. Concentrations for all target analytes will be determined by the method of internal standard, using RISs for quantification; sample data will be surrogate corrected in spreadsheet.

All PAH, LAB, PCB and pesticide results will be reported in nanograms per gram (ng/g) dry weight.

Trace Metals: Battelle's Marine Science Laboratory in Sequim Washington will perform trace metals analyses for Ag, Cd, and Hg. Sediment samples will be digested using a hydrochloric/nitric acid digestion according to Battelle SOP MSL-I-006 *Mixed Acid Sediment Digestion*. To prepare samples for metals analysis, samples are first freeze-dried and homogenized in a ball-mill. A 200- to 300-mg aliquot of each dried, homogeneous sample is combined with aqua regia (nitric and hydrochloric acids at a ratio of 5.0 mL:2.0 mL) in a Teflon bomb and heated in an oven at 130 ºC (±10 ºC) overnight. After heating and cooling, deionized water is added to the acid-digested sediment to achieve analysis volume and the digestates are submitted for analysis.

Alternatively, in cases where hydrochloric acid in the digestion procedure can be found to cause chloride interferences with certain metals during ICP-MS analysis, sediment samples may be processed using a nitric acid-only digestion procedure, Battelle SOP MSL-I-006-04 *Mixed Acid Sediment Digestion*. An approximately 200-mg aliquot of each dried, homogeneous sediment sample and nitric acid are combined in a glass vial. The vials are loosely capped and heated on a hot plate at a temperature just high enough to boil the acid, without boiling over or evaporating the sample to dryness. After heating and cooling, deionized water is added to the acid-digested sediment to achieve analysis volume and the digestates are submitted for analysis.

Note that Battelle MSL will also be responsible for shipping an aliquot of the freeze-dried, homogenous sediment sample to KLM Analytical for metals (Al, Fe, Cr, Ni, Pb, Zn, and Cu) analysis.

CVAA Analysis of Hg - Sample digestates will be analyzed for Hg using cold-vapor atomic absorption spectroscopy (CVAA) according to Battelle SOP MSL-I-016 *Total Mercury in Tissues and Sediments by Cold Vapor Atomic Absorption*, which is based on EPA Method 245.5 *Determination of Mercury in Sediments by Cold Vapor Atomic Absorption Spectrometry* (EPA 1991a). The CVAA will be calibrated according to the SOP. Acceptance criteria for the calibration are listed in Table 14. Results are reported as μg/g dry-weight.

ICP-MS Analysis of Ag and Cd - For analysis of multiple metals simultaneously, sample digestates will be analyzed for Ag and Cd using inductively coupled plasma - mass spectrometry (ICP-MS) according to Battelle SOP MSL-I-022 *Determination of Elements in Aqueous and Digestate Samples by ICP/MS*. This procedure is based on two methods modified and adapted for analysis of solid sample digestates, EPA Method 1638 *Determination of Trace Elements in Ambient Waters by Inductively Coupled Plasma - Mass Spectrometry* (EPA 1996) and EPA Method 1640 *Determination of Trace Elements in Water by Preconcentration and Inductively Coupled Plasma - Mass Spectrometry* (EPA 1997). The ICP-MS will be calibrated according to the SOP. Acceptance criteria for the calibration are listed in Table 14. Results are reported as μg/g dry-weight.

GFAA Analysis of Selected Metals - Sample digestates may also analyzed by graphite furnace atomic absorption (GFAA) when analysis of a single element (except Hg) is required. GFAA analysis will be conducted according to Battelle SOP MSL-I-029 *Determination of Metals in Aqueous and Digestate Samples by GFAA*. This procedure is based on EPA Method 200.9 *Determination of Trace Elements by Stabilized Temperature Graphite Furnace Atomic Absorption Spectrometry* (EPA 1991b). The GFAA will be calibrated according to the SOP. Acceptance criteria for the calibration are listed in Table 14. Results are reported as μg/g dry-weight.

EDXRF - Laboratory analysis of major metals Al and Fe, and trace metals Cr, Ni, Pb, Zn and Cu will be performed by KLM Laboratories using acquisition and data reduction procedures described in, and in compliance with, KLM Procedure XRF-01 (formerly 7-40.48). The received sample will be transferred to Teflon beakers and dried at 105 ºC for 24 hours. The total received sample then will be homogenized and approximately 500 mg of the resultant material will be ground to smaller than 300-μ mesh size for data acquisition. The samples probably will be presented to the analytical system as loose powders supported by para-film. Samples are prepared to fill the sensitive area viewed by the x-ray detector as to provide maximum count-rate. A USGS NIST matrix standard is placed in position 1 of 16. The remaining 15 positions generally are filled with at least one more NIST, USGS, or, NRCC standard and one field sample duplicate. The KEVEX 0810A and kevex-ray high voltage generator are set to computer control and the acquisition program is activated to acquire data on 17 samples. The standard mounted in position #1 is acquired at the start and end of each acquisition run. The spectral data from position 1, the inclusive standard, and duplicate field sample provide internal QA for the laboratory. Results are reported as μg/g dry-weight.

12.3.3 Physicochemical and Microbiological Parameters

Total Organic Carbon: Samples are processed and analyzed by AMS according to AMS – SOP 2201. Sediment samples for TOC analysis will be removed from the refrigerator just prior to drying. A portion of the sample will be dried at 70°C for 24 to 36 hours and ground to a fine powder. The sample will be treated with 10% HCl to remove inorganic carbon and dried at 70° for 24 hours. Between 10 and 500 mg

Table 14. Laboratory Instrument Calibration Procedures.

Parameter	Instrument Type[a]	Initial Calibration			Continuing Calibration		Corrective Action
		No. Stds	Acceptance Criteria	Frequency	Acceptance Criteria	Frequency	
PAH/LAB Coprostanol	GC/MS	≥ 5	RSD≤ 25% mean RSD≤ 15%	Prior to analytical run	PD from initial ≤ 25%; mean PD≤ 15%	every 12 hours	Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
Pesticide	GC/ECD	≥ 5	r≥ 0.995	Prior to analytical run	PD from true value≤ 25%; mean PD≤ 15%	every 10 to 12 samples (or 24 hours)	Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
Metals	CVAA (Hg);	≥ 3 (5)	r≥ 0.995	Prior to analytical run	PD≤ 15% of initial	every 10 samples	Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
	ICP-MS (Ag, Cd)	≥ 3 (4)	r≥ 0.995	Prior to analytical run	PD≤ 5% of initial	every 10 samples	Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
	GFAA (as required)	≥ 3	r≥ 0.995	Prior to analytical run	PD≤ 5% of initial	every 10 samples	Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
	EDXRF	> 1	<10%	Prior to analytical run	PD <10%	every 16 samples	Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
TOC (Sediment)	Coulometric Carbon Analyzer	3	5% R%D from known value	weekly	5% R%D	every 20 samples	Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
Grain Size	Analytical Balance, Thermometers	NA	Manufacturers specifications	Annually	NA	daily	Recalibrate
Microbiology: C. perfringens Fecal Coliform *Enterococcus*	Thermometers Incubators	NA	Manufacturers specifications	Annually Temperature checked daily	NA	daily	Recalibrate

NA: Not Available

[a]Analytical procedures are described in Section 12 and listed in Table 10.

of dry, finely ground, and homogenized sample will be weighed to the nearest 0.1 mg and placed in a crucible that has been precombusted for 4 hours at 500°C**.**

The analyzer operates through the high-temperature conversion of all carbon in the treated sample to carbon dioxide in the presence of oxygen. The carbon dioxide is quantified by coulometric detection. Results are reported as % dry-weight.

Sediment Grain Size: Grain size analysis will be performed by GeoPlan Associates of Hingham, Massachusetts. Samples will be analyzed for grain size by a sequence of wet sieving and dry sieving. Methodologies will follow Folk, 1974. Samples will be prepared by first splitting the individual sediment samples into the appropriate size for analysis. If sufficient sample material is available, optimal sample size will be 30 dry grams of mud and at least 70 dry grams of sand. The sample will be mixed by hand in 200 mL of a 5% solution of dispersant (sodium hexametaphosphate) to loosen clays. The mixture will be

left for at least 12 hours and mixed by hand a second time. A 3% hydrogen peroxide solution will be mixed and left at least 12 hours. This procedure will be repeated if necessary. The wash load, which contains the silt and clay fractions, will be transferred to a 1000-mL cylinder, topped to 1000 mL with deionized water, and covered. The material retained on the sieve is the sand and gravel fractions. This coarse load will be transferred to a 200-mL beaker, decanted, and dried overnight at 95°C.

The dried sand and gravel fraction will be mixed by hand to disaggregate the material, and then dry-sieved using the following six sieve sizes:

Millimeters	2	1	0.5	0.25	0.125	0.0635
Phi Units	−1.0	0.0	1.0	2.0	3.0	4.0
U.S. Standard Sieve Mesh #	10	18	35	60	120	230

Stacked sieves will be placed on a Fritsch Analysette vibrating table for 10 minutes. Material retained on the -1 phi sieve will be considered the gravel fraction. Material retained on the 0-, 1-, 2-, 3-, and 4-phi sieves will be considered the sand fraction. Particles smaller than 4 phi will be analyzed using the pipette method described below. Each size class will be weighed to the nearest 0.1 mg on a top-loading balance.

The mud (silt + clay) fraction will be analyzed using the pipette method. The procedure is based on Stokes Law, which computes sediment settling velocity. The sample in the cylinder will be mixed to fully and uniformly suspend the sediment in the cylinder. When the mixing stops, settling of mud will begin and the time will be recorded. Within the first 20 seconds of settling, a 25-mL aliquot will be removed by pipette from a depth of 20 cm and emptied into a pre-weighed (based on an average of at least three weighings) 50-mL beaker. Twenty-five milliliters of deionized water then will be drawn into the pipette and emptied into the beaker to wash out any sediment inside the pipette. This sample will represent the total mud fraction of the sample. The beaker will be dried overnight at 95°C and weighed to the nearest 0.1 mg. The total mud weight will be determined by subtracting the beaker weight and multiplying by 40 (25 mL × 40 = 1000 mL, total sample volume). A second withdrawal will be made at the time when all silt-sized (coarser than 8 phi) material has settled below the depth of the pipette. This withdrawal can be made at any depth, as long as the settling times are properly computed according to Stokes Law. According to calculations based on Stokes Law, at 10-cm depth this withdrawal time should occur at 2 hours, 3 minutes after mixing stops, and at 20-cm depth at about 4 hours, 5 minutes after mixing stops (Folk, 1974). Data will be presented in weight percent by size class. In addition, the gravel:sand:silt:clay ratio and a numerical approximation of mean size and sorting (standard deviation) will be calculated. A cumulative frequency curve of the data may be prepared using phi units.

*Microbiological Parameters: A*nalysis of sediment samples for *Clostridium perfringens*, fecal coliform, and *Enterococcus* will be performed by MTH Environmental Associates. Sediment extraction methods will follow methods developed by Emerson and Cabelli (1982) as modified by Saad (1992). Briefly, samples will be homogenized, and an aliquot of known weight transferred to a sterile 50-mL polypropylene centrifuge tube. Sterile sodium hexametaphosphate solution will be added to the sample, and the tube will be capped and mixed thoroughly for 10–15 seconds. Sterile deionized water will be added, the sample remixed, and allowed to settle for 10 minutes. The supernatant will be removed from the tube with a sterile pipette and placed in a sterile test tube. The tubes will be stored on ice and analyzed within 30 minutes.

Analysis of the supernatant will be performed by membrane filtration. Enumeration of *C. perfringens* spores will follow the method of Bisson and Cabelli (1979). Enumeration of fecal coliform and *Enterococcus* are described in the EPA method 821/R-97/004 (EPA, 2000) with the modification to the *Enterococcus* method discussed below. The extract will be filtered through a sterile, 0.45-μm pore size, gridded membrane filter that retains the bacteria. After filtration, the membrane containing the bacterial cells will be placed on a selective-differential medium and incubated.

The filters for enumeration of *C. perfringens* spores will be incubated anaerobically at 44.5°C for 24 hours. Following incubation, the filter will be exposed to ammonium hydroxide for 15–30 seconds. Yellowish colonies that turn red to dark pink upon exposure will be counted as *C. perfringens*.

Filters to be enumerated for fecal coliform will be incubated at 35°C for 2 hours, followed by incubation at 44.5°C for 18–20 hours. Yellow colonies will be counted and recorded as fecal coliform.

Following filtration, filters for *Enterococcus* enumeration will be incubated for 24 hours at 41°C following the procedure of Messer and Dufour (1998). This modification of the procedure described in EPA (1985) eliminates the need for the transfer of the filter to EIA agar and shortens the incubation time.

12.3.4 Sediment Profile Image Analysis

12.3.4.1 General Approach

Dr. Robert Diaz of Diaz and Daughters will perform the SPI analysis. Post field analysis will continue with a reanalysis of the videotapes previously examined in the field and the processing of the 35-mm film. After the film is processed (within 24 hours of completion of the field work), a visual analysis including the same parameters as estimated from the video SPI will be conducted. These data will be combined with the video data and the final rapid "quick look" analysis will be completed within 24 hours of film development.

After the film is developed, each slide will be labeled with station and replicate data. The first analytical step is accomplished visually by projecting the images and recording all observed features into a preformatted, standardized spreadsheet file. The videotapes also are analyzed visually, with all observed features also recorded into a preformatted, standardized spreadsheet. The sediment profile images are scanned with a Nikon CoolScan 2000 into TIFF format. Adobe Photoshop™ is used to preprocess the images (enhancements, color balance, etc.). Computer images will be analyzed by using a Power Macintosh microcomputer and NIH Image, the National Institutes of Health image analysis program. Computer analysis procedures for each image are standardized by executing a series of macro commands. Data generated from each image analyzed are saved sequentially to an ASCII file for additional analysis and reduction via Microsoft Excel™.

The actual image analysis is done through a series of macro commands executed from a video screen menu. After every step the analyst is asked if the results are satisfactory and given the chance to redo any step. While the computer will always examine a slide the same way, the operators do not, which results in slight variation of image areas analyzed within and between slides. To control for operator error, 10% of all slides will be reanalyzed and compared to previous results.

During the image analysis session, two computer files are opened to receive that data from each image. One file includes all computer executed statements and the resultant data. This file is archived and can be accessed should any questions arise as to how the analysis of any particular slide was conducted. A second file that includes only the selected image data to be used in reports is generated at the same time. After computer analysis, all slides are put into the SPI photo archives for future reference.

12.3.4.2 Specific Analyses

The specific data produced from analysis of profile images are described below. Further details about these analyses can be found in Kiley (1989) and in the standardized image analysis procedures of Viles and Diaz (1991).

Prism penetration provides a geotechnical estimate of sediment compaction, with the profile camera prism acting as a dead weight penetrometer. The farther the prism enters into the sediment the softer the sediments, and likely the higher the water content. Penetration is measured simply as the distance the sediment moves up the 25-cm length of the faceplate. If the weight of the camera frame is not changed during field image collection then the prism penetration provides a means for assessing the relative sediment compaction between stations or different habitat types. By taking two exposures, at 10 second intervals, per deployment, the camera can record overlapping photographs of the sediment as the prism penetrates. Penetration as deep as 27 cm has been obtained (18 cm in the 4-second image and an additional 9 cm in the 14-second image) on other studies using this technique. Deep prism penetration is indicative of recent rapid sediment accumulation where sediments have not had the time to dewater.

Surface relief is measured as the difference between the maximum and minimum distance the prism penetrates. This parameter provides an estimate of small-scale bed roughness, on the order of the prism faceplate width (15 cm). The causes of roughness often can be determined from a visual analysis of the images. In physically dominated sandy habitats, surface relief typically consists of small sand waves or bed forms. In muddy habitats, surface relief is typically irregular (being primarily derived from biological activity of benthic organisms, which form mounds or pit during feeding and burrowing) or smooth. Biological surface roughness can range from small fecal mounds and tubes to large colonies of hydroids or submerged aquatic vegetation (SAV). Surface relief provides qualitative and quantitative data on habitat characteristics, which can be used to evaluate recent and existing habitat quality.

Apparent color redox potential discontinuity (RPD) layer is an important estimator of benthic habitat quality. It is the depth to which sediments are oxidized. The term apparent is used in describing this parameter because no actual measurement is made of the redox potential. An assumption is made that, given the complexities of iron and sulfate reduction-oxidation chemistry, reddish-brown sediment color tones are indications that the sediments are oxic (oxidized), or at least are not intensely reducing (Diaz and Schaffner, 1988). This is in accordance with the classical concept of RPD depth, which associates it with sediment color (Fenchel, 1969).

The depth of the apparent color RPD is defined as the area of all the pixels in the image discerned as being oxidized divided by the width of the digitized image. The area of the image with oxic sediment is obtained by digitally manipulating the image to enhance characteristics associated with oxic sediment (greenish-brown color tones). The enhanced area then is determined from a density slice of the image or, if image quality is poor, the area is delineated with the cursor.

The apparent color RPD is very useful in assessing the quality of a habitat for epifauna and infauna from physical and biological perspectives. Rhoads and Germano (1986), Day *et al.* (1988), and Diaz and Schaffner (1988) found the depth of the RPD from profile images to be directly correlated to the quality of the benthic habitat in polyhaline and mesohaline estuarine zones. Thin RPDs, on the order of a few millimeters, tend to be associated with some environmental stress, whereas areas with deep RPDs, that is, deeper than 3 cm, usually were found to have flourishing epibenthic and infaunal communities.

Sediment grain size is a geotechnical feature of the sediments that is used to determine the type of sediments present. The nature of the physical forces acting on a habitat can be inferred from grain-size

distribution of the sediments. The sediment type descriptors used follow the Wentworth classification as described in Folk (1974) and represent the major modal class for each layer identified in an image. Sediment grain size is determined by comparing the collected images with a set of standardized images taken of sediments for which mean grain size has been determined by laboratory analyses. Sediment grain sizes ranging from pebble/rock to gravel, to sand, to silt, and clay can be estimated accurately from the images.

Surface features include a variety of physical and biological features that can be seen at or on the sediment surface. These can range from SAV, worm tubes, fecal pellets, epibenthic organisms, bacterial mats, algal mats, shells, mud clasts, bed forms, to feeding pits and mounds. Each feature provides information on the type of habitat and its quality. Certain surface features are indicative of the overall nature of a habitat. For example, bedforms are always associated with physically dominated habitats, whereas worm tubes or feeding pits are indicative of a more biologically accommodated habitat (Rhoads and Germano, 1986; Diaz and Schaffner, 1988). Surface features are visually evaluated from each slide and compiled by type and frequency of occurrence.

Subsurface features include a variety of features such as burrows, water filled voids, SAV rhizomes , infaunal organisms, gas voids, shell debris, detrital layers, and sediment lenses of different grain size. Subsurface features also reveal a great deal about the physical-biological control occurring in a habitat. For example, the presence of gas voids with a mixture of nitrogen and methane from bacterial metabolism (Reineck and Singh, 1975) has been found to be an indication of anaerobic metabolism (Rhoads and Germano, 1986) and associated with high rates of bacterial activity. Muddy habitats with large amounts of methane gas are generally associated with areas of oxygen stress or high organic loading (Day *et al*., 1988). On the other hand, habitats with burrows, infaunal feeding voids, and/or visible infauna are generally more biologically accommodated and considered unstressed.

Successional stages of the fauna in a habitat can be estimated by using SPI data (Rhoads and Germano, 1986). Characteristics that are associated with pioneering or colonizing (**Stage I**) assemblages (in the sense of Odum, 1969), such as dense aggregations of small polychaete tubes at the surface and shallow apparent RPD layers, are easily seen in sediment profile images. Advanced or equilibrium (**Stage III**) assemblages also have characteristics that are easily seen in profile images, such as deep apparent RPD layers and subsurface feeding voids. **Stage II** is intermediate to Stages I and III, and has characteristics of both (Rhoads and Germano, 1986).

12.3.5 Hard-bottom Videotapes and 35-mm Slides

The 35-mm film will be mounted, labeled (cruise, date, roll number, frame number, and waypoint), and scanned onto CDs immediately after the cruise. The slides will then be transferred to Dr. Barbara Hecker for analysis.

Each slide will be projected and analyzed for habitat characteristics and biota. These include:

- primary and secondary substrate
- degree of sediment drape
- estimated percent cover of crustose pink algae (previously identified as *Lithothamnium* spp.)
- relative abundance of hydroids, spirorbid/barnacle complex, *Ptilota serrata* (previously identified as *Asparagopsis*), and dulse
- occurrence and abundance of all recognizable taxa.

Data collected from the slides are numerically coded and entered directly into an MS Access loading application. At the end of analyzing the slides from each waypoint, the MS Access database is proofread for typographical errors. If errors are found, the slides from that waypoint are rechecked. The Access loading application will apply EM & MS constraint checks. An exception report will be generated and exceptions explained prior to submission to the database. The loading application is then transferred to Battelle for data management.

The video footage from each waypoint is viewed immediately after the stills from that waypoint are analyzed. This allows for cross-referencing between the greater areal coverage of the video and the higher visual resolution of the stills. The video footage is initially viewed once for habitat characteristics and heterogeneity (substrate types, sediment drape, habitat relief) and then a second time for biotic components. The data from the video footage is collected on data sheets and then transferred into a loading application.

13.0 SAMPLE CUSTODY

13.1 Sample Tracking

Sample custody will be tracked through station logs (Figure 6) and custody forms (Figure 7). All original SPI field data sheets and associated film (video and 35 mm) will be generated by and remain in the custody of the senior scientist from Diaz and Daughters. Similarly, all data from the yearly ROV surveys will be generated and maintained by Barbara Hecker of Hecker Environmental.

The NavSam© software system will generate a unique eight character *Sample ID* for each grab. The program creates a record of the sample time, date and location and links that record to the *Sample ID*. The assigned S*ample ID* is a concatenation of a five character *Event ID* and a three-character hexadecimal number (*Marker No*). The five character *Event ID* will be unique to each survey, such as BF021, with "BF" indicating that it is a farfield benthic survey, "02" indicating the survey year, and "1" signifying the first survey of the year. The *Marker No* is a non-repeating number generated by the NavSam© software when the *Event* key is hit as soon as slack on the wire indicates that the grab has touched bottom.

Each portion of a sample separated for analytical purposes will be assigned a unique *Bottle ID*, composed of the eight–character *Sample ID* plus a 3–character suffix designating the sample type and replicate number. For example, "FA1" indicates that the subsample is the first replicate for "infauna" analyses (see Table 15 for the two letter codes). The NavSam© software produces two labels for each bottle, one for the bottle and the second to be affixed to the Station Log (Figure 6). All data reporting will be keyed to Battelle's sample identification scheme. Note that for SPI data (analysis codes RS and SP) and hard-bottom data (analysis codes BV and BP) there is no physical sample, so no sample or bottle records will be reported to MWRA.

The scientific crew member operating the data collection system (NavSam©) will fill out the station log (Figure 6) at each station. The log includes header fields for entering pertinent information about each station, such as arrival time, bottom depth, and weather observations. In addition, the log sheets contain spaces for specific grab data, such as penetration depth, apparent RPD and general descriptions. These sheets will remain in the survey logbook and are maintained in the project files. During field collection, COC forms also will be completed and labels will be affixed to the sample containers, thereby creating a link between the sample and data recorded on the COC form. The COC forms will have a barcode label containing the same alphanumeric code as the corresponding label on the sample container, ensuring the tracking of sample location and status. Labels generated for "bad grabs" will be placed on the back of the station logs.

STATION LOG
For Benthic Sediment Grab Samples
Project Name: MWRA Harbor and Outfall Monitoring – Contract S366

SURVEY: **BC021** STATION ID: **NF24** TIME ON STATION:____________________ STATION DEPTH (M):____________________DATE:______________________	Weather:____________________________ — Recorded By:___________________________

Comments	Sample ID Label	Field Measurements
		Grab Size: 0.04-m^2 0.1-m^2
		Grab Penetration (cm):
		Sediment Texture:
		Redox Depth (cm):
		Analyses: (circle all applicable) Organics Metals TC GR CL EN/FE FA
		Comment:
	Sieved By:	
		Grab Size: 0.04-m^2 0.1-m^2
		Grab Penetration (cm):
		Sediment Texture:
		Redox Depth (cm):
		Analyses: (circle all applicable) Organics Metals TC GR CL EN/FE FA
		Comment:
	Sieved By:	
		Grab Size: 0.04-m^2 0.1-m^2
		Grab Penetration (cm):
		Sediment Texture:
		Redox Depth (cm):
		Analyses: (circle all applicable) Organics Metals TC GR CL EN/FE FA
		Comment:
	Sieved By:	
		Grab Size: 0.04-m^2 0.1-m^2
		Grab Penetration (cm):
		Sediment Texture:
		Redox Depth (cm):
		Analyses: (circle all applicable) Organics Metals TC GR CL EN/FE FA
		Comment:
	Sieved By:	

TC= total organic carbon, GR = grain size, CL=*C perfringens*, EN/FE= *Enterococcus* /Fecal Coliform, FA = Infauna

Figure 6. Example of a Station Log Form.

MWRA Harbor and Outfall Monitoring Program
Contract No. S366
Sample Custody Form

Today's Date : 2/22/02 9:30:55 AM

Laboratory : Applied Marine Sciences

Chain-of-Custody # : BC021-TC-0006
Survey ID : BC021
Analysis ID : TC
Analysis Description : TOC

502 N. Highway 3, Suite B
League City TX 77573
Mr. Kenneth Davis
281-554-7272 (Phone) 281-554-6356 (Fax)

Bottle ID :	Bottle ID :	Sampling Date :	Station ID :	Ck 1	Ck 2	Ck 3	Ck 4
[redacted]	BC0210E1TC1	2/20/02 10:06:39 AM	FF10	☐	☐	☐	☐
[redacted]	BC0210ECTC1	2/20/02 10:47:50 AM	FF10	☐	☐	☐	☐
[redacted]	BC0210EETC1	2/20/02 10:59:23 AM	FF10	☐	☐	☐	☐
[redacted]	BC0210F6TC1	2/20/02 11:35:14 AM	NF08	☐	☐	☐	☐
[redacted]	BC0210F8TC1	2/20/02 11:47:34 AM	NF08	☐	☐	☐	☐
[redacted]	BC0210FATC1	2/20/02 12:12:44 PM	NF08	☐	☐	☐	☐
[redacted]	BC021100TC1	2/20/02 12:48:56 PM	NF24	☐	☐	☐	☐
[redacted]	BC021101TC1	2/20/02 12:56:47 PM	NF24	☐	☐	☐	☐
[redacted]	BC021102TC1	2/20/02 1:06:20 PM	NF24	☐	☐	☐	☐
[redacted]	BC021106TC1	2/22/02 1:27:23 PM	NF22	☐	☐	☐	☐
[redacted]	BC021107TC1	2/20/02 1:36:57 PM	NF22	☐	☐	☐	☐
[redacted]	BC021108TC1	2/20/02 1:44:21 PM	NF22	☐	☐	☐	☐

Shipping Condition - Room Temperature: _____ Cold(ice): _____ Frozen(dry ice): _____
Received Condition - Room Temperature: _____ Cold(ice): _____ Frozen(dry ice): _____

Relinquished By / Date / Time / Company / Transport-Airbill #	Received By / Date / Time / Company

Page 1 of 1

Figure 7. Example of a Chain-of-Custody Form.

Table 15. Analysis Codes Used in *Bottle ID*.

Analysis Code	Description	Laboratory
RS	Rapid SPI Analysis	Diaz
TC	TOC	AMS
GR	Granulometry	GeoPlan
CL	*Clostridium*	MTH
LA	LAB	Battelle
MM	Major metals	KLM
TM	Trace metals	Battelle/KLM
PB	PCB	Battelle
PA	PAH	Battelle
PE	Pesticides	Battelle
CO	Coprostanol	Battelle
FE	Fecal coliform	MTH
EN	*Enterococcus*	MTH
FA	Infauna	Cove/ENSR
SP	SPI Data	Diaz
BV	Benthic Hard-bottom Video	Hecker
BP	Benthic Hard-bottom Photos	Hecker

13.2 Data Custody

Field custody of electronic data will be the responsibility of the NavSam© operator. This person will be identified for each survey. The field custody of the electronic data consists of creating floppy-disk backups of all electronic data generated each day. Each floppy disk label will include a survey ID, date, name of person creating the backup files, and a disk number. When the equipment is returned to Battelle, a second complete backup labeled as "Set 2", will be generated on floppy disks. The backup will be in the custody of the deputy field manager. The original will remain in the Battelle project files.

Battelle and several subcontractors will produce electronic data under this task. Subcontractors are responsible for the internal custody of their electronic data until they are forwarded to the Battelle database manager. At Battelle, the electronic files for chemical data will remain in the custody of the analysts until all analyses are completed and data have gone through the Battelle Quality Assurance Office. Data then are transferred to the Laboratory Manager who reviews the data, and forwards it to the database manager for loading.

13.3 Sample Custody

Sediment infauna samples will be in the custody of the survey chief scientist from collection until they are transferred to Cove Corporation for sorting. Custody forms generated by the NavSam© system (Figure 7) will accompany the samples. One complete copy of the infauna custody forms will be included in each shipping container. After the samples are sorted, Cove will return the appropriate specimens to ENSR for identification using its own custody transfer forms (see Appendix B).

Sediment chemistry samples will be collected by a designated Battelle technician and will remain in his/her custody until they are transferred to the Battelle field sample custodian for shipment to analytical laboratories.

Transfer of benthic chemistry and infaunal samples will be documented on the custody forms. All samples will be distributed to the appropriate laboratory personnel by hand or by Federal Express. A copy of the COC will be retained by the field sample custodian in the Field Log. The original will accompany the samples to the laboratory for subsequent sample transfer. When samples arrive at each of the laboratories, custody will be relinquished to the Laboratory Custodian. Upon receipt of the samples at Battelle or its subcontractors, the Sample Custodian will examine the samples, verify that sample-specific information recorded on the COC is accurate and that the sample integrity is uncompromised, log the samples into the laboratory tracking system, complete the custody forms, and sign the COC form so that transfer of custody of the samples is complete. Any discrepancies between sample labels and transmittal forms, and unusual events or deviations from the project CWQAPP will be documented in detail on the COC and the Task Leader and Project Manager notified. Copies of completed custody forms will be faxed back to the sampler within 24 hrs. of receipt. For biology samples, an e-mail confirming receipt of all samples will be sent to ENSR within 24 hours of receipt; the signed custody forms will follow by mail within one week. The signed original custody form will be returned to Battelle along with the data report for those samples. Sample numbers that include the complete field ID number will be used to track the samples through the laboratory.

13.4 Sample Archival Policies

The types of materials that may be archived include environmental samples, extracts, sample residues, and reference collections. Laboratories are not required to save specimens, sample processing residues, or extracts past viability, defined as the sample holding time. Infaunal sample residues will be held until the data report is accepted by MWRA. Unexpended samples are stored for 60 days and unexpended sample extracts are stored for 365 days past data delivery. The Laboratory Manager must be contacted prior to sample disposal. Based on discussions with the MWRA Project Manager, materials may then be disposed, returned to the client, or transferred to another location. All archived materials must be clearly identified, labeled with the project number and unique identification number, and be stored under appropriate conditions for the length of the storage period.

14.0 CALIBRATION PROCEDURES AND PREVENTIVE MAINTENANCE

Maintenance of and repairs to instruments will be in accordance with manufacturers' manuals.

14.1 Navigation Equipment

Details of the calibration procedures and preventative maintenance for the navigation equipment can be found in the Water Column Monitoring CWQAPP (Libby *et al.*, 2002).

14.2 Laboratory Equipment

Logs of maintenance, calibrations, and repairs made to instruments will be stored in laboratory files. All routine and non-routine repairs are documented in the maintenance section of the instrument logbook assigned to each analytical instrument. The information recorded includes analysts' initials, date maintenance was performed, and a description of all activities, including information such as flow rates. Additionally, the reasons for and results of all service calls are recorded and maintained in the instrument logbook. All routine and non-routine maintenance procedures are fully defined in the appropriate instrument operation SOPs (cited in the following sections).

14.2.1 Organic Analysis Equipment

14.2.1.1 GC/MS

Instrumental calibration, operation, maintenance, and QC procedures for the GC/MS analysis of samples for PAH will be performed according to Battelle SOPs 3-092 and 5-157. The GC/MS will be tuned with perfluorotributylamine before the initiation of the sample sequence. Analytical instruments will be calibrated before sample analysis and response factors (RF) will be generated for each PAH/LAB target analyte (Table 9).

The GC/MS system calibrations will be verified using a mid-range calibration check. Using the mean RF of each analyte from the initial calibration, the percent difference between those mean values and the RFs from the midrange calibration checks will be calculated. If the percent difference between the RFs is greater than the acceptability criteria, remedial maintenance will be performed on the instrument, and a new calibration check standard analyzed. If the check standard then meets the acceptance criteria, the affected samples will be reanalyzed. If the check standard still does not meet the acceptance criteria then a new initial calibration will be performed, and the affected batch of samples will be reanalyzed, at the discretion of the Task Leader. Because GC/MS analysis is a multi-component analysis, it may not be necessary to reanalyze all bracketed samples if a mid-range calibration check standard does not meet the acceptability criteria. This decision will be based on a comparison of the analytes detected in the samples vs. the target analytes that did not meet the mid-check acceptability criteria. Reanalysis will only be necessary if RFs for the analytes that are detected in a sample did not meet the criteria. Re-analyses will be performed at the discretion of the Task Leader. Deviations from calibration or data objectives will be documented in the project files.

Samples analyzed by GC/MS will be bracketed by two acceptable calibrations, initial or check. Analytes will be quantified by using the average RFs for that individual PAH/LAB analyte generated from the initial calibration following the method of internal standards, using RIS for quantification. Sample data will be surrogate corrected in the spreadsheet.

Response factors (RF) will be generated for each target analyte using the following equation:

$$RF = (A_x / A_{IS}) \times (C_{IS} / C_x)$$

where:
- A_x = peak area of the analyte in the calibration standard
- A_{IS} = peak area of the appropriate internal standard in the calibration standard
- C_x = concentration of the analyte in the calibration standard
- C_{IS} = concentration of the appropriate internal standard in the calibration standard.

Using the mean RF of each analyte from the initial calibration, the percent difference between those mean values and the RFs from the midrange calibration checks will be calculated by:

$$\% \text{ Difference} = [(RF_i - RF_r) \div RF_i] \times 100$$

where
- RF_i = average response factor from the initial calibration, and
- RF_r = response factor from the midrange calibration check.

14.2.1.2 GC/ECD

Instrumental calibration, operation, maintenance, and QC procedures for gas chromatography with electron capture detection (GC/ECD) will be performed in accordance with Battelle SOPs 3-116 and

5-128. The data collected from the confirmatory analysis will be used to qualitatively confirm target analytes. Second column confirmation is not required for samples where target pesticides and PCBs were not detected on the primary column. Analytical instruments will be calibrated before sample analysis and a calibration curve using the quadratic equation method will be generated for each PCB and pesticide target analyte (Table 9).

A mid-level calibration check standard will be analyzed to verify the GC/ECD system calibration during analysis. This check standard will be quantified in the same manner as field and QC samples. If the percent difference between the detected and true concentrations of the target pesticides and PCB congeners is greater than the acceptability criteria, remedial maintenance will be performed on the instrument, and a new calibration check standard analyzed. If the check standard then meets the acceptance criteria, the affected samples will be reanalyzed. If the check standard still does not meet the acceptance criteria then a new initial calibration will be performed, and the affected batch of samples will be reanalyzed, at the discretion of the Task Leader. Because GC/ECD analysis is a multi-component analysis, it may not be necessary to reanalyze all bracketed samples if a mid-range calibration check standard does not meet the acceptability criteria. This decision will be based on a comparison of the analytes detected in the samples vs. the target analytes that did not meet the mid-check acceptability criteria. Reanalysis will only be necessary if percent differences for the analytes that are detected in a sample did not meet the criteria. Reanalysis will be performed at the discretion of the Task Leader. Deviations from calibration or data objectives will be documented in the project files.

Samples analyzed by GC/ECD will be bracketed by two acceptable calibrations, initial and check. Analytes will be quantified using the calibration curve generated from the initial calibration following the method of internal standards, using RISs for quantification. Sample data will be surrogate corrected in the spreadsheet.

14.2.2 Metals Analysis Equipment

The CVAA, ICP-MS, and GFAA instruments will be calibrated prior to each analytical run (Table 14).

14.2.2.1 CVAA

Instrument calibration, operation, and maintenance procedures for CVAA analysis of sediment samples for Hg will be conducted according to Battelle SOP MSL-I-016 *Total Mercury in Tissues and Sediments by Cold Vapor Atomic Absorption*. The instrument is maintained by the analyst, with the assistance of service personnel from Thermo-Separation Products. The soda lime trap and reagents (stannous chloride, 3% nitric acid, and rinse water) are checked daily and changed weekly under constant use. The carbon trap and filters are checked weekly and changed bimonthly under constant use. The sample injection syringe, tubing, connectors, and lamp are checked weekly and changed as needed, and the autosampler arm should be cleaned and lubricated bimonthly.

14.2.2.2 ICP-MS

Instrument calibration, operation, and maintenance procedures for ICP-MS analysis of tissue samples for metals will be conducted according to Battelle SOP MSL-I-022 *Determination of Elements in Aqueous and Digestate Samples by ICP/MS*. The instrument is maintained by the analyst, with the assistance of a service engineer from Perkin-Elmer, under a maintenance agreement. The argon supply pressure, base and operating vacuum, temperature of cooling chiller, and nebulizer flow are checked daily by the analyst. Instrument sensitivity and stability are checked each day of operation.

14.2.2.3 GFAA

Instrument calibration, operation, and maintenance procedures for GFAA analysis of tissue samples for metals will be conducted according to Battelle SOP MSL-I-029 *Determination of Metals in Aqueous and Digestate Samples by GFAA*. The instrument is maintained by the analyst, with the assistance of a service engineer from Perkin-Elmer on an as-needed basis. Argon supply pressure is checked by the analyst daily. Other daily maintenance includes inspection of the furnace tube, contact rings, and optical windows.

14.2.2.4 EDXRF

The EDXRF instrument calibration is checked prior to daily sample analysis through the analysis of certified reference materials. If the instrument is not within the certified range for these standards, the corrective action recommended by the manufacturer will be taken.

Generally the SRMs are included at the start and finish of each analytical run. If the SRMs demonstrate a problem (*e.g.*, measured value not within the SRM certificate margin of error), then the complete run would be discarded. Samples will be reprocessed after the problem is identified and corrected.

14.2.3 TOC Analysis Equipment

Instrument calibration, operation and maintenance of the UIC Model 5012 Carbon Dioxide Coulometer conform to the Applied Marine Science SOP AMS-2201 and manufacturer specifications. The performance of the coulometer is verified by the analysis of 4.8%, 12%, and 42.1% carbon standards. The standards are treated in the same manner as the samples. Because the coulometer measures total CO_2 evolved from a sample, a three-level calibration can be evaluated by using standards with different concentrations of carbon. Once the standards have been analyzed, the percent carbon measured will be compared with the known carbon value of the standard. The difference between the measured and known values for the standard must be within 5%. Initial calibration will be performed on a weekly basis. The 4.8% standard will be analyzed as a continuing calibration check following the analysis of 20 field and the associated QC samples. The continuing calibration check must be within 5% of the known carbon content for the preceding analysis to be acceptable.

14.2.4 Grain Size Analysis Equipment

The top loading balance is calibrated monthly with a 50-g standard weight using an internal calibration procedure. The analytical balance is calibrated daily using an internal calibration method with internal standard weights. These automatic calibration procedures are verified with Class S weights monthly.

14.2.5 Microbiological Parameters

The temperature of the incubators used for the growth of bacterial cultures will be monitored twice daily, for days on which the incubators are in use. A NIST traceable thermometer, accurate to 0.1°C when immersed in water, will be used and the readings recorded.

14.3 Sediment Profile Image Analysis System

Prior to every field deployment, all video components are collected and tested for proper operation. Once the video SPI system is assembled on board the research vessel, a system check is initiated that includes all features of the video SPI system from tightening all bolts and video cable connectors to testing the video camera and deck video monitor and recorder. In addition, before every field deployment, the clock in the SPI system will be set to match the clock used by the navigation system aboard the research vessel.

Prior to and after every station deployment, a station card is placed in front of the prism and recorded for 5–10 seconds. This records the station data on the videotape for later analysis. Proper system functioning (penetration of prism, flash from film SPI camera) will be monitored in real time on deck via the video monitor. Any miss-fires or improper film camera operation then can be corrected while on station. Almost any electronic or mechanical failure of the video camera can be repaired in the field. Spare parts and complete back-up video and 35-mm cameras will be carried on each survey.

14.4 Hard-bottom ROV Video and 35-mm Cameras

The subcontractor, CR Environmental, is responsible for ensuring that all maintenance and calibrations of the still camera, video camera, and ROV are carried out prior to the survey, in accordance with the manufacturer's specifications.

15.0 DATA DOCUMENTATION, REDUCTION, AND REPORTING

15.1 Documentation

Initially, all data will be recorded either (1) electronically onto computer storage media from NavSam© or other laboratory systems or (2) manually into bound laboratory notebooks or onto established data forms. All data collection notes will be written in reproducible ink. Corrections to hand-entered data will be initialed, dated, and justified. Corrections to electronically captured data (*e.g.*, electronic "spikes") will be documented on a hard-copy plot of the data. Completed data forms or other types of hand-entered data will be signed and dated by the individual entering the data. Direct-entry and electronic data entries will indicate the person collecting or entering the data. It will be the responsibility of the laboratory managers to ensure that all data entries and hand calculations are verified in accordance with procedures described in Section 16 (below). Station logs associated with field and laboratory custody and tracking will be kept in a survey notebook for each survey. These notebooks will be held in the custody of the Field Manager.

For the SPI field program, data for every station sampled are logged into a plastic-paper field notebook. Data logged include station position, date, time, camera counter number, depth of prism penetration as determined from the deployment frame, water depth, and other parameters. This field notebook will be kept at Diaz & Daughters under the supervision of Dr. Robert Diaz, and a copy will be provided to complete the Battelle survey logbook.

Sample laboratory data recording forms are provided in Appendix B.

15.2 Data Reduction

Data reduction is the process of converting raw numbers (*e.g.*, numbers of organisms per replicate) into data that can be displayed graphically, summarized in tables, or compared statistically for differences between mean values for sampling times or stations. The data discussed in this section are those data that require some manipulation before being submitted to Battelle data management for entry into the database.

15.2.1 Infaunal Analysis

There is no manipulation of infaunal data prior to the submission of the infaunal data reports.

15.2.2 Sediment Chemistry Analyses

15.2.2.1 Organics and Metals

GC/MS data will be acquired and reduced on Hewlett-Packard PC-based chemstation minicomputers with dedicated chromatography software. GC/ECD data will be acquired and reduced by the Thermo Lab Systems XCHROME System. All GC/MS and GC/ECD data files will be transferred electronically to a PC so that the data can be incorporated into an electronic database or spreadsheets for final quantification and tabular results presentation. Data for metals analysis by GVAA, ICP-MS, and GFAA are collected and processed by the instruments' software systems. Processed data are electronically transferred to Excel™ spreadsheet format for electronic data deliverable (EDD) generation. The final reduction of analytical chemistry data will account for the size of the processed sample and dilution factors. EDXRF data will be recorded in Excel™ spreadsheets for EDD generation.

15.2.2.2 TOC

Total organic carbon measurements are acquired on instrument software and downloaded onto Excel™ spreadsheets for submission to Battelle data management. TOC results will be reported as percent total organic carbon on a dry weight basis.

15.2.2.3 Grain Size

Grain Size will be reported as percent of the total for each size fraction measured. Silt content is determined by subtracting the total clay content from the mud content, as described in section 12. Data are entered onto a spreadsheet for calculation of silt content. In addition to weight percent by size class, the Gravel: Sand: Silt: Clay ratio and a numerical approximation of mean size and sorting (Standard deviation) is calculated. A cumulative frequency curve of the data may be prepared using phi data.

15.2.2.4 Microbiological Parameters

All final data will be reported in units of spores/g dry weight (*C. perfringens*) or colonies/g dry weight (fecal coliform and *Enterococcus*). All microbiological data will be hand entered onto spreadsheets for submission to Battelle data management.

15.2.3 Hard-bottom Analysis

There is no additional manipulation of hard-bottom data prior to the submission of the hard-bottom data report.

15.2.4 SPI Analysis

After visual and computer image analyses are completed, a standard set of parameters (Table 5) taken from both analyses is combined and tabulated for reporting. If appropriate, statistical analyses can be done to test hypotheses by applying appropriate parametric (*e.g.*, *t*-test, ANOVA) and/or nonparametric (*e.g.*, Logistic regression, Log-linear Modeling, Friedman's test) techniques.

SPI data are used to summarize environmental conditions through the calculation of the Organism-Sediment Index (OSI). The OSI, as developed by Rhoads and Germano (1986), is an integrative estimate of the general ability of the benthic habitat to support fauna. The OSI is defined from SPI parameters and the indirect estimation of bottom dissolved oxygen levels. The lowest value of the OSI (–10) is given to habitats that have little or no dissolved oxygen, no apparent evidence of fauna (surface or subsurface data), and where methane gas is present (subsurface data). The highest value of the OSI (+11) is given to habitats that have high dissolved oxygen, a deep apparent RPD layer, evidence of fauna, and no methane gas. The index is calculated by using the RPD depth, the successional stage, the presence of methane

voids, and visual indications of low oxygen concentrations in the water column. The formulation for the OSI and three hypothetical examples are shown in Table 16. For SPI data collected from the nearfield, RPD values will be compared to the MWRA threshold levels (MWRA 2001, Appendix A).

15.3 Data Entry, Loading, and Reporting

15.3.1 Data Loading Applications

The data reporting for analytical and experimental data begins with the Battelle Data Management Team who will populate a loading application for each laboratory. The loading applications are populated with the Sample_ID numbers and analysis protocols extracted from the Access database containing data from field activities that is delivered to the data manager at the conclusion of each survey. A separate loading application will be prepared for each data deliverable.

15.3.2 Population of Loading Applications by Battelle

Analytical laboratories with existing data processing capabilities (Battelle, Sequim, KLM) will provide their laboratory's final computer-generated data spreadsheets to Battelle. The Battelle data management team will use a loading application to run the necessary quality control checks and load the data provided into the ORACLE database. Battelle uses generic loading applications that are designed to process large analytical datasets that are received in spreadsheet form and converts them into the correct format for entry into the ORACLE database. Each laboratory will have to meet its own internal laboratory format for the data to load successfully. Smaller laboratories (AMS, GeoPlan, MTH) also provide their data electronically to Battelle in spreadsheet form but the loading applications used by Battelle are smaller and specific to each of these data types.

15.3.3 Population of Loading Applications by Other Laboratories

When data contributors (Cove, ENSR, Diaz and Daughters, Hecker Environmental) open the database within the appropriate loading application they will be presented with a form that already contains the Sample_ID numbers and an analyte list for the required data submittal. The laboratory will enter the results of the analyses and other supporting information such as data qualifier codes. All entries will be constrained by the rules of EM&MS. Errors will be caught on entry and fixed by the data contributor. Primary keys will be in place so duplication cannot occur. Entry applications will be developed for each analytical laboratory. Laboratory staff receive one day of training on the application prior to analysis of the lab's first set of samples. When data entry is complete, the database will be sent back to Battelle.

The loading application will provide the laboratory with several function buttons. These include hard copy report, quality control checks, exception report, and analysis summary. The hardcopy report function button will allow the laboratory to create a hardcopy report to check for entry errors and to submit a final hardcopy report to Battelle along with the electronic data deliverable. The quality control checks will be comprised of the applicable sections of EM&MS check script and will also perform checks for outliers. This report will provide the data contributor a chance to confirm the reasonableness of the data prior to its submission to Battelle. The exception report will check the data that was expected against the results that were loaded. The data contributor must account for any entries in the exception report. The analysis report will produce a report of the number of analyses by analyte. A copy of this report will be included with the data deliverable and with the invoice for the analyses.

Within the loading application, the data entered by the laboratory will be translated into the correct codes and inserted into database tables with the same structure as the matching EM&MS table. Analytical

Table 16. Formulation of the Organism-Sediment Index.

SPI Parameter	Score	Three Hypothetical Examples		
		Station 1	Station 2	Station 3
RPD Depth (cm) (choose one value)				
0	0			
>0–0.75	1	X		
0.76–1.50	2			
1.51–2.25	3		X	
2.26–3.00	4			
3.01–3.75	5			X
>3.75	6			
Successional Stage (choose one value)				
Azoic	−4			
Stage I	1	X		
Stage I–II	2			
Stage II	3		X	
Stage II–III	4			
Stage III	5			X
Stage I on III	5			
Stage II on III	5			
Sediment/Near-bottom Gas (choose neither, one, or both as appropriate)				
Methane	−2	X	X	
No/Low DO	−4	X		
Calculated OSI		−4	+4	+10

parameters and database codes for the analytes collected under this task are shown in Table 17. Table 18 shows the parameters and database codes for the SPI analysis. Table 19 describes the database codes to be used by the laboratories. The laboratories will have the ability to add additional codes to describe their results but the new codes will be highlighted in the exception report. Battelle will notify MWRA concerning the new qualifier and will adjust the code table in the application to agree with any changes to the EM&MS code_list table. MWRA is responsible for maintaining the code list for the EM&MS.

The loading application for infaunal enumeration data will differ slightly from the chemistry applications. The users will not see a form populated with all the species names, instead they must choose the proper species code from a pull-down list (Figure 8). Selection of the proper code automatically enters the

Table 17. Parameters and Database Codes for Sediment Chemical / Physicochemical Analyses.

Parameter	Param_Code	Meth_Code	Unit_Code	Instr_Code
1-PHENYLNONANE (Surrogate)	MWRA85	BSOP5-157	PCTREC	GCMS
2,2',3,3',4,4',5,5',6-NONACHLOROBIPHENYL	40186-72-9	BSOP5-128DUAL	ng/g	GCECD
2,2',3,3',4,4',5,6-OCTACHLOROBIPHENYL	52663-78-2	BSOP5-128DUAL	ng/g	GCECD
2,2',3,3',4,4',5-HEPTACHLOROBIPHENYL	35065-30-6	BSOP5-128DUAL	ng/g	GCECD
2,2',3,3',4,4'-HEXACHLOROBIPHENYL	38380-07-3	BSOP5-128DUAL	ng/g	GCECD
2,2',3,4',5,5',6-HEPTACHLOROBIPHENYL	52663-68-0	BSOP5-128DUAL	ng/g	GCECD
2,2',3,4,4',5,5'-HEPTACHLOROBIPHENYL	35065-29-3	BSOP5-128DUAL	ng/g	GCECD
2,2',3,4,4',5'-HEXACHLOROBIPHENYL	35065-28-2	BSOP5-128DUAL	ng/g	GCECD
2,2',3,5'-TETRACHLOROBIPHENYL	41464-39-5	BSOP5-128DUAL	ng/g	GCECD
2,2',4,4',5,5'-HEXACHLOROBIPHENYL	35065-27-1	BSOP5-128DUAL	ng/g	GCECD
2,2',4,5,5'-PENTACHLOROBIPHENYL	37680-73-2	BSOP5-128DUAL	ng/g	GCECD
2,2',4,6,6'-PENTACHLOROBIPHENYL (Surrogate)	56558-16-8	BSOP5-128DUAL	PCTREC	GCECD
2,2',5,5'-TETRACHLOROBIPHENYL	35693-99-3	BSOP5-128DUAL	ng/g	GCECD
2,2',5-TRICHLOROBIPHENYL	37680-65-2	BSOP5-128DUAL	ng/g	GCECD
2,3,3',5,6-PENTACHLOROBIPHENYL (Surrogate)	74472-36-9	BSOP5-128DUAL	PCTREC	GCECD
2,3',4,4',5-PENTACHLOROBIPHENYL	31508-00-6	BSOP5-128DUAL	ng/g	GCECD
2,3',4,4'-TETRACHLOROBIPHENYL	32598-10-0	BSOP5-128DUAL	ng/g	GCECD
2,3,3',4,4'-PENTACHLOROBIPHENYL	32598-14-4	BSOP5-128DUAL	ng/g	GCECD
2',3,5-TRICHLOROBIPHENYL (Surrogate)	37680-68-5	BSOP5-128DUAL	PCTREC	GCECD
2,4'-DICHLOROBIPHENYL	34883-43-7	BSOP5-128DUAL	ng/g	GCECD
2,4,4'-TRICHLOROBIPHENYL	7012-37-5	BSOP5-128DUAL	ng/g	GCECD
3,3',4,4',5-PENTACHLOROBIPHENYL	57465-28-8	BSOP5-128DUAL	ng/g	GCECD
3,3',4,4'-TETRACHLOROBIPHENYL	32598-13-3	BSOP5-128DUAL	ng/g	GCECD
ACENAPHTHENE	83-32-9	BSOP5-157	ng/g	GCMS
4,4 DDD OLEFIN (DDMU)	1022-22-6	BSOP5-128DUAL	ng/g	GCECD
ACENAPHTHYLENE	208-96-8	BSOP5-157	ng/g	GCMS
ALDRIN	309-00-2	BSOP5-128DUAL	ng/g	GCECD
ALUMINUM	7429-90-5	KLM-XRF-01	PCTDRYWT	EDXRF
ANTHRACENE	120-12-7	BSOP5-157	ng/g	GCMS
BENZ(A)ANTHRACENE	56-55-3	BSOP5-157	ng/g	GCMS
BENZO(A)PYRENE	50-32-8	BSOP5-157	ng/g	GCMS
BENZO(B)FLUORANTHENE	205-99-2	BSOP5-157	ng/g	GCMS
BENZO(E)PYRENE	192-97-2	BSOP5-157	ng/g	GCMS
BENZO(G,H,I)PERYLENE	191-24-2	BSOP5-157	ng/g	GCMS
BENZO(K)FLUORANTHENE	207-08-9	BSOP5-157	ng/g	GCMS
BENZOTHIAZOLE	95-16-9	BSOP5-157	ng/g	GCMS
BIPHENYL	92-52-4	BSOP5-157	ng/g	GCMS
C1-CHRYSENES	MWRA70	BSOP5-157	ng/g	GCMS
C1-DIBENZOTHIOPHENES	MWRA68	BSOP5-157	ng/g	GCMS
C1-FLUORANTHENES/PYRENES	MWRA69	BSOP5-157	ng/g	GCMS
C1-FLUORENES	MWRA65	BSOP5-157	ng/g	GCMS
C1-NAPTHALENES	MWRA64	BSOP5-157	ng/g	GCMS
C1-PHENANTHRENES/ANTHRACENES	MWRA67	BSOP5-157	ng/g	GCMS
C2-CHRYSENES	MWRA4	BSOP5-157	ng/g	GCMS

Table 17. (continued)

Parameter	Param_Code	Meth_Code	Unit_Code	Instr_Code
C2-DIBENZOTHIOPHENES	MWRA5	BSOP5-157	ng/g	GCMS
C2-FLUORENES	MWRA6	BSOP5-157	ng/g	GCMS
C2-NAPTHALENES	MWRA7	BSOP5-157	ng/g	GCMS
C2-PHENANTHRENES/ANTHRACENES	MWRA57	BSOP5-157	ng/g	GCMS
C3-CHRYSENES	MWRA71	BSOP5-157	ng/g	GCMS
C3-DIBENZOTHIOPHENES	MWRA9	BSOP5-157	ng/g	GCMS
C3-FLUORENES	MWRA66	BSOP5-157	ng/g	GCMS
C3-NAPTHALENES	MWRA10	BSOP5-157	ng/g	GCMS
C3-PHENANTHRENES/ANTHRACENES	MWRA52	BSOP5-157	ng/g	GCMS
C4-CHRYSENES	MWRA72	BSOP5-157	ng/g	GCMS
C4-PHENANTHRENES/ANTHRACENES	MWRA54	BSOP5-157	ng/g	GCMS
CADMIUM	7440-43-9	MSL-I-029	ug/g	GFAA
CADMIUM	7440-43-9	MSL-I-029	ug/g	ICPMS
CHROMIUM	7440-47-3	KLM-XRF-01	ug/g	EDXRF
CHRYSENE	218-01-9	BSOP5-157	ng/g	GCMS
CHRYSENE-D12 (surrogate)	D12_218-01-9	BSOP5-157	PCTREC	GCMS
CIS-CHLORDANE	5103-71-9	BSOP5-128DUAL	ng/g	GCECD
Percent by weight of sediment clay fraction	CLAY	FOLK74	PCTDRYWT	SVSET
CLOSTRIDIUM PERFRINGENS	CPERF	EC182	#/GDW	MICR
COPPER	7440-50-8	KLM-XRF-01	ug/g	EDXRF
5(BETA)-CHOLESTAN-3(BETA)-OL (aka COPROSTANOL)	360-68-9	BSOP5-157	ng/g	GCMS
DECACHLOROBIPHENYL	2051-24-3	BSOP5-128DUAL	ng/g	GCECD
DIBENZO(A,H)ANTHRACENE	53-70-3	BSOP5-157	ng/g	GCMS
DIBENZOFURAN	132-64-9	BSOP5-157	ng/g	GCMS
DIBENZOTHIOPHENE	127330-66-9	BSOP5-157	ng/g	GCMS
DIELDRIN	60-57-1	BSOP5-128DUAL	ng/g	GCECD
ENDRIN	72-20-8	BSOP5-128DUAL	ng/g	GCECD
ENUMERATION OF *ENTEROCOCCUS*	ECOC	EPA 821/R-97/004	#/GDW	
ENUMERATION OF FECAL COLIFORM	FCOL	EPA 821/R-97/004	#/GDW	
FLUORANTHENE	206-44-0	BSOP5-157	ng/g	GCMS
FLUORENE	86-73-7	BSOP5-157	ng/g	GCMS
Percent by weight of sediment gravel fraction	GRAVEL	FOLK74	PCTDRYWT	SVSET
HEPTACHLOR	MWRA25	BSOP5-128DUAL	ng/g	GCECD
HEPTACHLOREPOXIDE	MWRA24	BSOP5-128DUAL	ng/g	GCECD
HEXACHLOROBENZENE	118-74-1	BSOP5-128DUAL	ng/g	GCECD
INDENO(1,2,3-C,D)PYRENE	193-39-5	BSOP5-157	ng/g	GCMS
IRON	7439-89-6	KLM-XRF-01	PCTDRYWT	EDXRF
LEAD	7439-92-1	KLM-XRF-01	ug/g	EDXRF
LINDANE	58-89-9	BSOP5-128DUAL	ng/g	GCECD
MERCURY	7439-97-6	MSL-I-016	ug/g	CVAA
MIREX	2385-85-5	BSOP5-128DUAL	ng/g	GCECD
NAPHTHALENE	91-20-3	BSOP5-157	ng/g	GCMS
NAPHTHALENE-D8 (surrogate)	D8_91-20-3	BSOP5-157	PCTREC	GCMS
NICKEL	7440-02-0	KLM-XRF-01	ug/g	EDXRF

Table 17. (continued)

Parameter	Param_Code	Meth_Code	Unit_Code	Instr_Code
O,P-DDD	MWRA33	BSOP5-128DUAL	ng/g	GCECD
O,P-DDE	MWRA34	BSOP5-128DUAL	ng/g	GCECD
O,P-DDT	789-02-6	BSOP5-128DUAL	ng/g	GCECD
P,P-DDD	72-54-8	BSOP5-128DUAL	ng/g	GCECD
P,P-DDE	75-55-9	BSOP5-128DUAL	ng/g	GCECD
P,P-DDT	50-29-3	BSOP5-128DUAL	ng/g	GCECD
Percent weight of the sample which is dry	PCTDRYWT	BSOP5-192	PCT	BAL
Percent weight of the sample which is dry	PCTDRYWT	MSL-C-003	PCT	BAL
PERYLENE	198-55-0	BSOP5-157	ng/g	GCMS
PHENANTHRENE	85-0108	BSOP5-157	ng/g	GCMS
PHENANTHRENE-D10 (Surrogate)	D10-85-0108	BSOP5-157	PCTREC	GCMS
PHENYL DECANES	MWRA39	BSOPS-157	ng/g	GCMS
PHENYL DODECANES	MWRA31	BSOPS-157	ng/g	GCMS
PHENYL TETRADECANES	MWRA30	BSOPS-157	ng/g	GCMS
PHENYL TRIDECANES	MWRA29	BSOPS-157	ng/g	GCMS
PHENYL UNDECANES	MWRA28	BSOPS-157	ng/g	GCMS
Phi Size -1 - 0	-1 - 0	FOLK74	PCT	SVSET
Phi Size 0 - 1	0 - 1	FOLK74	PCT	SVSET
Phi Size 1 - 2	1 - 2	FOLK74	PCT	SVSET
Phi Size 2 - 3	2 - 3	FOLK74	PCT	SVSET
Phi Size 3 - 4	3 - 4	FOLK74	PCT	SVSET
Phi Size <-1	<-1	FOLK74	PCT	SVSET
PYRENE	129-00-0	BSOP5-157	ng/g	GCMS
Redox potential discontinuity at the bottom of the bioturbation layer - where sediment is sulfidic	ARPD	WILL02	cm	RULER
r-squared of linear regression for estimation of parameter Aluminum	7429-90-5_R2	KLM-XRF-01		EDXRF
r-squared of linear regression for estimation of parameter Chromium	7440-47-3_R2	KLM-XRF-01		EDXRF
r-squared of linear regression for estimation of parameter Copper	7440-50-8_R2	KLM-XRF-01		EDXRF
r-squared of linear regression for estimation of parameter Iron	7439-89-6_R2	KLM-XRF-01		EDXRF
r-squared of linear regression for estimation of parameter Lead	7439-92-1_R2	KLM-XRF-01		EDXRF
r-squared of linear regression for estimation of parameter Nickel	7440-02-0_R2	KLM-XRF-01		EDXRF
r-squared of linear regression for estimation of parameter Zinc	7440-66-6_R2	KLM-XRF-01		EDXRF
Percent by weight of sediment sand fraction	SAND	FOLK74	PCTDRYWT	SVSET
Percent by weight of sediment silt fraction	SILT	FOLK74	PCTDRYWT	SVSET
SILVER	7440-22-4	MSL-I-022	ug/g	ICPMS
SILVER	7440-22-4	MSL-I-029	ug/g	GFAA
TOTAL ORGANIC CARBON	TOC	NS-T_TOC	PCTDRYWT	COULC
1-005TRANS_NONACHLOR	24143-69-9	BSOP5-128DUAL	ng/g	GCECD
ZINC	7440-66-6	KLM-XRF-01	ug/g	EDXRF

Table 18. Parameters and Database Codes for SPI Analysis.

Parameter	Param_code	Meth_ code	Unit_ code	Gear_code
Depth beneath sediment surface of anoxic voids, in cm	ANOXIC_VOID_DEPTH	KP93	cm	HMMSPCAM
Number of inactive water filled spaces in sediment resulting from abandonment of feeding voids	ANOXIC_VOID_NUM	KP93		HMMSPCAM
Average penetration	AVG_PEN	KP93	cm	HMMSPCAM
Average depth of redox potential discontinuity	AVG_RPD	KP93	cm	HMMSPCAM
Number of burrows	BURR_NO	KP93		HMMSPCAM
Type of burrow in sediments	BURR_TYPE	KP93		HMMSPCAM
Depth beneath sediment surface of sub-surface fauna, in cm	FAUNA_DEPTH	KP93	cm	HMMSPCAM
Depth beneath sediment surface of gas voids, in cm	GAS_VOID_DEPTH	KP93	cm	HMMSPCAM
Number of gas filled spaces in sediment resulting from methanogenesis	GAS_VOID_NUM	KP93		HMMSPCAM
Sediment grain size	GRN_SZ	KP93		HMMSPCAM
Presence of apparent low dissolved oxygen water	LOW_DO	KP93		HMMSPCAM
Median size class of amphipod tubes	MEDI_TUBE_SIZE	KP93		HMMSPCAM
Organism-Sediment Index	OSI	KP93		HMMSPCAM
Depth beneath sediment surface of oxic voids, in cm	OXIC_VOID_DEPTH	KP93	cm	HMMSPCAM
Num. of active, water-filled spaces in sed. resulting from sub-surface feeding activity of infauna	OXIC_VOID_NUM	KP93		HMMSPCAM
Maximum penetration depth of camera	PEN_MAX	KP93	cm	HMMSPCAM
Minimum penetration depth of camera	PEN_MIN	KP93	cm	HMMSPCAM
Maximum depth of redox potential discontinuity	RPD_MAX	KP93	cm	HMMSPCAM
Minimum depth of redox potential discontinuity	RPD_MIN	KP93	cm	HMMSPCAM
Sediment layer on rock substrate	SEDI_LAYER	KP93		HMMSPCAM
Surface relief across the 15 cm width of the face plate. Calculated as (PEN_MAX – PEN_MIN)	SR	KP93	cm	HMMSPCAM
Infaunal worms counted	SUB_FAUNA_WORMS	KP93		HMMSPCAM
Infaunal successional stage	SUCC_STG	KP93		HMMSPCAM
General description of processes causing surface roughness	SURF_ROUGH_TYPE	KP93		HMMSPCAM
Features on the sediment surface	SURFACE_FEATURES	KP93		HMMSPCAM
Amphipod tube	TUBE_AMPH	KP93		HMMSPCAM
Polychaete tube	TUBE_POLY	KP93		HMMSPCAM
Number of voids	VOID_NO	KP93		HMMSPCAM
Type of void in sediments	VOID_TYPE	KP93		HMMSPCAM

Table 19. Descriptions of other Database Codes.

Field Name	Code	Description
ANAL_LAB_ID	AMS	Applied Marine Sciences
ANAL_LAB_ID	BOS	Battelle Ocean Sciences
ANAL_LAB_ID	BSQM	Battelle Marine Sciences Laboratory
ANAL_LAB_ID	COV	Cove Corporation.
ANAL_LAB_ID	ENSR	ENSR Marine and Coastal Center
ANAL_LAB_ID	GOP	GeoPlan Associates
ANAL_LAB_ID	KLM	KLM Analytical - Ron Sanders
ANAL_LAB_ID	MTH	MTH ENVIR ASSOC
DEPTH_UNIT_CODE	m	Meters
DEPTH_UNIT_CODE	cm	Centimeters
GEAR_CODE	HMMSPCAM	HULCHER MODEL MINNIE SEDIMENT PROFILE CAMERA
GEAR_CODE	VV01	0.1-m2 Young-Modified Van Veen Grab
GEAR_CODE	VV04	0.04-m2 Young-modified Van Veen Grab
INSTR_CODE	BAL	Balance
INSTR_CODE	COULC	Coulometric carbon analyzer
INSTR_CODE	CVAA	COLD VAPOR ATOMIC ABSORPTION
INSTR_CODE	EDXRF	ENERGY DISPERSIVE XRAY FLUORESCENCE
INSTR_CODE	GCECD	Gas chromatograph electron capture detector
INSTR_CODE	GCMS	Gas chromatograph/mass spectrometer
INSTR_CODE	GFAA	Graphite Furnace Atomic Absorption
INSTR_CODE	ICPMS	Inductively coupled plasma mass spectrometer
INSTR_CODE	MICR	Microscope
INSTR_CODE	RULER	Measurement by ruler
INSTR_CODE	SVSET	Sieve/settling
MATRIX_CODE	SED	Sediment
METH_CODE	BSOP5-128DUAL	Battelle Ocean Sciences SOP No. 5-128, PCB/pesticides by GCECD, dual column
METH_CODE	BSOP5-157	Battelle Ocean Sciences SOP No. 5-157, PAH/LAB by GCMS
METH_CODE	BSOP5-192	Battelle Ocean Sciences SOP No. 5-192, Percent dry weight determination
METH_CODE	EC182	Emerson D., V. Cabelli. 1982. Extr of *C. perf.* spores. Appl. Environ. Microbiol. 44:1144-49
METH_CODE	ENUM	Enumeration
METH_CODE	EPA 821/004	EPA method 821/R-97/004 for membrane filtration and enumeration of indicator bacteria
METH_CODE	FOLK74	Folk (1974)
METH_CODE	KLM-XRF-01	KLM Procedure XRF-01, Energy Dispersive X-Ray Fluorescence Spectroscopy Using the BFP Approach with the Kevex 0810A System
METH_CODE	KP93	Kelly and Kropp 1993 Soft-bottom QA Plan
METH_CODE	MSL-C-003	Percent dry weight, conducted by a freeze-drying process
METH_CODE	MSL-I-016	Total mercury in tissues and sediments by CVAA
METH_CODE	MSL-I-022	Determination of elements in aqueous and digestate samples by ICP/MS
METH_CODE	MSL-I-029	Determination of metals in aqueous and digestate samples by graphite furnace atomic absorption (GFAA)
METH_CODE	NS-T_TOC	NATIONAL STATUS & TRENDS METHOD FOR TOC (GERG)
METH_CODE	WILL02	Williams *et al* 2002 Benthic QA Plan
SAMP_VOL_UNIT_CODE	cm3	Cubic centimeters
SAMP_VOL_UNIT_CODE	L	Liter
UNIT_CODE	#/GDW	Number of Colonies Per Gram Dry Weight
UNIT_CODE	0.04m2	Units associated with a VanVeen grab, gear_type of VV04
UNIT_CODE	cm	Centimeters
UNIT_CODE	ng/g	Nanograms per gram
UNIT_CODE	PCT	Percent
UNIT_CODE	PCTDRYWT	Percent dry weight
UNIT_CODE	PCTREC	Percent recovery
UNIT_CODE	ug/g	Micrograms per gram
VAL_QUAL	A	Value above maximum detection limit, *e.g.*, too numerous to count or beyond range of instrument
VAL_QUAL	As	Value above maximum detection limit and suspect/invalid, not fit for use
VAL_QUAL	B	Blank corrected, blank >= 5xMDL
VAL_QUAL	Br	Blank corrected, blank >= 5xMDL, value reported < detect_limit

Table 19. (continued)

Field Name	Code	Description
VAL_QUAL	D	Surrogate recovery < 50% or > 150%
VAL_QUAL	Ds	Surrogate recovery < 50% or > 150%, suspect/invalid, not fit for use
VAL_QUAL	E	Calibration level exceeded
VAL_QUAL	ELs	Calibration exceeded, concentration reported from dilution, suspect/invalid, not fit for use
VAL_QUAL	Es	Calibration exceeded, suspect/invalid, not fit for use
VAL_QUAL	F	Abundance recorded for a fraction or portion of the sample collected
VAL_QUAL	G	Co-eluting compound interferes with peak of interest
VAL_QUAL	Gs	Co-eluting compound, suspect/invalid, not fit for use
VAL_QUAL	H	Thick mat
VAL_QUAL	I	Interferant from standard
VAL_QUAL	L	Analytical concentration reported from dilution
VAL_QUAL	LE	Analytical concentration reported from dilution, calibration level exceeded
VAL_QUAL	LT	Analytical concentration reported from dilution, holding time exceeded
VAL_QUAL	Ls	Analytical concentration reported from dilution, suspect/invalid, not fit for use
VAL_QUAL	P	Present but uncountable, value given is NULL
VAL_QUAL	S	Not surrogate corrected
VAL_QUAL	T	Holding time exceeded
VAL_QUAL	a	Not detected - value reported as negative or null
VAL_QUAL	aG	Not detected, value is null, co-eluting compound
VAL_QUAL	aGs	Not detected, value is null, co-eluting compound, suspect/invalid, not fit for use
VAL_QUAL	aGx	Not detected, value is null, co-eluting compound, matrix interference
VAL_QUAL	aL	Below MDL; value reported as negative or null, analytical conc. reported from dilution
VAL_QUAL	aLT	Not detected, analytical conc. reported from dilution, holding time exceeded
VAL_QUAL	aLs	Not detected, analytical conc. reported from dilution, suspect/invalid, not fit for use
VAL_QUAL	aT	Not detected - value reported as negative or null, and holding time exceeded
VAL_QUAL	as	Not detected - value reported as negative or null, and not fit for use
VAL_QUAL	asT	Not detected - value reported as negative or null, not fit for use, and holding time exceeding
VAL_QUAL	ax	Not detected, value is null, matrix interference
VAL_QUAL	b	Not blank corrected, blank >= 5xMDL
VAL_QUAL	bs	Not blank corrected, blank >= 5xMDL, suspect/invalid, not fit for use
VAL_QUAL	e	Results not reported, value given is NULL. Explanation in COMMENTS field
VAL_QUAL	f	VALUE reported is below method detection limit
VAL_QUAL	fG	Reported value below mdl and co-eluting compound interferes with peak of interest
VAL_QUAL	fL	Value reported is between zero and MDL, analytical conc. reported from dilution
VAL_QUAL	fT	Reported value below MDL and holding time is exceeded
VAL_QUAL	fs	VALUE reported is below method detection limit, not fit for use
VAL_QUAL	fsT	Reported value is below MDL, suspect/invalid, not fit for use, and holding time is exceeded
VAL_QUAL	fx	Below method detect limit, matrix interference
VAL_QUAL	g	Recovery outside data objectives
VAL_QUAL	h	Below the standard curve 0
VAL_QUAL	j	Estimated value
VAL_QUAL	jBS	Estimated, Blank corrected, blank > mdl by factor of 5 or greater, not surrogate corrected
VAL_QUAL	jS	Estimated, not surrogate corrected
VAL_QUAL	jp	Estimated value and bottles mislabeled
VAL_QUAL	o	Value out of normal range judged fit for use by principal investigator
VAL_QUAL	p	Lab sample bottles mislabeled - caution data us
VAL_QUAL	q	Possibly suspect/invalid and not fit for use. Investigation pending.
VAL_QUAL	r	Precision does not meet data quality objectives
VAL_QUAL	s	Suspect/Invalid. Not fit for use.
VAL_QUAL	sT	Suspect/invalid, not fit for use and holding time is exceeded
VAL_QUAL	sv	Value is suspect/invalid and not fit for use, arithmetic mean of multiple results
VAL_QUAL	v	Arithmetic mean
VAL_QUAL	w	This datum should be used with caution, see comment field
VAL_QUAL	x	Matrix interference

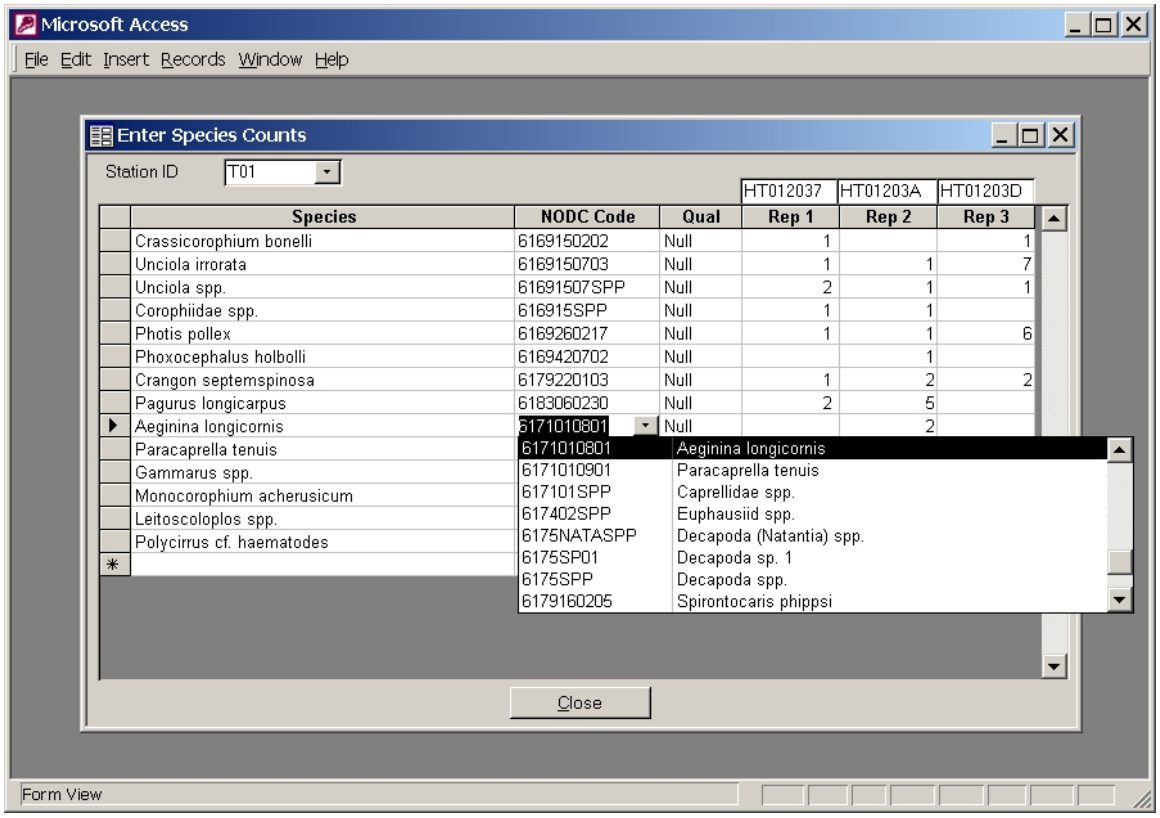

Figure 8. Example of the Data Loading Application for Infaunal Analyses.

correct species name in the species field. The codes in the list will be those from the EM&MS species code table. These codes are a combination of NODC and MWRA codes. If the users do not find the proper species code for an identified taxon on the pull-down list (thus indicating that the species has not been found previously on an MWRA survey), they will be able to add a new one. These new codes will be flagged on the exceptions report. Battelle will request a new code from MWRA upon receipt of the data. Populating the infaunal loading application will be coordinated between Cove Corporation and ENSR Marine & Coastal Center. Cove Corporation personnel will load their infaunal data first, perform their internal QC checks, and then send the populated application to ENSR. ENSR will then load their taxonomic data into the application, perform another QC check, and then return the database to Battelle.

Table 18 lists the database codes used for the sediment profile imaging data. The hard-bottom codes (LOC_DRUMLIN_CODE, PRIMARY_SUBS_CODE**,** SECONDARY_SUBS_CODE, and SED_DRAPE_CODE, and PARAM_CODE) are too numerous to list, as are the SPEC_CODEs found in the infaunal abundance data. These codes can be found in the Oracle table maintained by MWRA. The database tables CODE_LIST and SPECIES_CODES have been populated with most of the codes used for these data. Additional codes are added by the MWRA DBA when requested by Battelle data management.

15.3.4 Loading Analytical and Experimental Data into the Harbor and Outfall Studies Database

Data submissions from the laboratory will consist of final electronic spreadsheets or final loading applications as discussed above. The submissions will be logged in upon receipt and a copy of the login

will be maintained on file under the login id. Data will be loaded into a temporary table by striking a button on the application. A transfer script will copy the data into the proper table in Battelle's copy of the EM&MS. Data from the laboratories will receive a quality assurance review by Battelle after the data have been synthesized into a data report. Any issues will be corrected in the database and the script output will be supplied to MWRA with the export of the database. The MWRA check script will be run on the database prior to export. Any issues will be sent to the Battelle Data Manager via email. Any irresolvable issues in the database as a result of quality control checks (for example, stations more than specified distance from target) will also be submitted to MWRA with the data export. Processing of data and development of data reports are defined in MWRA SOP 005-01.

15.3.5 Data Report Quality Control Checks

Prior to data submission to MWRA, Battelle will perform a series of data report quality control checks. These include plots of various parameters against previously accepted data for sediment chemistry, tracers, infauna, and SPI. The benthic area senior scientists, Drs. Jim Blake and Nancy Maciolek will review the results of the checks prior to submission of the data report. Table 20 presents a list of QC checks that will be performed on benthic data.

15.3.6 Benthic Threshold Evaluation

One of the requirements of the discharge permit is to test the current environmental conditions against baseline conditions to detect any noticeable changes. These thresholds are defined in the Contingency Plan (MWRA 2001). The documentation for each threshold test is maintained by MWRA in a series of SOPs. The SOPs pertinent to the benthic task area are found in Appendix A. The threshold evaluation is performed as part of the data report.

15.3.7 Reporting Data to MWRA

The data contained in each hard copy data report will be submitted to MWRA as a database export; hard copy data reports will be prepared following Battelle SOP MWRA 005-01 Loading and Reporting Benthic Data. The supporting documentation files will be included with the data submission. Data deliverables will be combined only with permission from MWRA.

16.0 DATA VALIDATION

The data validation procedures for this project are defined in the HOM4 Project Management Plan (Battelle, 2002). As a part of data validation, each laboratory will ensure that:

- All data that are hand-entered (*i.e.*, typed) will be 100% validated by qualified personnel prior to use in calculations or entry into the database.
- All manual calculations will be performed by a second staff member to verify that calculations are accurate and appropriate.
- Calculations performed by software will be independently verified at a frequency sufficient to ensure that the formulas are correct, appropriate, and consistent, and that calculations are accurately reported. All modifications to data reduction algorithms will be verified prior to submission of data to the Authority.

Electronic submissions will be loaded to temporary files prior to incorporation into the database, and will be analyzed selectively using methods such as scatter plots, univariate and multivariate analyses, and range checks to identify suspect values. Routine system back-ups are performed daily.

Table 20. Data Report Quality Control Checks – Benthic Area

Parameter	Nearfield	Farfield	Harbor
Sediment chemistry/ grain size/ micro-biology	Plot the following, with new data in dark symbol, suspect data in a different color, and previously accepted data in different symbol (e.g. gray) TOC vs. % fines (x-axis) Total PAH vs. TOC (x-axis) Totals summed as in data report Total PCB vs. TOC (x-axis) Totals summed as in data report Hg vs. Al (x-axis) Ag vs. Al (x-axis) Clostridium vs. TOC		
Infauna	Plot % identified to species ("good" vs. total individuals) vs. time • for all species • for major taxonomic groups: Arthropoda, Mollusca, Oligochaeta, Polychaeta, all others • Harbor and Bay separately within a season (i.e., April Harbor compared to April Harbor over time)		
SPI	Range check each quantitative variable. Min, Max, Avg. by variable for event.		

Once data have been generated and compiled in the laboratory, Senior Scientists will review the data to identify and make professional judgments about any suspicious values. All suspect data will be reported, but flagged with a qualifier. These data may not be used in calculations or data summaries without the review and approval of the appropriate Senior Scientist. No data measurements will be eliminated from the reported data or database and data gaps will never be filled with other existing data. The loss of samples during shipment or analysis will be documented in the data reports to the Authority and noted in the database.

17.0 PERFORMANCE AND SYSTEM AUDITS

The Battelle QA Officer for the Harbor and Outfall Monitoring Project is Ms. Rosanna Buhl. She oversees the conduct of at least one systems audit to ensure that Tasks 17–20 are carried out in accordance with this CWQAPP. Ms. Buhl will coordinate this activity with Ms. Deborah McGrath, ENSR QA Officer. A systems audit will verify the implementation of the Project Management Plan (Battelle, 2002) and this CWQAPP for the work conducted in the Benthic monitoring.

Tabular data reported in deliverables, and associated raw data generated by Battelle will be audited under the direction of the Project QA Officer. Raw data will be reviewed for completeness and proper documentation. For electronically acquired data (*e.g.*, navigational data), Ms. Buhl will verify that

computer software used to process the data has been validated. Errors noted in data audits will be communicated to analysts and project management and corrected data will be verified.

Audits of the data collection procedures at subcontractor laboratories will be the responsibility of the subcontractor laboratories. Each subcontractor is fully responsible for the verification and validation of the data it submits. Data must be submitted in CWQAPP-prescribed formats; no other will be acceptable. During the time while work is in progress, the subcontractor QA Officer or his/her designee will conduct an inspection to evaluate the laboratory data-production process. All data must be reviewed by the subcontractor QA Officer prior to submission to the Battelle Database Manager and must be accompanied by a signed QA statement, a copy of which can be found in the Project Management Plan (Battelle, 2002) that describes the types of audits and reviews conducted, the results, any outstanding issues that could affect data quality, and a narrative of activities.

Performance audits, procedures used to determine quantitatively the accuracy of the total measurement system or its components, will be the responsibility of the subcontractor laboratory and may include SRMs, internal performance evaluation samples, and participation in external certification programs.

18.0 CORRECTIVE ACTION

All technical personnel share responsibility for identifying and resolving problems encountered in the routine performance of their duties. Ms. Ellen Baptiste Carpenter, Battelle's Project Manager, will be accountable to MWRA and to Battelle management for overall conduct of the Harbor and Outfall Monitoring Project, including the schedule, costs, and technical performance. She is responsible for identifying and resolving problems that (1) have not been addressed timely or successfully at a lower level, (2) influence multiple components of the project, or (3) require consultation with Battelle management or with MWRA. Dr. Carlton Hunt, Battelle's technical director, will identify and resolve problems that necessitate changes to this QAPP.

Issues that affect the schedule, cost, or performance of Tasks 17-20 will be reported to the Battelle Project Manager. She will be responsible for evaluating the overall impact of the problem on the project and for discussing corrective actions with the MWRA Project Manager.

Problems identified by the QA Officer will be reported and corrected as described in Section 17 and the Project Management Plan (Battelle, 2002).

19.0 REPORTS

Documents that will be generated under the Benthic (Sea-Floor) Monitoring tasks are:

- Survey plans;
- Survey reports;
- Data reports; and
- Synthesis reports.

19.1 Survey Plans

Survey plans will be prepared for each survey conducted. In the case of combined surveys, a single plan covering all aspects of the combined surveys will be submitted to MWRA. Each survey plan will follow the guidelines established by U.S. Environmental Protection Agency for use of the OSV *Anderson* and

will be submitted as a final unbound, double side copy on 3-hole punched paper at least one week prior to the start of the survey. Each survey plan will include the following information:

- General information
- Schedule of operations
- Background information
- Justifications and rationale
- Objectives
- Environmental management questions asked by the survey
- Specific location and coordinates of each station
- Survey/sampling methods
- Sample Handling and Custody
- Sequence of Tasks and Events
- Navigation and positioning control
- Vessel, equipment, and supplies
- QA/QC Procedures
- Documentation procedures
- Scientific party
- Reporting requirements
- Safety Procedures
- Documentation of any deviations from this CWQAPP

19.2 Survey Reports

Survey reports will describe the survey conducted and will include a table that contains all information specific to each survey (including, but not limited to, survey date, sampling times, Survey_ID, sample types, etc.). The table will be derived from the electronic file that is generated for loading the data into the MWRA database. In addition to the general survey information, any problems experienced and the corrective actions required will be noted. Any incidental observations of marine mammals will be included. Any deviations from this CWQAPP, not known at the time of survey plan preparation, will also be incorporated into the survey reports. The PMP (Battelle, 2002) describes the general requirements for survey reports in Section 5.9.1.

A survey report is expected to include about 4-5 pages of text, with accompanying station maps and sample table. A table listing stations occupied, station locations, samples collected, and station data for all samples will be included in the survey reports. A supplementary table will include descriptive field measurements, sediment texture, observed surface fauna, and apparent RPD depth that are not included in the database. Two unbound, double-sided copies of the draft survey report will be submitted to MWRA no later than four weeks after the completion of each survey. MWRA's comments will be due two weeks after receipt of the draft report. One unbound copy (double-sided on three-hole punched paper) of the final survey report, addressing MWRA's comments, will be due two weeks after receipt of the comments. If MWRA does not submit comments within the two-week period, the draft survey report will be considered final.

Within two business days of the completion of the Nearfield Benthic and Nearfield SPI surveys, a survey summary will be sent via e-mail to MWRA from the survey chief scientist. This e-mail will include a summary of the survey operational dates, weather conditions, summary of preliminary observations, deviations from survey scope, observations of marine mammals, and identify technical problems encountered and resolutions. In addition to highlighting anything noteworthy about the survey, the summary will report any monitoring thresholds that apparently have been exceeded, or conditions that may lead to a threshold being exceeded. In addition, the e-mail summary that follows each nearfield SPI survey will contain the results of the rapid review of the images (see Section 12.2.3 for the parameters included in the rapid review). Survey e-mail summaries will be reviewed by the Battelle technical director prior to submission.

19.3 Data Reports

Following each analytical subtask conducted under the Benthic (Sea-Floor) Monitoring program (except Task 20.1, which requires a Status Report), a data report will be prepared and delivered to MWRA. All data reports will be generated from the central MWRA database by Battelle. Each report will include a brief introduction, brief written summary, and some preliminary summary descriptive statistics (such as results of the QC checks). The data table will include the sample ID, collection date, the station and replicate numbers, and the analytical results. Some of the specific reports produced under Task 20 have additional individual requirements. The narrative accompanying sediment chemistry data reports (Tasks 19.1–19.5) will include a summary of all quality control data (procedural/method blank results on a concentration basis using representative weight of analytical batch; SRM PD results; MS percent recoveries; SIS recoveries; sample replicate R%Ds or RSDs). The infaunal data reports (Tasks 20.2–20.5) also will include the species code, the taxon name, the number of individuals counted for each taxon, a three-letter major taxon abbreviation, and, where possible, the family name. The Hard-bottom Survey data reports (Task 20.8) will be accompanied by copies of the videotapes and scanned photographic images taken during the survey.

The due dates for the various data reports are listed in Section 9.

19.4 Reference Collection Status Report

Once per year (June 2003–2006), a reference collection status report will be prepared after MWRA accepts all infaunal data reports from a year's sampling. The report, in letter format, will include:

- a hierarchical taxonomic list of all taxa comprising the collection, including the MWRA station ID from which the specimen came
- the current species code for all taxa from the EM&MS database,
- the staff with custody of parts of the collection, any new taxa identified in the previous year's samples, and
- any taxonomic changes to previously identified taxa and a justification for the change.

19.5 Synthesis Reports

Benthic synthesis reports will be prepared from data collected during the Benthic (Sea-floor) Monitoring program under three tasks. The Outfall (Task 33.5) and Harbor (Task 33.6) reports are annual reports and a single CSO (Task 33.7) report will be prepared using data collected in 2002. All data used in the synthesis reports will be accessed from the Battelle copy of the MWRA database. Descriptions of infaunal, sediment chemistry, and hard-bottom data analyses performed on data that has already been

entered into the database are described below. For SPI data, only descriptive statistics are performed on SPI data extracted from the database, in preparation of the synthesis reports.

19.5.1 Infaunal Data Analyses

Analysis of the faunal data from Boston Harbor will focus on (1) evaluating the current status of soft-bottom communities in Boston Harbor and (2) documenting the long-term trends in the recovery of the Harbor benthos following various pollution abatement programs.

The detailed analysis of the faunal data from the Outfall area will focus on (1) assessing the patterns of community structure in Massachusetts Bay, and (2) determining the nature of any changes in community structure through time and evaluating whether these changes could be attributed to discharges from the MWRA outfall. Nearfield data analyses will include farfield stations FF10, FF12, and FF13.

Analysis of the soft-bottom benthic data for both the Harbor and Outfall areas will be directed by Dr. James A. Blake. The analyses will be performed by Drs. Eugene Gallagher and Nancy J. Maciolek. A general analysis plan is presented below.

19.5.1.1 Preliminary Data Treatment

Prior to analysis, the senior scientists will scan the data to see if preliminary modifications are warranted. All such data modifications will be documented in the synthesis reports; any modifications involving permanent changes to the data (e.g. re-identification of a taxon) will be communicated to data management staff. Data will be inspected for any obvious faunal shifts or species changes between surveys or between the laboratories doing the identifications.

The INFAUNA_REF table in the EM&MS database provides a lookup table for information specific to benthic infaunal species. Within this table, the GOOD_BAD_CODE is used to determine how a species should be used in data and synthesis reports, as well as contingency plan threshold calculations. For example, some taxa, *e.g.*, epifaunal, encrusting, or non-benthic taxa, are classified as "worse" (GOOD_BAD = 'W') and are eliminated from all calculations. Other taxa are included in calculations of abundance but not diversity; such taxa are usually those infaunal organisms that cannot be identified to species level.

Only those individuals identified to species level (GOOD_BAD = 'G') will be included in all remaining calculations (*e.g.*, diversity, evenness, number of species, multivariate analyses). However, some taxa identified to a taxonomic level other than species (*e.g.*, genus) may be chosen to be included in the species-level calculations if they are unique in some way. If decisions are made to re-classify a taxon within the good/bad/worse framework, such modifications will be well documented, included in the synthesis report, and in the database script used to extract the data.

19.5.1.2 Diversity Analyses

Using MATLAB™ as an operating platform and programs written by Dr. Gallagher, several diversity indices will be calculated, including Shannon's H' (base $\log_2$). Shannon's H' will be calculated using base $\log_2$ because that provides results closest to Shannon's original intent. Pielou's (1966) J', which is the observed H' divided by H_{max}, is a measure of the evenness component of diversity and will also be calculated . Evenness values J' and V, associated with H' and B, respectively, will be calculated. The rarefaction (ES_n) method (Sanders, 1968) as modified by Hurlbert (1971) is more sensitive to rare species than is Shannon's index, and is another indication of diversity. Rarefaction curves will be generated for each replicate sample, with the number of points set at 25, from 1 to the maximal number of specimens in the sample.

Fisher *et al*., (1943) developed a diversity index, alpha, based on the assumption that the distribution of individuals among species follows a log-series distribution. May (1975) demonstrated that Sanders-Hurlbert rarefaction curves are often identical to log-series alpha curves. Dr. Gallagher has developed a plotting procedure, termed a non-dimensional diversity plot, to show the relationship between rarefaction curves and the expected log-series curve. Using programs written by Dr. Gallagher, Fisher's log-series alpha will be calculated to approximate a perfect log-series curve for each sample; this curve will then be compared with the one generated by the Hurlbert rarefaction method, and a non-dimensional diversity (NDD) curve produced for each sample. Gallagher suggests an NDD value of 0.75 or more (in either direction) as a benchmark to indicate severe departure from an undisturbed community (Gallagher, in prep.).

19.5.1.3 Cluster & Ordination

Cluster analysis programs are included in COMPAH96, originally written by Dr. Donald Boesch and now available from Dr. Gallagher (http://www.es.umb.edu/edgwebp.htm). Patterns in benthic communities will be analyzed by cluster analysis using CNESS (chord-normalized expected species shared), which was developed by Gallagher and is related to Grassle and Smith's (1976) NESS (normalized expected species shared). NESS was originally developed for analysis of deep-sea benthic community structure. CNESS and NESS include several indices that can be made more or less sensitive to rare species in the community and as such are more versatile than other similarity measures such as Bray-Curtis similarity, which is influenced by dominant species. Differences between CNESS and NESS are detailed in Trueblood *et al*. (1994). Both NESS and CNESS are calculated from the expected species shared (ESS) between two random draws of *m* individuals from two samples. The station and species cluster groups will be generated using unweighted pair group mean average sorting (UPGMA) and chord normalized expected species shared (CNESS) to express similarity.

Principal Components Analysis of Hypergeometric Probabilities (PCA-H) will also be applied to the benthic data for each study area. PCA-H is an ordination method for visualizing CNESS distances among samples (see Trueblood *et al*., 1994, for details). The PCA-H method produces a metric scaling of the samples in multi-dimensional space, as well as two types of plots based on Gabriel (1971). The Euclidean distance biplot provides a two-dimensional projection of the major sources of CNESS variation. The species that contribute to the CNESS variation can be determined using matrix methods adapted from Greenacre's correspondence analysis (Greenacre, 1984). These species are plotted as vectors in the Euclidean distance biplot. The second plot, the Gabriel covariance biplot, shows the association among species. Species that co-occur plot with species vectors with very acute angles. Species that have discordant distributions plot with angles approaching 180º.

For HOM4, a full community analysis will be developed using classification analysis to explore the data for evidence of impact of the outfall. Cluster and PCA-H analyses will be conducted on the current year's data and, in a limited manner, on the baseline data. We do not anticipate performing a full retrospective, multivariate synthesis until the last year of the program.

19.5.1.4 Other Analyses

Dr. Gallagher is currently testing new canonical techniques to evaluate the linkage between biological, physical, and chemical data. If the methods are sufficiently developed, they will be applied to the 2002 data in the 2003 report.

19.5.2 Statistical Analyses for Sediment Chemistry Data

Correlation analyses will be performed on grain size, TOC, microbiological, and contaminant data to examine the correlation between these parameters. In addition, sediment chemistry data will be evaluated

using Principal Component Analysis (PCA). PCA analysis will be performed by Ein*Sight (Version 4.0; Infometrix, Inc., Seattle, WA). PCA will be performed on sediment samples collected in August from the nearfield (all nearfield plus FF10, FF12 and FF13) and regional (all farfield plus NF12, NF17 and NF24) locations. The analytes may include Sand, Silt, Clay, TOC, *Clostridium*, total PAH, total PCB, total pesticides, total DDT, total chlordane, total LAB, Al, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Ag, and Zn. The reported values for these analytes will be log transformed and Z-score normalized prior to PCA (Reyment and Joreskog, 1996). Each new year of monitoring data (e.g., 2002) will be superimposed upon a PCA model constructed for the baseline data set (1992-2000). Sample data may be omitted if analytical or technical problems occur.

19.5.3 Hard-bottom Data Analyses

Analysis of the hard-bottom data will include comparisons of pre- and post discharge conditions. The parameters that will be compared will include: degree of sediment drape, percent cover of coralline algae, relative abundance of filamentous red algae and dulse, dominant taxa, and general community characteristics. To facilitate these comparisons, sediment drape categories will be converted to numerical codes as follows: clean to very light (0); light (1); moderately light (2); moderate (3); moderately heavy (4); and heavy (5). In addition, the five levels of percent cover (1-5%, 6-10%, 11-50%, 51-90%, >90%) of coralline algae and relative abundance categories (rare, few, common, abundant, very abundant) of filamentous red algae will be assigned corresponding abundance values (1, 2, 5, 15, 20).

Data from the still photographs will be normalized to account for differences in the number of still photographs collected at each station and data from the video will be normalized to account for differences in the amount of time spent on the bottom. The structure of the benthic communities inhabiting the hard-bottom stations will be examined using hierarchical classification analysis with the percent similarity coefficient and unweighted pair-group clustering.

19.5.4 Preparation of Synthesis Reports

Data collected under the Benthic (Sea-Floor) Monitoring program will be used to prepare synthesis reports (under Tasks 33.5-33.7). Each report will be reviewed by the Battelle Technical Director and other scientists who are knowledgeable in the subject matter of the report. This will ensure that interpretations made in the reports are scientifically and technically valid and meet the MWRA's needs. To ensure readability and accuracy in use of scientific language, symbols, and format, each report will be reviewed by a technical editor and ENSR's QA Officer. Thirty days prior to the due date of the draft report, an outline will be delivered to MWRA. The due dates for the draft and final annual synthesis reports are listed in Section 9. The specific approach to each report is presented below.

Task 33.5 — Outfall Benthic Report. There have been nine baseline (pre-operational) surveys in the nearfield and farfield of Massachusetts Bay (1992–2000); the first post-discharge survey was conducted in August 2001. This extensive database provides a guide to understanding year-to-year patterns in benthic infauna, status of pre-discharge contaminant levels, and some aspects of sediment transport patterns across the nearfield that affect and alter benthic patterns. From these data, a series of key indicators (threshold parameters) have been established, with caution and warning levels to indicate where changes from baseline might be occurring due to the new outfall (MWRA 2001). At present, transport models suggest that outfall impacts on the benthos will be minimal outside of 2 km; contaminants are predicted to take decades to reach toxic levels, if at all. Therefore, the post-discharge monitoring plays a different role from that of baseline monitoring in that selected measures are watched to detect deviations from baseline and determine whether predictions are accurate.

This annual report will evaluate the status of benthic communities and associated sediment and chemical parameters in the nearfield and farfield of Massachusetts Bay will focus on factors that might suggest changes in the benthic environment. The analyses will include the following:

- Evaluation of the most recent year's data collected at the nearfield and farfield stations in context of the baseline understanding.
- Evaluation of data against all relevant monitoring thresholds, devoting special attention to understanding the background of any thresholds that appear to have been exceeded.
- Assessment of soft-bottom nearfield and farfield communities from the standpoint of the current year's status and comparison with baseline.
- Analysis of long-term trends in soft-bottom benthic community structure, species diversity, species richness, and species composition at individual stations and between sedimentary environments. Station pooling in the nearfield (i.e. nearfield analysis includes stations FF10, FF12, and FF13) will be used to evaluate long-term trends in species richness, diversity, and abundant species.
- Evaluation of the current and long-term hard-bottom results in terms of effects of the Outfall discharge on attached organisms and sedimentation rates.
- Mapping and interpretation of the distribution and possible changes in the sedimentary environment near the Outfall following analysis of sediment profile images (RPD, etc.) and sediment parameters collected with traditional methods (TOC, grain size, and *Clostridium* spores). Climatological events such as winter storms and hurricanes will be taken into account when interpreting any changes in the sedimentary environment.
- Determination of trends in the distribution and potential accumulation of organic and metal contaminants in nearfield and farfield sediments.
- Integration of results, where possible, with data collected as part of the Water Column monitoring, and Benthic Flux results with special emphasis on seasonal trends in near bottom chlorophyll and dissolved oxygen and sediment respiration as possible integrators of benthic processes.

The technical content of each report will be presented in chapters that describe the results from the year's studies and provide comparisons to previous MWRA studies. These chapters will be based on the physico-chemical analyses, traditional infaunal analysis, SPI analysis, and hard-bottom analysis. Each chapter will discuss the data with respect to thresholds, and incorporate, as appropriate, results from other studies. Conclusions will also be presented.

Task 33.6 — Harbor Benthic Report. The analysis and interpretation of the Harbor benthic data is similar to that proposed for the Outfall Benthic Report (Task 33.5), except that there is a different objective: instead of tracking potential impacts from a new outfall, the Harbor benthic analysis will focus on changes that might be due to improvement in the benthic environment, including the relocation of the outfall to Massachusetts Bay. The Harbor benthic synthesis will be prepared annually.

Specific objectives for the Harbor Benthic report are as follows:

- Evaluate the most recent year's data in Boston Harbor (April and August);
- Compare current results with the historical data by performing retrospective analysis of the April and August databases using multivariate techniques with the objective of evaluating long-term trends in benthic community parameters and faunal assemblages;
- Continue to document the distribution of *Ampelisca* spp. in Boston Harbor as a possible measure of improving benthic conditions;
- Map benthic processes in Boston Harbor as indicated in Sediment Profile Images and other results;
- Compare sediment chemistry results with long-term data to evaluate improvements in the Harbor as they relate to contaminants, and
- Integrate results with other on-going studies such as Benthic Flux (Tasks 16; 33.4), the Harbor water quality data being collected separately by MWRA, CSO sediment study (Tasks 17.3; 33.7), and the Outfall Monitoring results (Tasks 18; 33.5).

Task 33.7 — CSO Report. For HOM4, one CSO synthesis report, using data obtained in 2002, will prepared. The primary objectives of this report are to examine the potential effects of CSO discharges on sediments in receiving water areas and to assess temporal differences in sediment contaminant concentrations between the 2002 study and the previous CSO studies performed for MWRA in 1990, 1994, and 1998 (Durell *et al*., 1991; Durell 1995; Lefkovitz 2000). Data from CSO effluent studies conducted by MWRA will be used to compare CSO contaminant loadings with results from the sedimentary analyses. Sediment microbiological data will be compared with MWRA beach and CSO receiving water quality data.

In general, the analytical approach will involve graphical presentation and statistical comparisons of the data similar to those used by Lefkovitz 2000. An attempt will be made to describe the relative contributions of particular pollutant sources to sediment contamination, although this can be difficult. In Boston Harbor, CSO impacts are confounded by inputs from treatment plants, upstream river sources, boats, stormwater runoff, and atmospheric deposition. When appropriate, microbial indicators will be used to help discriminate among these sources at sites near to and far from CSOs. An attempt will be made to relate toxic contaminants to pollutant sources.

20.0 REFERENCES

Battelle. 2002. Project management plan for Massachusetts Water Resources Authority Harbor and Outfall Monitoring Project (HOM) IV. 29 pp. + Attachments.

Bisson, J.W. and V.J. Cabelli. 1979. Membrane filter enumeration method for *Clostridium perfringens*. *Applied Environmental Microbiology*. 37:55-66.

Blake, J. and B. Hilbig. 1995. Combined work/quality assurance project plan for benthic monitoring: 1995-1997. MWRA Environmental Quality Technical Report Series No. MS-34. Massachusetts Water Resources Authority, Boston, MA. 68 pp.

Blake, J. A., N. J. Maciolek, D. C. Rhoads, E. D. Gallagher, and I. P. Williams. 1998. Boston Harbor soft-bottom benthic monitoring program: 1996 and 1997 results. Boston: Massachusetts Water Resources Authority. Report ENQUAD 98-15. 182 pp.

Brown, B. and J. Neff. 1993. Bioavailability of sediment-bound contaminants to marine organisms. Report to the National Oceanic and Atmospheric Administration, National Ocean Pollution Program Office, Rockville, MD.

Coats, D. A. 1995. 1994. Annual soft-bottom benthic monitoring: Massachusetts Bay outfall studies. MWRA Environmental Quality Technical Report Series No. 95-20. Massachusetts Water Resources Authority, Boston, MA. 184 pp.

Day, M. E., L. C. Schaffner, and R. J. Diaz. 1988. Long Island Sound sediment quality survey and analyses. Tetra Tech, Report to the National Oceanic and Atmospheric Administration, NOS, OMA, Rockville, MD. 113 pp.

Diaz, R. J. and R. Rosenberg. 1995. Marine benthic hypoxia: a review of its ecological effects and the behavioral responses of benthic macrofauna. *Oceanography and Marine Biology, An Annual Review* 33:245-303.

Diaz, R. J. and L. C. Schaffner. 1988. Comparison of sediment landscapes in the Chesapeake Bay as seen by surface and profile imaging. Pp. 222-240. In: M. P. Lynch and E. C. Krome, eds. *Understanding the Estuary; Advances in Chesapeake Bay Research*. Chesapeake Research Consortium Publication 129 CBP/TRS 24/88.

Durell, G. S. 1995. Concentrations of contaminants in Dorchester Bay and Boston Harbor sediments collected in the vicinity of CSO discharges and comparison to 1990 concentrations. MWRA Environmental Quality Technical Report Series No. 95-14. Massachusetts Water Resources Authority, Boston, MA. 128 pp.

Durell, G., L. Ginsburg, and D. Shea. 1991. CSO Effects on contamination of Boston Harbor sediment. MWRA Environmental Quality Technical Report Series No. 91-8. Massachusetts Water Resources Authority, Boston, MA, 146 pp.

Emerson, D. J. and V. J. Cabelli. 1982. Extraction of *Clostridium perfringens* spores from bottom sediment samples. *Applied Environmental Microbiology* 44:1144-1149.

EPA (U.S. Environmental Protection Agency). 1988. Boston Harbor Wastewater Conveyance System, Final Supplemental Environmental Impact Statement, U.S. Environmental Protection Agency, Region I. Boston, MA.

EPA (U.S. Environmental Protection Agency). 1992. Monitoring Guidance for the National Estuary Program, Final. EPA Office of Water; Office of Wetlands, Oceans, and Watersheds, Ocean and Coastal Protection Division. EPA-503/8-91-002, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1997. Method 1640: Determination of Trace Elements in Water by Preconcentration and Inductively Coupled Plasma - Mass Spectrometry. EPA Office of Water and Office of Science and Technology. Washington, DC.

EPA (U.S. Environmental Protection Agency). 1996. Method 1638: Determination of Trace Elements in Ambient Waters by Inductively Coupled Plasma - Mass Spectrometry. EPA Office of Water and Office of Science and Technology. Washington, DC.

EPA (U.S. Environmental Protection Agency). 1991a. Methods for the Determination of Metals in Environmental Samples. EPA-600/4-91-010. Method 245.5: Determination of Mercury in Sediments by Cold Vapor Atomic Absorption Spectrometry. Environmental Protection Agency, Environmental Services Division, Monitoring Management Branch. Cincinnati, Ohio.

EPA (U.S. Environmental Protection Agency). 1991b. Methods for the Determination of Metals in Environmental Samples. EPA-600/4-91-010. Method 200.9: Determination of Trace Elements by Stabilized Temperature Graphite Furnace Atomic Absorption Spectrometry. Environmental Protection Agency, Environmental Services Division, Monitoring Management Branch. Cincinnati, Ohio.

EPA (U.S. Environmental Protection Agency). 2000. Improved Enumeration Methods for the EPA 821/R-97/0004. U.S. Environmental Protection Agency, Office of Science and Technology, Washington DC.

Fenchel, T. 1969. The ecology of marine microbenthos. IV. Structure and function of the benthic ecosystem, its chemical and physical factors and microfauna communities with special reference to the ciliated Protozoa. *Ophelia* 6:1-182.

Fisher, R.A., A.S. Corbet, and C.B. Williams. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology* 12:42-58.

Folk, R. L. 1974. *Petrology of Sedimentary Rocks.* Hemphill Publishing Company, Austin, TX. 184 pp.

Gabriel, K. R. 1971. The biplot graphic display of matrices with application to principal component analysis. *Biometrika* 58: 453-467.

Grassle, J. F. and W. Smith. 1976. A similarity measure sensitive to the contribution of rare species and its use in investigation of variation in marine benthic communities. *Oecologia 25*:13-25.

Greenacre, M. J. 1984. Theory and applications of correspondance analysis. Academic Press, London and Orlando, 364 pp.

Hilbig, B. 1997. Draft nearfield hard-bottom survey report: June 1997 survey. Massachusetts Water Resources Authority, Boston, MA.

Hilbig, B., J. A. Blake, E. Butler, B. Hecker, D. C. Rhoads, G. Wallace, and I. P. Williams. 1996. Massachusetts Bay outfall monitoring program: 1995 benthic biology and sedimentology. MWRA Environmental Quality Technical Report Series No. 96-5. Massachusetts Water Resources Authority, Boston, MA. 230 pp.

Hurlbert, S. M. 1971. The non-concept of species diversity: a critique and alternative parameters. *Ecology 52*:577-586.

Kelly, J. R. and R. K. Kropp. 1992. Benthic recovery following sludge abatement in Boston Harbor: Part I Baseline survey 1991 and Part II Spring survey 1992. Technical report to MWRA Environmental Quality Department, November 1991. Massachusetts Water Resources Authority, Boston, MA. 45 + 29 pp.

Kiley, K. 1989. Report on the use of personal computer based image analysis software and hardware for dredge material disposal monitoring. Virginia Institute of Marine Sciences, College of William and Mary, Gloucester Pt., VA. Report. to U. S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. 32 pp.

Kropp, R. K. and J. D. Boyle. 2001. Combined work/quality assurance plan for benthic monitoring: 1998-2001 revision 1. MWRA Environmental Quality Department Miscellaneous Report Number ms-050. Massachusetts Water Resources Authority, Boston, MA 124 pp.

Kropp, R. K. and R. J. Diaz. 1995. Infaunal community changes in Boston Harbor, 1991-1994. MWRA Environmental Quality Technical Report Series No. 95-21. Massachusetts Water Resources Authority, Boston, MA. 94 pp.

Kropp, R. and C. Peven. 1993. Combined work/quality assurance plan for soft-bottom benthic monitoring: 1993-1994. MWRA Environmental Quality Technical Report Series No. ms-12. Massachusetts Water Resources Authority, Boston, MA. 64 pp.

Kropp RK, Diaz RJ, Hecker B, Dahlen DT, Keay KE, Gallagher ED, Boyle JD. 1999. 1998 outfall benthic monitoring report. Boston: Massachusetts Water Resources Authority. Report ENQUAD 1999-15. 172 p.

Kropp RK, Diaz RJ, Dahlen DT, Shull DH, Boyle JD, Gallagher ED. 2000a. 1998 Harbor Benthic Monitoring Report. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2000-06. 83 p.

Kropp RK, Diaz RJ, Hecker B, Dahlen DT, Boyle JD, Keay KE, Hunt CD. 2000b. 1999 Outfall Benthic Monitoring Report. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2000-15. 230 p.

Kropp RK, Diaz RJ, Dahlen DT, Boyle JD, Hunt CD. 2001. 1999 harbor benthic monitoring report. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2001-03. 94 p.

Kropp RK and JD Boyle. 2001. Combined work/quality assurance plan for benthic monitoring: 1998-2000 revision 1. MWRA Environmental Quality Department Miscellaneous Report Number ms-050. Massachusetts Water Resources Authority, Boston, MA. 124 pages.

Lefkovitz L, Dahlen D.T., Hunt C.D., Ellis B.D. 2000. 1998 CSO sediment study synthesis report. Boston: Massachusetts Water Resources Authority. Report ENQUAD 1999-12. 68 pp.

Libby, P. S., C. Gagnon, C. Albro, E. Baptiste Carpenter, P. Dragos, C. A. Oviatt, A. Keller, and J. Turner. (2002) Combined work/quality assurance plan for baseline water quality monitoring: 2002-2005. Boston: Massachusetts Water Resources Authority. Report ENQUAD ms-XX. 132 pp.

May, R. M. 1975. Patterns of species abundance and diversity. Pp. 81-120 *in* M. L. Cody and J. M. Diamond, *eds*., Belknap Press, Cambridge.

Messer, J.W., and A.P. Dufour. 1988. A rapid, specific membrane filtration method procedure for enumeration of enterococci in recreational water. Applied and Environmental Microbiology Feb. 1998:678-680.

MWRA (in Prep) Procedures for calculation and testing of Contingency Plan thresholds. Boston: Massachusetts Water Resources Authority. Report ENQUAD ms-064.

MWRA 1997a. Massachusetts Water Resources Authority Contingency Plan. Boston: Massachusetts Water Resources Authority. Report ENQUAD ms-069. 41 p.

MWRA. 1997b. Massachusetts Water Resources Authority effluent outfall monitoring plan: Phase II post-discharge monitoring. Boston: Massachusetts Water Resources Authority. Report ENQUAD ms-044. 61 p.

MWRA. 2001. Massachusetts Water Resources Authority Contingency Plan Revision 1. Boston: Massachusetts Water Resources Authority. Report ENQUAD ms-071. 47 p.

NOAA. 1993. Comprehensive descriptions of trace organic analytical methods. Sampling and Analytical Methods of the National Status and Trends Program, National Benthic Surveillance and Mussel Watch Project, 1984 - 1992 (Volume IV). NOAA Technical Memorandum NOS/ORCA/CMBAD 71. 182 pp.

NRC. 1990. Managing troubled waters: The role of marine environmental monitoring. National Research Council (NRC). National Academy Press, Washington DC. 125 pp.

Odum, E. P. 1969. The strategy of ecosystem development. *Science* 164:262-270.

Parmenter, C. M. and M. H. Bothner. 1993. The distribution of *Clostridium perfringens*, a sewage indicator, in sediments of coastal Massachusetts. US Geological Survey Open File Report 93-8.

Pearson, T. H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology, An Annual Review* 16:229-311.

Peven, C. S. and A. D. Uhler. 1993. Analytical procedures for trace and major element analysis. In: Sampling and Analytical methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch Project. Volume III. NOAA Technical Memorandum NOS ORCA 71. National Oceanic and Atmospheric Administration, Silver Spring, MD.

Pielou, E. C. 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal of theoretical Biology 10*:370-383.

Reineck, E. and I. B. Singh. 1975. *Depositional Sedimentary Environments*. Springer-Verlag, New York.

Reyment, R. and K. Joreskog, 1996. Applied Factor Analysis in the Natural Sciences. Cambridge University Press, NY, 371 pp.

Rhoads, D. C. and J. D. Germano. 1986. Interpreting long-term changes in benthic community structure: a new protocol. *Hydrobiologia* 142:291-308.

Sanders, H. L. 1968. Marine benthic diversity: a comparative study. *American Naturalist* 102:243-282.

Saad, D. L. 1992. Simplified Method for Extraction of *Clostridium perfringens* spores and Indicator Bacteria from Marine Sediments. In: *Seasonal Disinfection with Respect to Marine Waters*. Ph.D. Dissertation, University of Rhode Island, Kingston, RI.

Salomons, W., N. M. de Rooij, H. Derdijk, and J. Bril. 1987. Sediments as a source for contaminants. *Hydrobiologia* 149:13-30.

Shea, D. 1993. Combined work/quality assurance plan for detailed effluent characterization: 1993-1994. Amended 3/24/94 by D. West and P. Doering. MWRA Environmental Quality Department Miscellaneous Report No. ms-13. Massachusetts Water Resources Authority, Boston, MA. 48 pp.

Shea, D. 1994. Quality assurance project plan for inventories and concentrations of organic contaminants in sediments of Massachusetts and Cape Cod Bays. Report to Massachusetts Bays Program, Boston, MA.

Trueblood, D. D., E. D. Gallagher, and D. M. Gould. 1994. Three stages of seasonal succession on the Savin Hill Cove mudflat, Boston Harbor. *Limnology and Oceanography 39*:1440-1454.

Viles, C. and R. J. Diaz. 1991. Bencore, an image analysis system for measuring sediment profile camera slides. Virginia Institute of Marine Science, Gloucester Pt. VA. 13 pp.

Willie, S. 1997. NOAA/11: Eleventh Round Intercomparison for Trace Metals in Marine Sediments and Biological Tissues. Final Report National Research Council of Canada. 51 pp.

APPENDICES

Appendix A: Benthic Threshold SOPs

Appendix B: Data Forms

Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129
(617) 242-6000
http://www.mwra.state.ma.us