Combined work/quality assurance project plan (QAPP)

for

Benthic Monitoring 2008–2009

Massachusetts Water Resources Authority
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COMBINED WORK/QUALITY ASSURANCE PROJECT PLAN (QAPP)

for

Benthic Monitoring: 2008–2009

Tasks 1-10
MWRA Harbor and Outfall Monitoring Project
Contract No. S453B

Submitted to

Massachusetts Water Resources Authority
Environmental Quality Department
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A. PROJECT MANAGEMENT

VERSION 0

A1. TITLE AND APPROVALS

COMBINED WORK/QUALITY ASSURANCE PROJECT PLAN
(QAPP)
for

BENTHIC MONITORING 2008–2009

MWRA Harbor and Outfall Monitoring Project
Contract No. S453B

Prepared by
ENSR Marine and Coastal Sciences
Woods Hole, MA

July 2008
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Appendix E: Diaz and Daughters SPI Parameters

A3. DISTRIBUTION LIST

Copies of this QAPP, and any subsequent revisions, will be distributed by ENSR after approvals have been obtained. The following personnel will either receive a hard copy of the QAPP, or a notice that a PDF is available on the MWRA website.

Name	Date Sent
Andrea Rex, MWRA	
Kenneth E. Keay, MWRA	
Yong Lao, MWRA	
Wendy Leo, MWRA	
James A. Blake, ENSR	
Debra Simmons, ENSR	
Stacy Doner, ENSR	
Pamela A. Neubert, ENSR	
Nancy J. Maciolek, ENSR	
IP Williams, ENSR	
Paula Winchell, ENSR	
Ellen Baptiste Carpenter, Battelle	
Deirdre Dahlen, Battelle	
Greg Lescarbeau, Battelle	
Robert Diaz, Diaz & Daughters	
Barbara Hecker, Hecker Environmental	
Nancy Mountford, Cove Corporation	
R. Eugene Ruff, Ruff Systematics	
Woollcott Smith, Independent Consultant	
Russ Winchell, Ocean’s Taxonomic Services	

A4. PROJECT AND TASK ORGANIZATION

The Benthic Monitoring tasks will be accomplished through the coordinated efforts of personnel from ENSR, Battelle, Diaz and Daughters, Hecker Environmental, and several independent consultants. In addition, the MWRA's Department of Laboratory Services (DLS) will analyze sediment samples collected during this project for chemical parameters.

MWRA

The following MWRA managers will be informed of matters pertaining to work described in this QAPP.

- Dr. Andrea Rex, Director of the MWRA Environmental Quality Department (ENQUAD).
- Mr. Ken Keay, MWRA Harbor and Outfall Monitoring Program (HOM) Project Manager. Mr. Keay has primary administrative and budgetary oversight of the program.
- Ms. Wendy Leo, MWRA Environmental Monitoring and Management System (EM&MS) Database Manager.
- Dr. Yong Lao, MWRA DLS. Dr. Lao will be responsible for all sediment chemistry laboratory analyses.

ENSR

- Dr. James Blake, ENSR Program Manager, is responsible for the overall performance of this project and for ensuring that products and services that meet MWRA's expectations are delivered in a timely and cost-effective manner. He is responsible for ensuring that data collection and interpretation are scientifically defensible and for responding to technical challenges as they arise.
- Mr. Donald Galya, ENSR Principal-in-Charge, will be responsible for providing overall direction and coordination of the project, ensuring that project goals are achieved, and providing adequate resources to the project manager and management team.
- Ms. Debra Simmons, ENSR Project Quality Assurance (QA) Officer, is responsible for reviewing the QAPP, survey and data reports, and the harbor and outfall synthesis reports. She will also review QA Statements submitted by subcontractors for quality, completeness, and adherence to the QAPP.
- Ms. Kathleen Harvey, ENSR's Health & Safety Officer, will oversee the health and safety procedures for the project.
- Dr. Pamela Neubert is ENSR's Deputy Program Manager for the HOM6 contract and Task Leader for the Project Surveys. She will also support Dr. Hecker in the analysis of images collected on the hard-bottom survey.
- Ms. Stacy Doner is the ENSR Task Manager for the laboratory analyses and the resultant databases and will support the Benthic Infaunal task.
- Ms. Isabelle Williams will support the Benthic Infaunal task.
- Dr. Nancy J. Maciolek is task manager and editor in charge of the harbor and outfall synthesis reports and will develop the Benthic Monitoring QAPP under the guidance of Ms. Simmons. She will also support the laboratory analyses for the Benthic Infaunal task.

Battelle

- Mr. Gregory Lescarbeau is the database specialist who will oversee the data loading to MWRA.
- Dr. Carlton Hunt and Ms. Deirdre Dahlen will be responsible for the chemistry chapter of the harbor and outfall synthesis reports. Battelle has overall responsibility for review and synthesis of sediment chemistry analytical results.
- Navigational support for all benthic field programs is being provided by Battelle. Mr. Matt Fitzpatrick is the Battelle Field Manager responsible for navigation as well as vessel support for the soft-bottom (Tasks 5.1, 5.3, 6.1, and 6.2) and sediment profile imaging (Tasks 5.2 and 6.3) field programs.

Cove Corporation

- Ms. Nancy Mountford and Mr. Tim Morris will support the Benthic Infauna task by managing the sorting of the soft-bottom benthic samples and providing identifications of the organisms found in a subset of the samples.

CR Environmental, Inc.

- Mr. John H. Ryther, Jr. will provide vessel support and equipment logistics for the hard-bottom survey (Task 6.4).

Diaz and Daughters

- Dr. Robert Diaz is the Principal Investigator for Sediment Profile Imagery (SPI)

Hecker Environmental

- Dr. Barbara Hecker is Principal Investigator for hard-bottom community analysis.

Ocean's Taxonomic Services

- Mr. Russell Winchell will support the Benthic Infauna task by providing identifications of oligochaete annelids found in the soft-bottom benthic samples.

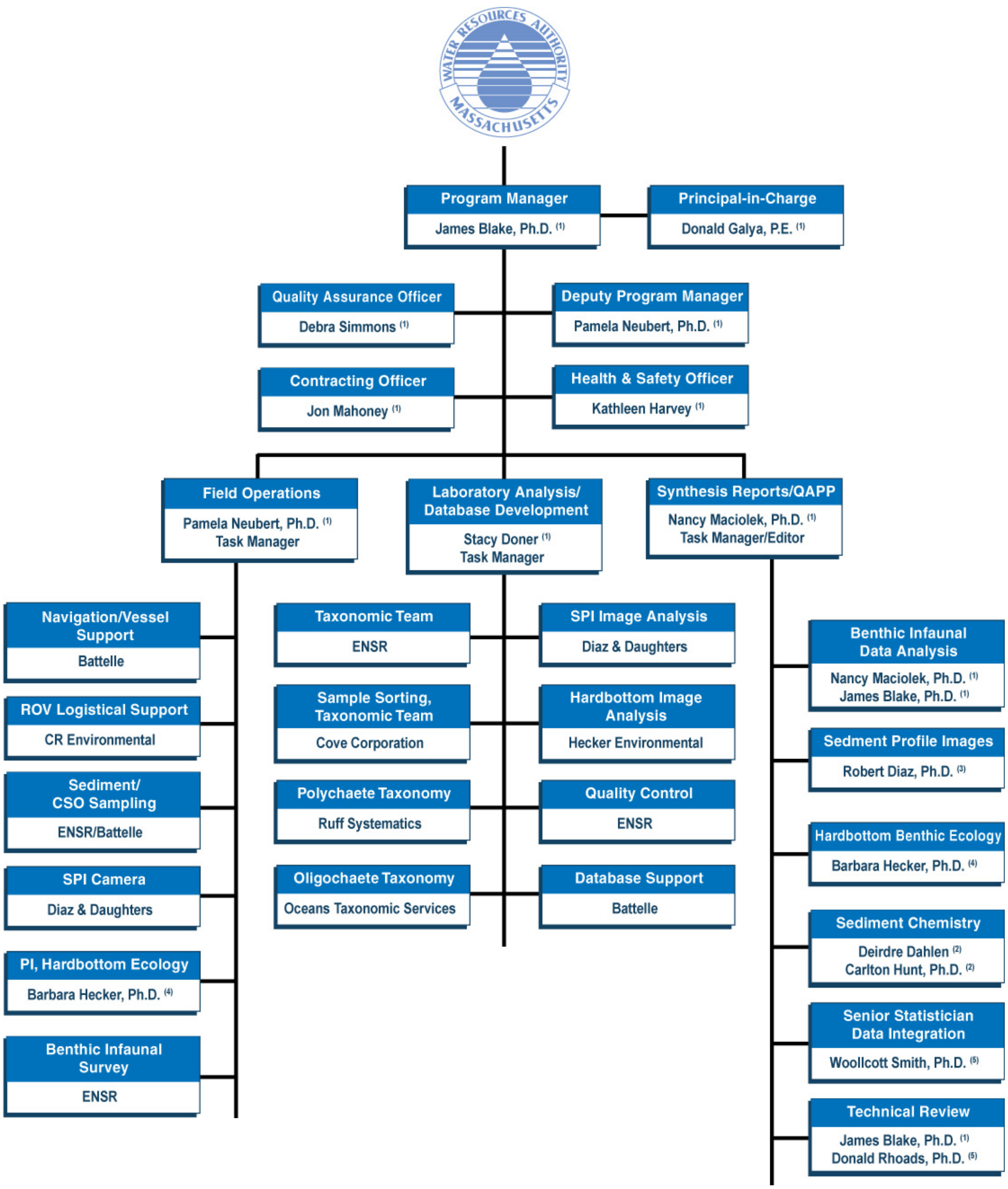
Ruff Systematics

- Mr. R. Eugene Ruff will support the Benthic Infauna task by providing identifications of a subset of the polychaete annelids found in the soft-bottom benthic samples.

Independent Consultants

- Dr. Woollcott Smith will serve as senior statistician for all aspects of the benthic monitoring program.
- Dr. Donald Rhoads will provide a technical review of the (SPI image analysis) portions of the harbor and outfall synthesis reports.

Figure 1 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. Addresses, telephone and fax numbers, and Internet addresses, as well as specific project roles and responsibilities for project participants, are summarized in Table 1.



Firm Affiliation:
(1) ENSR
(2) Battelle
(3) Diaz & Daughters
(4) Hecker Environmental
(5) Independent Consultant

Figure 1. Benthic monitoring task organization.

Table 1. Personnel Responsibilities and Contact Information for Benthic Monitoring Program.

Name/ Affiliation	Address	Project Area Assignment	Contact Information
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Mr. Ken Keay		Project Manager; Benthic Monitoring Project Area Manager	Ph: 617-788-4747 Fx: 617-788-4888 kenneth.keay[at]mwra.state.ma.us
Ms. Wendy Leo		EM&MS Database Manager	Ph: 617-788-4748 Fx: 617-788-4888 wendy.leo[at]mwra.state.ma.us
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Dr. Yong Lao	Department of Laboratory Services MWRA 190 Tafts Avenue Winthrop, MA 02152	DLS Project Manager Primary point of contact concerning sediment chemistry analyses	Ph: (617) 660-7800 Fx: (617) 660-7960 yong.lao[at]mwra.state.ma.us
ENSR Corporation			
Dr. James A. Blake	ENSR Marine and Coastal Center 89 Water St. Woods Hole, MA 02543	Program Manager – Benthic Monitoring; Polychaete Taxonomy – Consultant; Harbor and Outfall Benthic Infaunal Analyses Results; **(Tasks 1, 2, 5, 6, 7, 8, and 10)**	Ph: (508) 457-7900 Fx: (508) 457-7595 jblake[at]ensr.aecom.com
Dr. Pamela A. Neubert		Deputy Program Manager –Benthic Monitoring; Task Manager –Field Operations; Co-chief Scientist –Field Surveys Hard-bottom Image Analysis – Support; **(Tasks 1, 2, 5, 6, 7, and 8)**	Ph: (508) 457-7900 Fx: (508) 457-7595 pneubert[at]ensr.aecom.com
Dr. Nancy J. Maciolek		QAPP Development Task Leader – Infaunal Benthic Data Analysis and Synthesis Reports; Task Manager/Editor – Benthic Data Analysis and Synthesis Reports Polychaete Taxonomy – Consultant **(Tasks 1, 3, 7, 8, and 9)**	Ph: (508) 457-7900 (ENSR) Ph: (781)585-5822 (direct) Fax: (508) 457-7595 njmaciolek[at]gmail.com
Ms. Stacy Doner		Task Manager – Infaunal Benthic Data; QA Documentation and Transmission; QAPP Development Support; Co-chief Scientist – Field Surveys Task Leader – Benthic Faunal Analysis; Reference Collection **(Tasks 1, 3, 4, 5, 6, and 7)**	Ph: (508) 457-7900 Fx: (508) 457-7595 sdoner[at]ensr.aecom.com
Ms. Isabelle P. Williams		Benthic Taxonomic Analysis, Crustaceans, Molluscs, Misc. Fauna (Task 7)	Ph: (508) 457-7900 Ph: (508 548-6450 (direct) Fx: (508) 457-7595 iwilliams[at]ensr.aecom.com
Ms. Debra Simmons	ENSR Corporation 2 Technology Park Drive Westford, MA 01886	Quality Assurance Officer; **(Tasks 1, 3 and 4)**	Ph: (978) 589-3358 Fx: (978) 589-3035 dlsimmons[at]ensr.aecom.com

Table 1, continued.

Name/ Affiliation	Address	Project Area Assignment	Contact Information
Battelle			
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Mr. Matt Fitzpatrick		Battelle Field Manager; **(Tasks 5 and 6)**	Ph: (781) 952-5329 Fx: (781) 934-2124 fitzpatrickm[at]battelle.org
Other Subcontractors			
Dr. Barbara Hecker	Hecker Environmental 26 Mullen Way Falmouth, MA, 02540	Hard-bottom: Data analysis; QA; Documentation and Transmission ; Surveys and Reports; Hard-bottom Image Analysis; Results **(Tasks 1, 4, 6, 7, and 10)**	Ph: (508) 457-4672 bhhecker[at]earthlink.net
Dr. Robert J. Diaz	Diaz & Daughters 6198 Driftwood Lane Ware Neck, VA, 23178	Sediment Profile Imaging: Sample analysis; QA, data Documentation and Transmission; Surveys and Reports; Sediment Profile Image Analysis; Results **(Tasks 1, 4, 5, 6, 7, and 10)**	Ph: (804) 815-2252 Fx: (804) 684-7399 bdiaz[at]visi.net or diaz[at]vims.edu
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Ms. Nancy K. Mountford Mr. A. Timothy Morris	Cove Corporation 10200 Breeden Road Lusby, MD, 20657	Benthic Taxonomic Analysis Molluscs, Polychaetes (NKM); Crustaceans, Polychaetes, Misc. (ATM); Lab QA (ATM) **(Task 7)**	Ph: (410) 326-4577 Fx: (410) 326-4767 covelab[at]chesapeake.net
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Independent Consultants			
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A5. PROBLEM DEFINITION AND BACKGROUND

A5.1 Historical Background

Boston Harbor has a long history of anthropogenic impacts including the damming of rivers, filling of salt marshes and shallow embayments, and the direct discharge of sewage waste products, all of which have had profound impacts on the composition of the biological communities in the harbor. Prior to the 1950s, raw sewage was discharged into Boston Harbor primarily from three locations: Moon Island, Nut Island, and Deer Island. In 1952, the Nut Island treatment plant became operational and began treating sewage from the southern part of Boston's metropolitan area. The Deer Island treatment plant was completed in 1968, thus providing treatment for sewage from the northern part of the area. Moon Island was relegated to emergency status at that time and little used thereafter. The effluent was discharged continuously from both plants, averaging a total of 360 million gallons per day (MGD). Storm events caused up to 3.8 billion gallons per year (BGY) of additional material to be occasionally discharged to the harbor through the system of combined sewer overflows (CSOs) (Rex *et al.* 2002).

Sludge, after separation from the effluent, was digested anaerobically prior to discharge. Digested sludge from Nut Island was discharged through an outfall near Long Island on the southeastern side of President Roads. Sludge from Deer Island was discharged on the northern side of President Roads. Sludge discharges were timed to coincide with the outgoing tide, under the assumption that the tide would carry the discharges out of the harbor and away offshore. Unfortunately, studies showed that the material from Nut Island often was trapped near the tip of Long Island and carried back into the harbor on incoming tides (McDowell *et al*. 1991). In 1972, the Federal Clean Water Act (CWA) mandated secondary treatment for all sewage discharges to coastal waters, but an amendment allowed communities to apply for waivers from this requirement. The metropolitan Boston area's waiver application was denied by the US Environmental Protection Agency (EPA), partly on the basis of the observed degradation of the benthic communities in Boston Harbor. In 1985, in response to both the EPA mandate to institute secondary treatment and a Federal Court order to improve the condition of Boston Harbor, the Massachusetts Water Resources Authority (MWRA) was created. The MWRA instituted a multifaceted approach to upgrading the sewage treatment system, including an upgrade in the treatment facility itself and construction of a new outfall pipe to carry the treated effluent to a diffuser system in Massachusetts Bay located 15 km offshore in deep water.

Since 1985, the MWRA has been responsible for the development and maintenance of greater Boston's municipal wastewater system. In 1989, discharge of more than 10,000 gallons per day of floatable pollutants comprising grease, oil, and plastics from the Deer Island and Nut Island treatment plants was ended. Sludge discharge ceased in December 1991. In 1995, a new primary treatment plant at Deer Island was completed, increasing the system's overall capacity and the effectiveness of the treatment. In August 1997, the first phase of secondary treatment was completed, increasing the level of solids removal to 80%. For the first time, the MWRA's discharge met the requirements of the CWA (Rex *et al.* 2002).

In October 1998, the old Nut Island plant was officially decommissioned. By 2000, the average effluent solids loading to the harbor had decreased to less than 35 tons per day (TPD). Secondary treatment was achieved in phases, with the final phase completed in 2000 and becoming fully operational in 2001. In September 2000, the effluent from Deer Island was diverted to a new outfall approximately 15 km offshore, in 32 m water depth in Massachusetts Bay.

Ongoing MWRA pollution abatement projects for Boston Harbor involve reducing the number and discharge volumes from Combined Sewer Overflows (CSOs). In 1988, 88 CSOs discharged a total of about 3.3 billion gallons per year (BGY). By 1998, 23 CSOs had been closed, and pumping improvements reduced discharges to about 1 BGY, of which about 58% was screened and disinfected. At the end of 2004, 63 CSOs remained in Boston Harbor and its tributaries (Coughlin 2005). By 2015, ongoing projects will reduce the number of CSO outfalls to fewer than 50, with an estimated discharge of 0.5BGY, of which 95% will be treated by screening and disinfection (MWRA 2007).

All of these improvements—the improved effluent treatment, the complete cessation of sludge discharge to the harbor in 1991, and the transfer of wastewater discharge offshore—were implemented to improve the water quality in Boston Harbor and to increase effluent dilution with minimal impact on the environment of Massachusetts and Cape Cod Bays. Taylor (2005, 2006) summarized the major patterns in freshwater flows and loadings of total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and particulate organic carbon (POC) to Boston Harbor between 1995 and 2005 and showed that the changes in wastewater discharge from 1991 to 2005 resulted in an 80–95% decrease in loadings to the harbor. Annual average loadings of TSS and POC showed a progressive decrease, starting in 1991/1992 and proceeding through 2001, after which the average loadings remained low and similar between years. For TN and TP, loadings showed some decrease with the end of sludge discharge, but remained elevated through 1998, when Nut Island flows were discharged closer to the mouth of the harbor, resulting in decreased inputs to the harbor. TN and TP showed additional, larger decreases with the transfer of the effluent discharge offshore in 2000.

A5.2 Regulatory Overview

The offshore outfall is regulated under a permit issued to MWRA by the United States Environmental Protection Agency (USEPA) and Massachusetts Department of Environmental Protection (DEP), under the National Pollutant Discharge Elimination System (NPDES). The permit stipulates that MWRA must monitor the outfall effluent and the ambient receiving waters to test for compliance with NPDES permit requirements; specifically, whether the impact of the discharge on the environment is within the bounds predicted by the Supplemental Environmental Impact Study (SEIS) (EPA 1988), and whether any changes within the system exceed any of the Contingency Plan thresholds, including those for sediment redox depth, toxic contaminant concentrations, community structure, or abundance of opportunistic species (MWRA 2001).

The Contingency Plan (MWRA 2001), which was developed pursuant to a Memorandum of Agreement among the National Marine Fisheries Service, USEPA, and MWRA, is an attachment to MWRA's discharge permit. Warning-level thresholds listed in the plan are based on effluent limits, observations from baseline monitoring, national water quality criteria, state standards, and, in some cases, best professional judgment. The Contingency Plan also details the process of how the MWRA would respond to any exceedances of the threshold values. Threshold values for benthic monitoring were originally based on averages calculated for the period 1992 through 2000, *i.e*., from the beginning of the monitoring program through September 2000, when diversion of highly treated effluent to the new outfall was initiated. Beginning in 2004, a subset of the original suite of stations was sampled, with some stations scheduled to be sampled every year and others to be sampled every other year (Williams *et al.* 2005). Consequently, the benthic community thresholds were recalculated to reflect the stations actually sampled in alternate years (Appendix A).

A5.3 Scientific Perspective

Most pollutants are particle reactive; therefore, the sediments become the final sinks for these pollutants and represent the part of the ecosystem where disruption by toxic or enrichment effects is expected. Surficial sediments are critical to many ecosystem functions with energy flows (organic carbon, living biomass, secondary production) and nutrients (nitrogen, phosphorus) regulated by processes at the sediment-water interface. Thus, characterization of the benthic environment from physical and biological points of view has been a key part of the MWRA's long-term sediment monitoring within Boston Harbor and Massachusetts Bay. In Boston Harbor, the focus is on tracking the potential recovery of the benthic communities after pollution abatement (Maciolek *et al*. 2008).

Plans to relocate the outfall raised concerns about potential effects of the discharge on the offshore benthic (bottom) environment. These concerns, which were focused on three issues (eutrophication and related low levels of dissolved oxygen, accumulation of toxic contaminants in depositional areas, and smothering of animals by particulate matter), are addressed by the benthic monitoring component of MWRA's Harbor and Outfall Monitoring (HOM) program. The studies included in the monitoring plan (MWRA 1991, 1997a, 2004) are more extensive than necessary to calculate the Contingency Plan threshold values or to meet the NPDES permit requirements (MWRA 2004).

The outfall benthic monitoring program was designed to address a series of questions (MWRA 2001) regarding sediment contamination and tracers, and the benthic communities:

- *What is the level of sewage contamination and its spatial distribution in Massachusetts and Cape Cod Bays sediments before discharge through the new outfall?*
- *Has the level of sewage contamination or its spatial distribution in Massachusetts and Cape Cod Bays sediments changed after discharge through the new outfall?*
- *Have the concentrations of contaminants in sediments changed?*
- *Have the sediments become more anoxic; that is, has the thickness of the sediment oxic layer decreased?*
- *Has the soft-bottom community changed?*
- *Are any benthic community changes correlated with changes in levels of toxic contaminants (or sewage tracers) in sediments?*
- *Has the hard-bottom community changed?*

Extensive information collected over a nine-year baseline period and a seven-year post-diversion period has allowed a more complete understanding of the bay system and has provided data to address these monitoring questions. Annual monitoring of the benthic environment at both nearfield and farfield locations has indicated only modest impacts at stations closest to the discharge, and no evidence of outfall-related changes in the farfield (Maciolek *et al.* 2007). The only change that appears to have been directly related to the operation of the outfall was a localized increase in the abundance of the sewage tracer *Clostridium perfringens* at stations located within 2 km of the discharge, and this increase was reversed in 2006. Other changes, such as levels of anthropogenic contaminants, deepening of the apparent color-RPD layer, and changes in the numbers of certain benthic species, appear to be related to processes such as storm-induced shifts in sediment composition or the natural fluctuations of biological populations. Some changes seen at hard-bottom reference stations may be related to physical disturbances caused by increased anchoring activities in the farfield.

A5.3.1 *Objectives and Scope*

The objectives of the benthic monitoring program are to (1) verify compliance with discharge permits, (2) improve MWRA's ability to predict the environmental impact of relocating the outfall to Massachusetts Bay, (3) measure the actual impact on the bay, and (4) measure the recovery of the harbor.

The principal objective of the harbor studies is the 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. Some infaunal community changes, such as increased species richness, are consistent with those expected with habitat improvements (Maciolek *et al*. 2007). 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 the 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 potential 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 distant from the diffuser.

Additional objectives are to provide data that will be used to

- Evaluate responses 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 ecosystem
- Correlate changes in benthic community parameters to changes in sediment concentrations of organic matter, sewage tracers, and potentially toxic chemical contaminants.

These objectives are addressed by four major tasks as defined in the MWRA Benthic Monitoring Agreement II (see tasks 5-7 and11 below). Tasks 5 and 6 focus on sampling activities that will take place in Boston Harbor, Massachusetts Bay, and Cape Cod Bay in 2008 and 2009. Task 7 includes the analysis of the collected faunal samples and benthic images. The purpose of Task 11 is to produce interpretations and syntheses of the faunal, chemical, and sedimentary data collected during each year.

Harbor Benthic Surveys (Task 5) include traditional grab sampling to collect sediment samples for characterization of the physical, chemical (TOC), and biological status of surficial sediments at nine stations throughout Boston Harbor and an extensive reconnaissance survey based on sediment profile images (SPI).

Outfall Benthic Surveys (Task 6) include nearfield and farfield soft-bottom surveys using traditional grab sampling methods, SPI sampling in the nearfield to provide a rapid evaluation of those sedimentary habitats, and a nearfield benthic remotely operated vehicle (ROV) survey to provide semi-quantitative data about hard-bottom community responses in the vicinity of the outfall. Summer outfall benthic data will be evaluated by MWRA for possible exceedance of monitoring thresholds.

Analysis of Benthic Fauna (Task 7) includes the determination of the benthic soft- and hard-bottom community structure. Benthic fauna recovered from sediment grab samples collected under Tasks 5 and 6 will be identified and counted. Results will be 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. A reference collection of all soft-bottom taxa (identified and unidentified specimens) will be stored, maintained, and compiled throughout the project.

Synthesis Reports (Task 11) include the preparation of two (harbor and outfall) synthesis reports in which data developed under Tasks 5–7 will be examined. These synthesis reports will include data on sedimentary characteristics and contaminants provided by MWRA's Department of Laboratory Services (DLS). The synthesis reports will evaluate the current status of benthic communities in the nearfield and farfield of Massachusetts and Cape Cod Bays and Boston Harbor. In 2009, data developed under Tasks 5–7 will be presented in summary form rather than in a detailed synthesis report. The summary will be based on presentations made at the annual multidisciplinary technical workshop hosted by MWRA. In 2010, a full synthesis report will be prepared for each study area (harbor and outfall).

A6. PROJECT/TASK DESCRIPTION

A6.1 Boston Harbor Studies

Boston Harbor surveys provide benthic samples and other data that can document long-term improvement of sediment quality and recovery of benthic communities following the cessation of sludge and effluent discharge into the harbor. Information from an extensive reconnaissance (SPI) survey supplements traditional infaunal data to provide a broad-scale picture of harbor benthic conditions. Harbor surveys also provide the opportunity to take samples necessary for monitoring sediment contamination near CSO discharges, however, CSO stations will not be sampled in 2008 or 2009.

During the harbor surveys (Task 5.1), conducted in August of each year, soft-sediment grab samples will be collected from nine locations (Table 2, Figure 2). Eight stations (T01–T08) were selected early in this monitoring program after consideration of historic sampling sites and harbor circulation patterns (Kelly and Kropp 1992). A ninth station, CSO station C019, was added in 2004. Following faunal identification and enumeration (Task 7.2), data from these nine stations will be analyzed for benthic infaunal community parameters (Task 11.2). Sediment samples from these same stations will be analyzed for selected physical sediment parameters and sewage tracers by MWRA's DLS.

To provide greater geographic coverage for the study of benthic community recovery, a harbor reconnaissance survey (Task 5.2) will be conducted during August of each year. Sediment profile images (SPI) will be obtained at 61 reconnaissance stations in 2008 and 2009 (Table 2, Figure 2).

Details of field collection, sample handling, and laboratory methods to be used in the harbor benthic studies are given in Sections B-2, B-3, and B-4, respectively.

Table 2. Target Locations for Harbor Traditional and Reconnaissance Stations

Station	Latitude	Longitude	Depth (m)
Traditional Stations			
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	4.0
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
C019	42°21.55′N	71°02.72′W	9.3
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	6.7
R07	42°20.85′N	70°58.53′W	5.6
R08	42°20.66′N	70°59.50′W	3.5
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	7.0
R15	42°18.92′N	71°01.15′W	4.4
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	7.0

Table 2. (continued)

Station	Latitude	Longitude	Depth (m)
R27	42°16.83′N	70°54.98′W	4.8
R28	42°16.90′N	70°54.52′W	8.4
R29	42°17.38′N	70°55.25′W	11.0
R30	42°17.43′N	70°54.25′W	3.8
R31	42°18.05′N	70°55.03′W	10.0
R32	42°17.68′N	70°53.82′W	5.0
R33	42°17.65′N	70°59.67′W	5.0
R34	42°17.33′N	71°00.42′W	4.0
R35	42°17.05′N	70°59.28′W	4.8
R36	42°16.53′N	70°59.20′W	5.0
R37	42°17.93′N	70°59.08′W	6.0
R38	42°17.08′N	70°57.83′W	7.0
R39	42°17.73′N	70°58.22′W	8.0
R40	42°19.73′N	71°01.45′W	4.3
R41	42°18.67′N	71°01.50′W	5.5
R42	42°19.18′N	71°01.50′W	3.9
R43	42°18.40′N	71°00.13′W	4.5
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	3.8
R52	42°15.71′N	70°56.09′W	3.6
R53	42°16.15′N	70°56.27′W	6.0

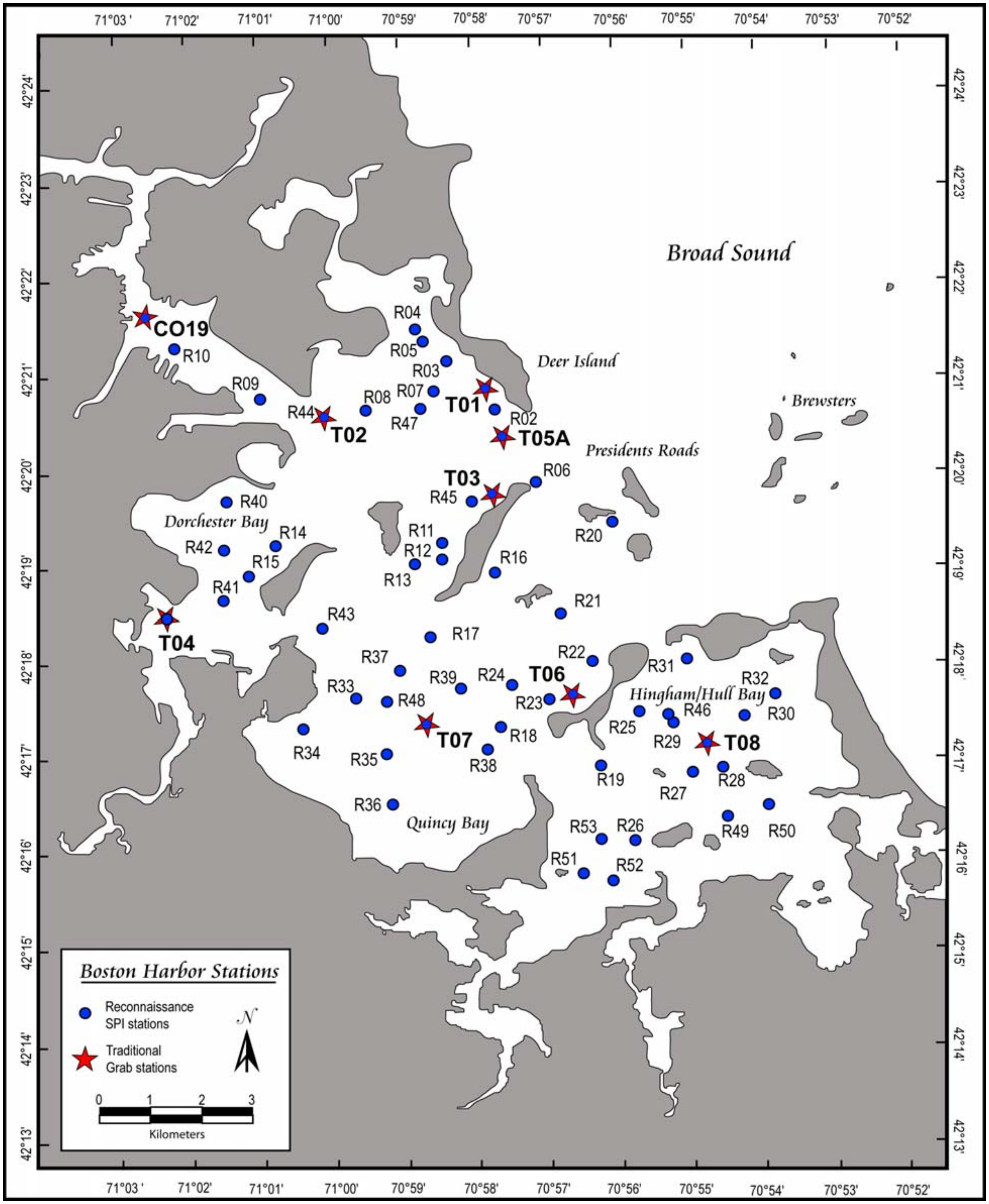

Figure 2. Locations of Boston Harbor grab and reconnaissance stations.

A6.2 Outfall Studies

The studies conducted in the vicinity of the offshore outfall provide quantitative measurements of benthic community structure and patterns of contaminant concentrations in the sediments of Massachusetts and Cape Cod Bays. Baseline data were collected yearly in August from 1992 to 2000. 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. Studies conducted under this part of the program will provide the data required for a quantitative assessment (Task 11.1) of the effects of discharged effluent on benthic infaunal and epifaunal communities and sediment chemistry (samples to be analyzed by MWRA's DLS). The objectives of the monitoring program in the post-diversion 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, 2001; Appendix A).

A6.2.1 *Technical Overview*

The nearfield benthic surveys, conducted in August of each year (Task 6.1), are designed to provide spatial coverage and local detail of faunal communities inhabiting depositional environments within about 8 km of the diffuser. In 2004, the 23 nearfield stations were divided into two subsets, each group to be sampled every other year. Two core stations, Stations NF12 and NF17, are sampled every year (Tables 3 and 4). Samples for sediment chemistry and benthic infauna will be collected at all 23 nearfield stations during the period of this contract (Table 3; Figure 3), but a different subset of stations will be sampled each year.

Farfield benthic surveys, also conducted in August each year (Task 6.2), contribute reference and early-warning data on soft-bottom habitats in Massachusetts and Cape Cod Bays. Stations FF04 and FF05 are within the Stellwagen Bank National Marine Sanctuary. In 2004, the eight farfield stations were divided into two subsets of four stations each, which are sampled every other year (Tables 3 and 4, Figure 4).

Nearfield sediment profile image surveys (Task 6.3), conducted in August each year at all 23 nearfield stations (Table 3, Figure 4), 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. Because sediment profile imagery (digital since 2002) allows a faster evaluation of the benthos to be made than can be accomplished through traditional faunal analyses, these surveys allow a rapid comparison of benthic conditions to the Contingency Plan threshold (Appendix A) for depth of sediment redox potential discontinuity (RPD). 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-bottom surveys (Task 6.4) will take place in June each year. Videotape footage and either 35-mm slides or digital still images will be taken at 23 waypoints/stations along six transects and five solitary waypoints, one of which is Diffuser #44 (Table 5, Figure 5). Twenty minutes of video and 36 still photographs of the bottom will be acquired at each station.

Details of field collection, sample handling, and laboratory methods to be used in the outfall benthic studies are given in Sections B-2, B-3, and B-4, respectively.

Table 3. Target Locations for Outfall Survey Stations.

Station	Latitude	Longitude	Depth (m)
Nearfield Stations			
FF10 [1]	42°24.84′N	70°52.72′W	28.7
FF12 [2]	42°23.40′N	70°53.98′W	23.5
FF13 [1]	42°19.19′N	70°49.38′W	20.7
NF02 [2]	42°20.31′N	70°49.69′W	26
NF04 [2]	42°24.93′N	70°48.39′W	34
NF05 [1]	42°25.62′N	70°50.03′W	36
NF07 [1]	42°24.60′N	70°48.89′W	32
NF08 [1]	42°24.00′N	70°51.81′W	28
NF09 [1]	42°23.99′N	70°50.69′W	29
NF10 [2]	42°23.57′N	70°50.29′W	32.9
NF12 [1,2]	42°23.40′N	70°49.83′W	34.9
NF13 [2]	42°23.40′N	70°49.35′W	33.8
NF14 [2]	42°23.20′N	70°49.36′W	34.1
NF15 [2]	42°22.93′N	70°49.67′W	32.7
NF16 [1]	42°22.70′N	70°50.26′W	31.1
NF17 [1,2]	42°22.88′N	70°48.89′W	30.6
NF18 [1]	42°23.80′N	70°49.31′W	33.3
NF19 [1]	42°22.30′N	70°48.30′W	33.2
NF20 [2]	42°22.69′N	70°50.69′W	28.9
NF21 [2]	42°24.16′N	70°50.19′W	30
NF22 [1]	42°20.87′N	70°48.90′W	30
NF23 [1]	42°23.86′N	70°48.10′W	36
NF24 [2]	42°22.83′N	70°48.10′W	37
Farfield Stations			
FF01A [2]	42°33.84′N	70°40.55′W	35
FF04 [1]	42°17.30′N	70°25.50′W	90
FF05 [1]	42°08.00′N	70°25.35′W	65
FF06 [2]	41°53.90′N	70°24.20′W	35
FF07 [1]	41°57.50′N	70°16.00′W	39
FF09 [1]	42°18.75′N	70°39.40′W	50
FF11 [2]	42°39.50′N	70°30.00′W	88.4
FF14 [2]	42°25.00′N	70°39.29′W	73.3

[1] Stations to be sampled for benthic infauna in 2008
[2] Stations to be sampled for benthic infauna in 2009

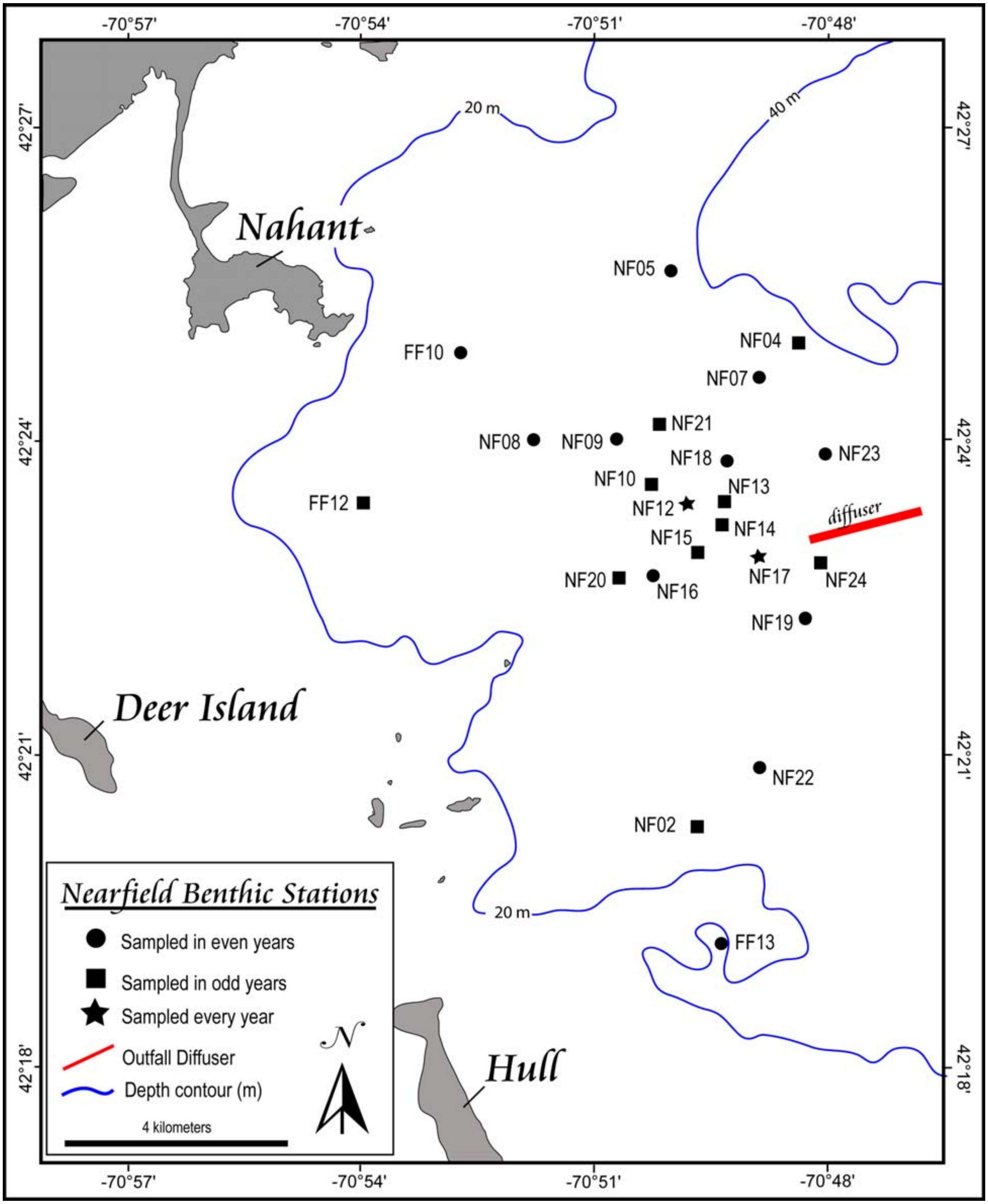

Figure 3. Locations of nearfield benthic monitoring stations.

Table 4. Sampling Design for Nearfield and Farfield Benthic Collections in 2008 and 2009.

Station Group Name	Stations	Years to be Sampled	Samples/Station for Biology	Samples/Station for Metals/ Organics	Samples/Station for TOC/ Grain size/ *Clostridium*
Core (2 stations)	NF12, NF17	2008, 2009	3	2	2
2008 replicated nearfield (2 stations)	FF10, FF13	2008	3	2	2
2008 unreplicated nearfield (9 stations)	NF05, NF07, NF08, NF09, NF16, NF18, NF19, NF22, NF23	2008	1	1	1
2008 farfield (4 stations)	FF04, FF05, FF07, FF09	2008	3	2	2
2009 replicated nearfield (2 stations)	FF12, NF24	2009	3	0	2
2009 unreplicated nearfield (8 stations)	NF02, NF04, NF10, NF13, NF14, NF15, NF20, NF21	2009	1	0	1
2009 farfield (4 stations)	FF01A, FF06, FF11, FF14	2009	3	0	2

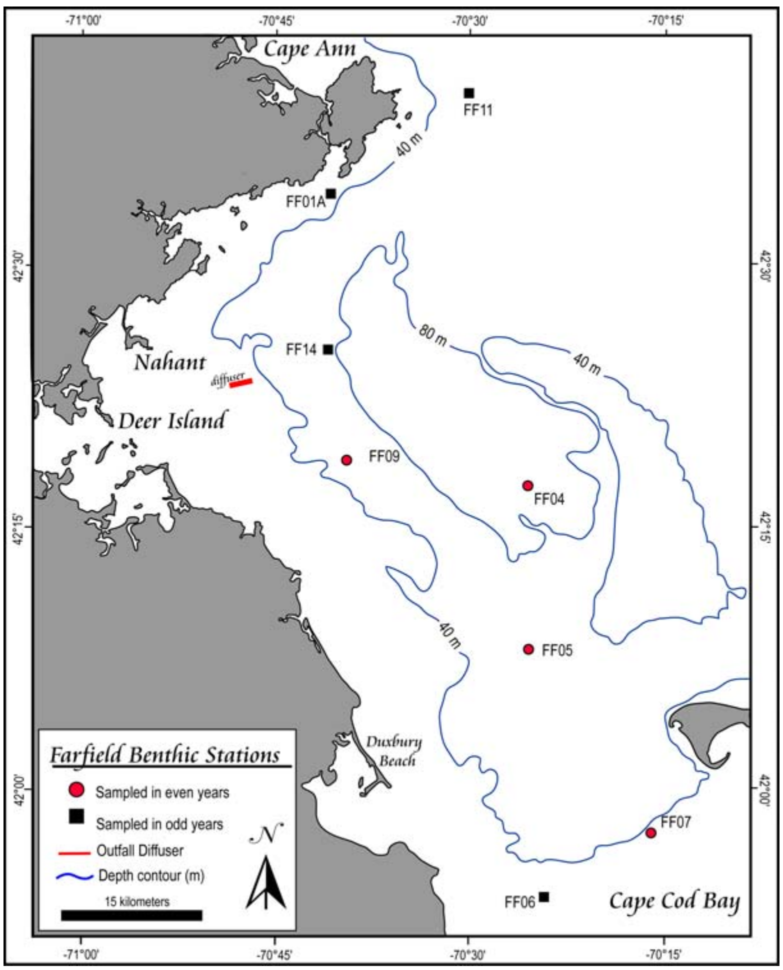

Figure 4. Locations of farfield benthic monitoring stations.

Table 5. 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	2	42°23.012'N	70°46.960'W	29
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
T11	1	42°14.405'N	70°34.373'W	36
T12	1	42°21.477'N	70°45.688'W	29
Diffuser # 44		42°23.116'N	70°47.931'W	33

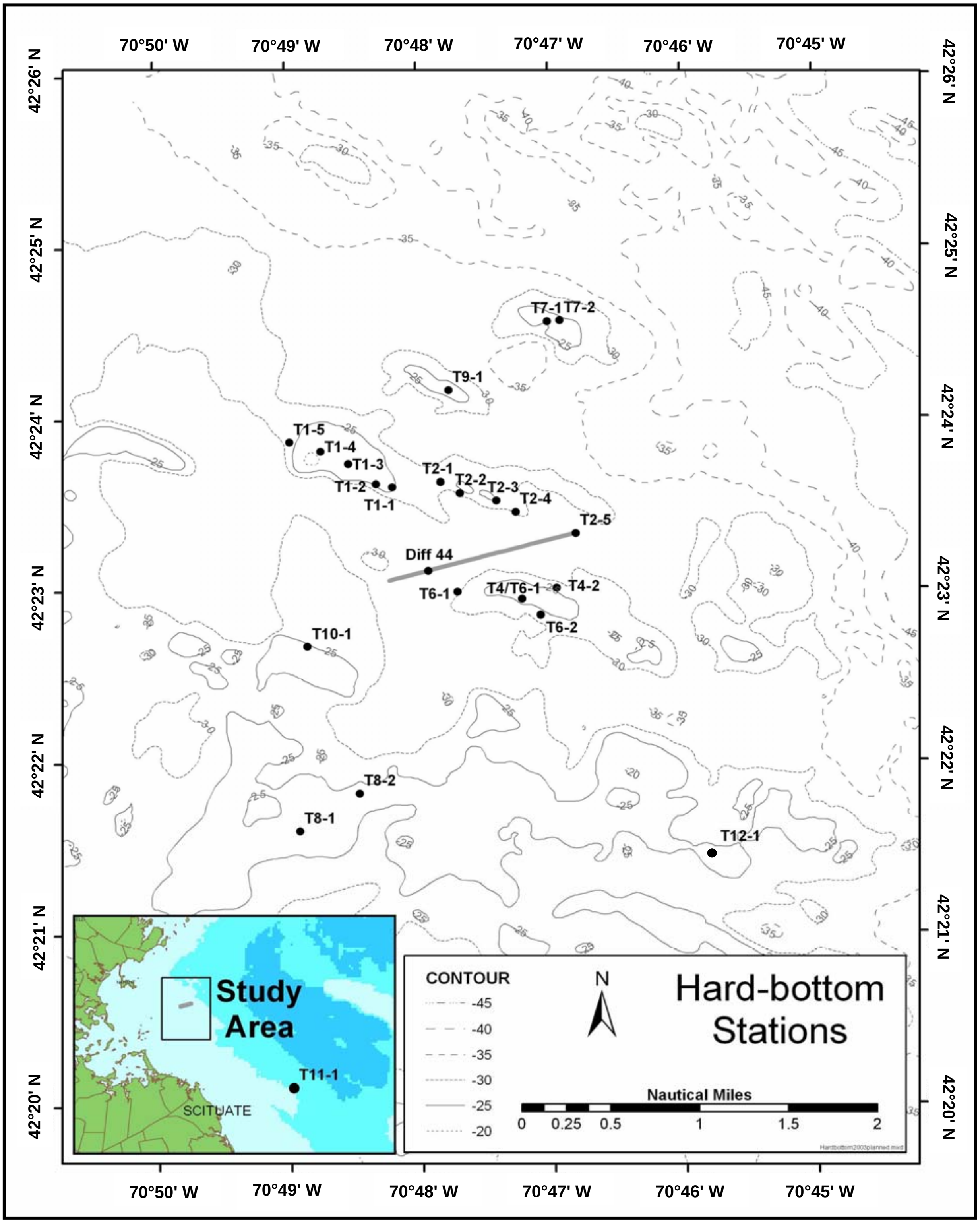

Figure 5. Locations of hard-bottom benthic monitoring stations.

A6.2.2 *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 RPD depth, benthic community diversity and relative abundance of opportunistic species, and sediment contaminant concentrations (MWRA, 1997a, b, 2001; Appendix A).

Following the 2004 reduction in sampling, the benthic community thresholds were recalculated to reflect the stations actually sampled (Appendix A). Table 6 presents a summary of the contingency plan thresholds to be used by MWRA in HOM6. ENSR will not be directly testing data against thresholds under this agreement, but will notify MWRA of observed data anomalies (*e.g.*, extremely high abundances of a single species) with the potential to affect the threshold computations when data are delivered.

A6.3 Schedule of Activities and Deliverables

Benthic monitoring activities under this contract will span the period from the date of project initiation (January 2008) through September 2010 when the final annual (Boston Harbor) synthesis report is due. Activities include field sampling and laboratory analyses, with deliverables consisting of a Quality Assurance Project Plan, survey plans, survey summaries, survey reports, reference collection reports, sample analysis data submissions, data report reviews, and synthesis reports (prepared under Task 11). Schedules for these activities and deliverables for 2008–2010 are outlined in Tables 7 and 8.

Table 6. Contingency Plan Thresholds Established by MWRA.

Location	Parameter	Caution Level	Warning Level
Even Years Benthic diversity, nearfield	Species per sample	<48.41 or >82.00	None
	Fisher's log-series *alpha*	<9.99 or >16.47	None
	Shannon diversity (base 2)	<3.37 or >4.14	None
	Pielou's evenness	<0.58 or >0.68	None
Odd Years Benthic diversity, nearfield	Species per sample	<46.52 or >79.95	None
	Fisher's log-series *alpha*	<9.95 or >15.17	None
	Shannon diversity	<3.30 or >3.91	None
	Pielou's evenness	<0.56 or >0.66	None
All Years Species composition, nearfield	Percent opportunists	10%	25%
Sediments, nearfield	RPD depth	1.18 cm	None
Sediment toxic contaminants, nearfield	Acenaphthene	None	500 ppb dry
	Acenaphylene	None	640 ppb dry
	Anthracene	None	1100 ppb dry
	Benz(a)pyrene	None	1600 ppb dry
	Benzo(a)pyrene	None	1600 ppb dry
	Cadmium	None	9.6 ppm dry
	Chromium	None	370 ppm dry
	Chrysene	None	2800 ppb dry
	Copper	None	270 ppm dry
	Dibenzo(a,h)anthracene	None	260 ppb dry
	Fluoranthene	None	5100 ppb dry
	Fluorene	None	540 ppb dry
	Lead	None	218 ppm dry
	Mercury	None	0.71 ppm dry
	Naphthalene	None	2100 ppb dry
	Nickel	None	51.6 ppb dry
	p,p'-DDE	None	27 ppm dry
	Phenanthrene	None	1500 ppb dry
	Pyrene	None	2600 ppb dry
	Silver	None	3.7 ppm dry
	Total DDTs	None	46.1 ppb dry
	Total HMWPAH	None	9600 ppb dry
	Total LMWPAH	None	3160 ppb dry
	Total PAH	None	44792 ppb dry
	Total PCBs	None	180 ppb dry
	Zinc	None	410 ppm dry

Table 7. Overview of Harbor and Outfall Surveys and Associated Deliverables.

Survey Date	Survey	Due Dates		
		Survey Plan	Summary Report (1 week after survey completion)	Draft Survey Report* (2 weeks after survey completion)
June 2008	Nearfield Hard-bottom Survey (Task 6.4)	May 2008		July 2008
August 2008	Harbor Traditional and Outfall Soft-Bottom Survey[1] (Tasks 5.1, 6.1, 6.2)	July 2008[1]	August 2008 (Task 6.1 only)	September 2008[1]
August 2008	Harbor Reconnaissance (SPI) Survey[2] (Task 5.2)	July 2008[2]		September 2008[2]
August 2008	Nearfield SPI Survey[2] (Task 6.3)	July 2008[2]	August 2008	September 2008[2]
June 2009	Nearfield Hard-bottom Survey (Task 6.4)	May 2009		July 2009
August 2009	Harbor Traditional and Outfall Soft-Bottom Survey[1] (Tasks 5.1, 6.1, 6.2)	July 2009[1]	August 2009 (Task 6.1 only)	September 2009[1]
August 2009	Harbor Reconnaissance (SPI) Survey[2] (Task 5.2)	July 2009	September 2009[2]	September 2009[2]
August 2009	Nearfield SPI Survey[2] (Task 6.3)	July 2009	August 2009[2]	September 2009[2]

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

[1] One survey plan and one survey report will be prepared each year to include both the Harbor Traditional and Outfall Soft-Bottom Surveys.

[2] One survey plan and one survey report will be prepared each year for the Harbor Reconnaissance (SPI) and Nearfield SPI Surveys combined.

Table 8. Overview of Data Submissions and Synthesis Reports.

Survey Date (2008)	Deliverable	Due Dates*
		Data/Report
June 2008	Nearfield Hard-bottom Data Submission (Task 7.7.1, analysis reported under Task 4)	15 December 2008
	Nearfield Hard-bottom Data Report Review (Task 7.7.2)	31 January 2009
August 2008	Nearfield Faunal Sorting Completion Letter Report (Task 7.3.1)	60 days after survey completion (approximately early October)
	Farfield Faunal Sorting Completion Letter Report (Task 7.4.1)	15 October 2008
	Nearfield Faunal Data Submission (Task 7.3.2 analysis reported under Task 4)	15 November 2008
	Nearfield Faunal Data Report Review (Task 7.3.3)	31 December 2008
	Farfield Faunal Data Submission (Task 7.4.2 analysis reported under Task 4)	15 January 2009
	Farfield Faunal Data Report Review (Task 7.4.3)	28 February 2009
	Harbor Faunal Sorting Completion Letter Report (Task 7.2.1)	15 January 2009
	Harbor Faunal Data Submission (Task 7.2.2 analysis reported under Task 4)	15 March 2009
	Harbor Faunal Data Report Review (Task 7.2.3)	30 April 2009
	Nearfield Sediment Profile Imaging Data Submission (Task 7.6.3 analysis reported under Task 4)	30 October 2008
	Nearfield Sediment Profile Imaging Data Report Review (Task 7.6.4)	15 December 2008
	Harbor Sediment Profile Imaging Data Submission (Task 7.5.1 analysis reported under Task 4)	15 January 2009
	Harbor Sediment Profile Imaging Data Report Review (Task 7.5.2)	28 February 2009
2008 Annual	Outfall Benthic Synthesis Report - Draft (Task 11.1)	May 2009
	Reference Collection Status Report (Task 7.1)	June 2009
	Outfall Benthic Synthesis Report - Final (Task 11.1)	July 2009
	Harbor Benthic Synthesis Report - Draft (Task 11.2)	July 2009
	Harbor Benthic Synthesis Report - Final (Task 11.2)	September 2009

Table 8. (continued)

Survey Date (2009)	Deliverable	Due Dates*
		Data/Report
June 2009	Nearfield Hard-bottom Data Submission (Task 7.7.1 analysis reported under Task 4)	15 December 2009
	Nearfield Hard-bottom Data Report Review (Task 7.7.2)	31 January 2010
August 2009	Nearfield Faunal Sorting Completion Letter Report (Task 7.3.1) Farfield Faunal Sorting Completion Letter Report (Task 7.4.1) Nearfield Faunal Data Submission (Task 7.3.2 analysis reported under Task 4) Nearfield Faunal Data Report Review (Task 7.3.3) Farfield Faunal Data Submission (Task 7.4.2 analysis reported under Task 4) Farfield Faunal Data Report Review (Task 7.4.3)	60 days after survey completion (approximately early October) 15 October 2009 15 November 2009 31 December 2009 15 January 2010 28 February 2010
	Harbor Faunal Sorting Completion Letter Report (Task 7.2.1) Harbor Faunal Data Submission (Task 7.2.2 analysis reported under Task 4) Harbor Faunal Data Report Review (Task 7.2.3)	15 January 2010 15 March 2010 30 April 2010
	Nearfield Sediment Profile Imaging Data Submission (Task 7.6.3 analysis reported under Task 4) Nearfield Sediment Profile Imaging Data Report Review (Task 7.6.4)	30 October 2009 15 December 2009
	Harbor Sediment Profile Imaging Data Submission (Task 7.5.1 analysis reported under Task 4) Harbor Sediment Profile Imaging Data Report Review (Task 7.5.2)	15 January 2010 28 February 2010
2009 Annual	Outfall Benthic Synthesis Report - Outline (Task 11.1)	April 2010
	Outfall Benthic Synthesis Report - Draft (Task 11.1)	May 2010
	Outfall Benthic Synthesis Report - Final (Task 11.1)	July 2010
	Reference Collection Status Report (Task 7.1)	June 2010
	Harbor Benthic Synthesis Report - Outline (Task 11.2)	June 2010
	Harbor Benthic Synthesis Report - Draft (Task 11.2)	July 2010
	Harbor Benthic Synthesis Report - Final (Task 11.2)	September 2010

* Data Report Reviews are due 30 days after receipt of each data report from MWRA.

A7. QUALITY OBJECTIVES AND CRITERIA

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 QAPP depend to some extent upon the selection of the sampling sites. All soft-bottom stations to be visited during this program will be the same as those sampled in HOM2 (Blake and Hilbig 1995), HOM3 (Kropp and Boyle 2001), HOM4 (Williams *et al.* 2005), and HOM5 (Williams *et al*. 2006). Hard-bottom survey sites will be the same as those listed in Williams *et al*. 2006.

Quality objectives are given below. Details of how these criteria are met for each component of the Benthic Monitoring tasks are presented in Section B5.

A7.1 Field Activities

A7.1.1 *Navigation*

The quality objective for navigation is that the system used be accurate and precise to enable the sampling vessel to reliably re-occupy those stations that are to be sampled during each survey. Navigation equipment should be suitable for consistently fixing the vessel's position to within 10 meters. Samples will be collected within a target radius of 30 meters.

A7.1.2 *Grab Sampling*

The quality objectives for collection of sediment grab samples are that (1) samples be collected within 30 meters of the target location, (2) all samples required be collected, (3) samples be of sufficient quantity to be representative of the station, (4) samples be undisturbed, and (5) samples be uncontaminated.

The determination of sufficient quantity is made by measuring the depth of penetration of the grab. The 0.04-m^2 Ted Young-modified Van Veen grab sampler used for biology samples must contain sediment to a depth of at least 7 cm (out of a possible 10 cm). The 0.1-m^2 Ted Young-modified Van Veen grab sampler used to collect sediment for chemical analysis must be at least half full to contain enough sediment for distribution among the several required sample jars. Procedures for collecting undisturbed and uncontaminated samples are described in Section B3.

The quality objectives for the handling of benthic infaunal samples are that (1) samples be handed gently during the sieving process, (2) samples be fixed in 10% formalin as quickly as possible to prevent deterioration of the fauna, and (3) sample jars be labeled accurately. Procedures for sample handling are detailed in Section B3.

The quality objectives for the handling of sediment samples to be used for sedimentary and chemical analysis are that (1) samples remain uncontaminated, (2) samples be well homogenized, and (3) samples be subsampled and preserved following methods detailed in Section B3.

All sediment samples scheduled to be analyzed for Total Organic Carbon (TOC), organic contaminants, and metals during HOM6 will be analyzed by the MWRA's DLS. The data quality objectives (DQOs) for the DLS are provided in Prasse *et al.* (2007). Sediment grain size and *Clostridium perfringens* analyses will be performed by laboratories to be determined by the MWRA. DQOs for grain size and *C. perfringens* analyses are also provided in an update to Prasse *et al.* (2007).

A7.1.3 *Sediment Profile Imagery*

The DQOs for the field collection of the SPI are that (1) images be collected from the same locations that have been sampled in previous surveys, and (2) images be clear and of high quality.

A7.1.4 *Hard-bottom ROV Survey*

The DQOs for the field collection of the hard-bottom survey are that (1) surveyed transects and stations be the same as those that have been sampled in previous surveys, and (2) that images be clear and of high quality.

A7.2 Laboratory Activities

A7.2.1 *Infaunal Analysis*

The DQOs for the analysis of benthic infauna are that (1) all samples be processed, (2) all animals be removed from the sediment for identification and enumeration, (3) all infaunal animals be counted accurately, (4) the taxonomic identifications be accurate (correct) and (5) the identifications correspond to those used throughout the monitoring program. At least 95 percent of all animals must be removed from a sample to pass the quality control (QC) evaluation as discussed in Section B5.

A7.2.2 *Sediment Profile Image Analysis*

The QC objectives for SPI analysis are that (1) at least three images from each station be analyzed, (2) all parameters defined in this QAPP be analyzed for all images, and (3) that analytical systems used enable repeatable measurements and determinations to be made. Accuracy and precision for SPI analysis cannot be quantified but will be optimized by QC procedures discussed in Section B5.

A7.2.3 *Hard-bottom Video and 35-mm Slide (or Digital Still Image) Analysis*

The DQOs for analysis of hard-bottom videos and still images are that (1) the required minutes of video footage (20 minutes) and number of still images (36) be analyzed for each station, and (2) all parameters defined in this QAPP be counted and/or measured as appropriate.

A8. SPECIAL TRAINING/CERTIFICATIONS

A8.1 Special Training

Field personnel will be experienced in the sampling techniques documented in this QAPP. Prior to starting work, any new personnel will be given instructions specific to the project, covering the following areas:

- Organization and lines of communication and authority
- Overview of the QAPP
- QA/QC requirements
- Documentation requirements
- Health and safety requirements

Instructions will be provided and documented by the ENSR Project Manager, ENSR Chief Scientist, ENSR Health and Safety Officer, and ENSR Project QA Officer.

Personnel responsible for shipping samples will also be trained in the appropriate regulations, *i.e.*, Department of Transportation (DOT), International Civil Aviation Organization (ICAO), and International Air Transport Association (IATA).

A8.2 Certifications

No special certifications are required for the work covered under this QAPP.

A9. DOCUMENTS AND RECORDS

A9.1 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 made in permanent ink, initialed, and dated, and no erasures or obliterations will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark and the correct entry will be made, initialed, and dated by the person making the correction. Corrections to electronically captured data will be documented on a hard-copy 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 according to the procedures described in Sections D-1 and D-2 (below).

A9.2 Field Records

Field logbooks will provide the primary means of recording the data collection activities performed during the sampling surveys. As such, entries will be described in as much detail as possible so that events occurring during the survey can readily be reconstructed after the fact. At the beginning of each survey, the date, start time, weather, names of all sampling team members present, and the initials of the person making the entry will be entered. Measurements made and samples collected will be recorded.

Information specific to sample collection will include:

- Station name
- Sample identification number
- Time and date of sample collection
- Sample description (color, texture, etc.)
- Samplers' initials
- Requested analyses
- Location (for HOM6, whenever a sample is collected, the geographic location of the station will be recorded by entry into Battelle's NavSam© software program)

Navigation and all of the above information will be recorded on standardized forms. These computer generated station logs associated with field and laboratory custody and tracking will be kept in a survey notebook, using a 3-ringed binder, for each survey. Barcoded sample labels, which are printed using the NavSam© computer program, are affixed to each station log sheet. These notebooks will be held in the custody of the ENSR Project Manager. Copies will be provided to the Battelle Field Manager immediately after each survey.

For the soft-bottom and hard-bottom field programs, supplementary data for every station sampled are recorded into Polypaper bound field logbooks. These logbooks are assigned to field personnel but will be stored in the ENSR project files when not in use. Each field logbook will be identified by a project-specific document number. For the soft-bottom survey, additional data may include notes on presence/absence of anemones, and numbers and sizes of jars used for each sample. For the hard-bottom survey, additional data may include notes on sampling difficulties, currents, and video observations.

For the SPI field program, data supplemental to the NavSam© information are entered into an Excel spreadsheet on a laptop computer as the images are acquired. Data logged include station, date, time, camera counter number, depth of prism penetration as determined from the camera frame, water depth, and other parameters. This spreadsheet will be archived at Diaz & Daughters under the supervision of Dr. Robert Diaz, and a copy will be provided to the ENSR chief scientist to complete the survey logbook.

A9.3 Laboratory Records and Deliverables

Laboratory data reduction procedures will be performed according to the following protocol. All information related to analysis will be documented in controlled laboratory logbooks, instrument printouts, or other approved forms. All entries that are not generated by an automated data system will be made neatly and legibly in permanent, waterproof ink. Information will not be erased or obliterated. Corrections will be made by drawing a single line through the error and entering the correct information adjacent to the cross-out. All changes will be initialed, dated, and, if appropriate, accompanied by a brief explanation. Unused pages or portions of pages will be crossed out to prevent future data entry. Analytical laboratory records will be reviewed by the supervisory personnel on a regular basis, and by the Laboratory QA Manager periodically, to verify adherence to documentation requirements.

The hard-copy data packages from laboratories subcontracted to ENSR will be described in their statement of work (SOW). Ruff Systematics and Ocean's Taxonomic Services will submit faunal data to ENSR as electronic or hard-copy data sheets. Cove Corporation, Hecker Environmental, and Diaz &

Daughters will provide one copy of an electronic data deliverable (EDD). Cove will also provide their hand-written data sheets. The EDD for benthic infauna (Cove) and hard-bottom fauna (Hecker) will be in the form of an Access loading application provided by Battelle. Diaz & Daughters will provide two versions of the SPI data in Excel. The first will be the original data produced by Diaz & Daughters' image analysis system. The second is reformatted according to Battelle's instructions for loading into Excel. ENSR will use the original output to ensure that the resulting Access database is correct.

Data deliverables in the form of CSV files suitable for loading into the HOML database will be provided to MWRA by ENSR on the schedule described in this QAPP (Section A6.3).The format of the EDD is discussed in Section B10.

Sample laboratory data recording forms are provided in Appendix B.

A9.4 Reports and Data Submissions

Documents and data submissions and reviews that will be generated under the Benthic Monitoring tasks are listed below. The due dates for these reports and data submissions are tabulated in Section A6.3.

- Quality Assurance Project Plan (QAPP)
- Survey plans
- Survey summaries
- Survey reports
- Reference collection reports
- Sample analysis data submissions
- Review of MWRA generated data reports
- Synthesis reports

A9.4.1 *Quality Assurance Project Plan (QAPP)*

The QAPP will be the first document produced during the Benthic Monitoring program and will be organized in the format documented in U.S. EPA QA/R-5 (2001) and further elucidated in U.S. EPA QA/G-5 (2002). Copies, either electronic or hardcopy, of this QAPP, and any subsequent revisions, will be distributed by the ENSR QA Officer or the officer's designee to the personnel shown on the Distribution List (section A3, page 7, of this document). The version number is given in the header.

A9.4.2 *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 be submitted as a final unbound, double-sided 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 QAPP

A9.4.3 *Survey Summaries*

For the nearfield faunal sampling and SPI surveys only, an e-mail summary will be delivered to the MWRA Task Manager within one week of survey completion. The nearfield infaunal survey summary will confirm completion of the survey and mention any noteworthy problems or events encountered. This summary will highlight any unusual observations that may be a cause for concern; for example, if it is observed that few stations have little or no apparent RPD. The SPI survey summary will contain the above information and will also include a preliminary review of the images obtained.

A9.4.4 *Survey Reports*

Survey reports are prepared after each survey to describe the sampling activities. Each report is expected to include about 4–5 pages of text, and will contain the following information:

- Introduction with overview of the survey, including the vessel, schedule, and a table of survey personnel (including roles and responsibilities)
- Methods for observations and sample collection
- Survey chronology using local time
- Survey results presented as a narrative and including:
    - Any incidental observations of marine mammals
    - Any unusual observations of environmental conditions (especially those that might impact subsequent testing of Contingency Plan Thresholds)
    - Table of actual vs. planned samples and measurements collected
    - Table of summary data (outlined for soft-bottom infaunal survey below)
    - Table of samples collected (table generated by MWRA as described below)
    - Map illustrating the actual station locations and track lines
- Problems experienced, actions taken, and recommendations, including deviations from this QAPP, that were not known at the time of survey plan preparation

- References

All survey reports will include a station data table containing information specific to each individual survey (including, but not limited to, survey_ID, survey date, sampling times, sample types, sample locations, etc.). This survey report table will be generated by MWRA from the EM&MS database once the relevant survey data submission meets the quality assurance criteria described in Section B5. For the soft-bottom infaunal survey, a supplementary table will include descriptive field measurements such as sediment texture, observed surface fauna, and apparent RPD depth measurements 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, in which MWRA's comments are addressed, 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.

A9.4.5 *Reference Collection Status Report*

Once per year (June 2009 and June 2010), after MWRA accepts all infaunal data submissions and ENSR has reviewed all resultant reports from the prior year's sampling, a reference collection status report will be prepared. 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
- Any taxonomic changes to previously identified taxa and a justification for the change

A9.4.6 *Sample Analysis Data Submissions*

Following each analytical subtask conducted under the Benthic Monitoring program (except Task 7.1, which requires only a status report), the sample analysis data will be prepared and delivered to MWRA. For the benthic infauna and hard-bottom analysis tasks, the completed loading applications will be sent to Battelle for processing into the appropriate MWRA HOM Data Loading (HOML) application format as defined in the contract. For the SPI analysis task, the spreadsheet generated by the image analysis program will be delivered to Battelle for loading into a loading application and processing into HOML format. These data will then be exported into ASCII-delimited files as defined by MWRA and delivered to ENSR for submission to MWRA. If HOML is online, Battelle will deliver the data submission directly to MWRA.

The hardcopy documentation package will follow the successful loading of data via HOML. For all data sets, documentation will include:

- Cover letter describing any problems encountered during loading
- List of problems encountered and corrective action taken
- List of samples/images planned vs. collected or measurements planned vs. reported
- Quality Assurance Statement including a checklist of QA actions and notes on deviations and corrective actions (electronic and signed hard copy)

- Table(s) of data submitted
- Exceptions report showing results of checks (for data sets submitted via the HOML application)

The infaunal data submissions (Tasks 7.2.2, 7.3.2, and 7.4.2) will include hardcopy printouts showing the station, sample_ID, taxon name, and the number of individuals counted for each taxon. The SPI analysis data submissions (Tasks 7.5.1 and 7.5.3) will be accompanied by copies of the three images that were analyzed from each site. The hard-bottom survey data submissions (Task 7.6.1) will be accompanied by copies of the videotapes and photographic images taken during the survey.

A9.4.7 *Review of MWRA Generated Data Reports*

The data reports generated by the MWRA will be reviewed and any errors will be reported to MWRA within 30 days after receipt of each data report.

A9.4.8 *Synthesis or Summary Reports*

Analytical reports will be prepared under two tasks: Task 11.1 (Outfall) and Task 11.2 (Harbor). In 2009, only summary reports for both the outfall and harbor study areas will be prepared. These reports will be based on the materials presented at the annual technical meeting; copies of the full presentations will be included as appendices. In 2010, full synthesis reports for both the outfall (see section A9.4.8.1) and harbor (see section A9.4.8.2) study areas will be prepared. Thirty days prior to the due date of the draft report, an outline will be delivered to the MWRA. The due dates for the draft and final summary or synthesis reports are listed in Section A6.3.

All project data used in these reports will be derived from the MWRA EM&MS database. MWRA will provide ENSR with data generated by MWRA's DLS (all sediment chemistry, physicochemical, and microbiological parameters), along with the data generated by ENSR and subcontractors.

Dr. Nancy J. Maciolek will be the task manager and editor for the summary and synthesis reports. She will assemble the presentations made in 2009 (for the 2008 data) and will be lead author for several of the individual chapters of the full synthesis report in 2010 (for the 2009 data). Each full synthesis report will be reviewed by scientists who are knowledgeable in the subject matter of the report, as well as ENSR's QA Officer. Such review will ensure that interpretations made in the reports are scientifically and technically valid and meet the MWRA's needs.

A9.4.8.1 *Outfall Benthic Report (Task 11.1)*

The full synthesis report (2010) will evaluate the status of benthic communities and associated sediment and chemical parameters in the nearfield and farfield of Massachusetts Bay and will focus on results indicative of changes in the benthic environment. The technical content of the report will be presented in chapters that describe the results from the year's studies and provide comparisons with previous MWRA studies. Chapters will be prepared for the field program, physico-chemical parameters, SPI, soft-bottom infauna, and hard-bottom fauna. A summary chapter, in which the monitoring questions are specifically addressed, will also be prepared. Each technical chapter will discuss the data with respect to relevant monitoring questions posed in the monitoring plan (MWRA 1997b, 2001, 2004):

- *What is the level of sewage contamination and its spatial distribution in Massachusetts and Cape Cod Bays sediments before discharge through the new outfall?*
- *Has the level of sewage contamination or its spatial distribution in Massachusetts and Cape Cod Bays sediments changed after discharge through the new outfall?*

- *Have the concentrations of contaminants in sediments changed?*
- *Have the sediments become more anoxic; that is, has the thickness of the sediment oxic layer decreased?*
- *Has the soft-bottom community changed?*
- *Are any benthic community changes correlated with changes in levels of toxic contaminants (or sewage tracers) in sediments?*
- *Has the hard-bottom community changed?*

A9.4.8.1.1 Statistical Analyses for Sedimentary and Chemistry Data

The sediment data will be analyzed using a variety of statistical and graphical methods. These tests may include analysis of variance (ANOVA), different type of correlation analyses (*e.g*., Pearson product-moment, and Kendall), Students t-test, Shapiro-Wilk test, Bartlett's test, and principal component analysis (PCA). Where the ANOVA shows significant differences between the two variables tested, a regression analyses may be performed to attempt to explain the relationship. Normality may be checked with the Shapiro-Wilk test and homogeneity of variance with Bartlett's test. Additional evaluations using box plots, ternary plots, and range plots may be performed to assess temporal and spatial trends over time.

Year-to-year differences in the data will also be analyzed for key parameters, including considering changes that have occurred in discharges (volumes, locations, treatment, etc.); analyses will be performed using sediment data from multiple time periods**,** including baseline and post-diversion station mean values for the outfall. These data analyses will be employed to detect outfall effects if present.

A9.4.8.1.2 SPI Analyses

A variety of statistical analyses will be used to compare SPI parameters and to display temporal variations. Analysis of variance (ANOVA) or Student's t-test for paired data will be used to test for differences between and within areas for quantitative parameters. Normality will be checked with the Shapiro-Wilk test and homogeneity of variance with Bartlett's test. If variance is not homogeneous, Welch analysis of variance, which allows standard deviations to be unequal, will be used in testing for mean differences (Zar 1999). Cochran-Mantel-Haenszel statistics and Fisher Exact Test will be used for comparisons involving categorical parameters (Agresti 1990). All statistical tests will be conducted using SAS's JMP program for Macintosh.

A9.4.8.1.3 Infaunal Data Analyses

Prior to analysis of the soft-bottom faunal data, some modifications to the dataset will be made. For example, some taxa, *e.g*., epifaunal, encrusting, or non-benthic taxa, 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 will be included in all remaining calculations (*e.g*., diversity, evenness, number of species, multivariate analyses).

For HOM6 synthesis reports, three categories of diversity indices will be explored: (1) species richness indices (*e.g.*, rarefaction); (2) indices based on the proportional abundances of species (*e.g.*, Shannon index) and (3) species abundance indices (*e.g.*, Fisher's-series *alpha*) (Magurran 1988). The PRIMER v. 6 package of statistical routines will be used to calculate these indices and to generate species accumulation curves (Clarke and Gorley 2006).

Multivariate analysis will be used to explore the data for evidence of impact of the outfall in Massachusetts Bay. Cluster and PCA-H analyses will be conducted on the current year's datasets and, in a limited manner, on the baseline datasets. Changes in infaunal community structure that are suspected to be due to the outfall can be assessed by comparing community structure differences between the nearfield and farfield through time, and evaluating changes in community structure before and after the outfall went online in September 2000.

A9.4.8.1.4 Hard-bottom Data Analyses

Data reduction and analysis will focus on several goals: (1) to obtain baseline spatial and temporal data on habitat characteristics at each waypoint, (2) to assess temporal stability of community structure at each of the waypoints, (3) to assess temporal variability in percent cover of coralline algae at each of the waypoints, and (4) to evaluate if observed changes, if any, in biotic parameters can be attributed to discharges from the outfall. Included in this synthesis will be a determination of habitat types, summary distributions of the flora and fauna observed, and a multivariate analysis of the hard-bottom community structure. Data analysis products will include descriptions of habitat characteristics, species lists, hierarchical classification analysis, and descriptive multi-year comparisons in map and table form.

Analysis of the hard-bottom data will include comparisons of pre- and post-diversion conditions. The parameters that will be compared will include: degree of sediment drape, percent cover of coralline algae, relative abundance of filamentous red algae, dominant benthic taxa (with species counts normalized to mean number per slide), and general community characteristics.

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. Additional statistical treatments of the data may be implemented during HOM6.

A9.4.8.2 *Harbor Benthic Report (Task 11.2)*

The analysis of the harbor sediment, SPI, and infaunal data is similar to that of the outfall data, except that the focus is on any long-term trends in the recovery of the harbor benthos following various pollution abatement programs. The technical content of each report will be presented in chapters that describe the results from the year's studies and provide comparisons with previous MWRA studies. Chapters will be prepared for the field program, SPI, and soft-bottom infauna; the sediment data will be presented in an appendix. A summary chapter will also be prepared.

Specific objectives for the harbor benthic report are to:

- Evaluate the most recent year's data from Boston Harbor
- Compare current results with historical data with the objective of evaluating long-term trends in benthic community parameters and faunal assemblages. Data may be evaluated according to time periods corresponding to various level of pollution abatement in Boston Harbor (*e.g.*, Taylor 2005, 2006).
- Map benthic processes in Boston Harbor as determined from analysis of SPI images. Correlation and principal components analyses will be used to arrive at a relative benthic habitat quality ranking for all Boston Harbor grab stations based on sediment, infauna, and SPI images data.

A9.5 Project files

The project files will be the central repository for all documents relevant to sampling and analysis activities as described in this QAPP, except for those relating to sediment chemistry: MWRA's DLS will be responsible for sediment chemistry records. ENSR is the custodian of the project files and will maintain the contents of the project files, including all relevant records, reports, logs, field notebooks, pictures, subcontractor reports, and data reviews in a secured, limited access area and under custody of the ENSR Project Manager.

The project files will contain at a minimum:

- Field logbooks
- Survey plans and reports
- Station and sample collection logs
- Laboratory data deliverables
- Data quality assurance reports
- Data submissions and reports
- Reference collection reports
- Synthesis reports
- Progress reports, interim project reports, etc
- All custody documentation (chain of custody forms, air bills, etc.)

Electronic versions of correspondence, reports, and statistical analyses will be stored in the project-specific network file. The original EDDs received from the laboratories and the project data will also be stored on the network, which is backed up daily and periodically archived off-site in accordance with ENSR Information Management policy.

Records associated with HOM6 will be retained with all the project records for at least six years after the termination of the project.

B. DATA GENERATION AND ACQUISITION

B1. SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

The rationale for the design of the harbor and outfall studies is given in section A6. The harbor study (A6.1) is designed to document any long-term changes in the benthic communities and sediment parameters at a variety of locations after the cessation of sludge and effluent discharge. The outfall study (A6.2) is designed to measure any potential impacts on both soft- and hard-bottom communities, as well as sedimentary parameters and incidence of *Clostridium perfringens*, as a result of moving the discharge offshore.

A summary of 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 9. The numbers of samples are listed separately for each survey and for all surveys within a subtask. Table 4 (section A6.2.1) also provides additional detail on samples to be collected on the outfall surveys.

Samples for laboratory measurements of sedimentological properties, such as grain size, levels of contaminants, and levels of *Clostridium perfringens* spores, will be collected but not analyzed under this contract; those samples will be delivered to MWRA's DLS for analysis.

B2. SAMPLING METHODS

B2.1 Navigation

Navigation data from NavSam© will be used for reporting purposes. Refer to the Water Column QAPP (Libby *et al*. 2008) 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.

B2.2 Benthic Sample Collection/Shipboard Processing

Appropriate permits to allow sampling within the Sanctuary will be requested by MWRA Project Manager Kenneth Keay; a copy will be provided to the Chief Scientist prior to the survey.

The shipboard processing and storage requirements for all samples collected for the benthic monitoring tasks are listed in Table 10 (harbor benthic surveys) and Table 11 (outfall benthic surveys). At all stations, the time, sea state and other weather conditions, and water depth will be recorded by hand onto a field log. Station coordinates will be captured by the NavSam© computer program. DLS provides sample containers for chemistry samples; ENSR provides sample containers for biology samples.

Any incidental observations of marine mammals will be recorded in the log. Right whale sightings will be reported immediately to NOAA National Marine Fisheries Sighting Advisory System. Contact and additional information on right whale guidance is given in Appendix C.

Table 9. Number of Samples to be Collected on Each Survey (2008 and 2009) and the Project Total

	Task 5 Harbor Surveys		**Task 6 Outfall Surveys**							
	5.1 (Grabs) & 5.2 (SPI)		**6.1 (NF Grabs)**		**6.2 (FF Grabs)**		**6.3 (NF SPI)**		**6.4 (NF Hard)**	
	Survey	***Project Total***	***Survey***	***Project Total***	***Survey***	***Project Total***	***Survey***	***Project Total***	***Survey***	***Project Total***
Infauna (2008, 2009)	27, 27	54	21, 20	41	12,12	24				
Sediment Chemistry (2008, 2009) • Organics • Metals			• 17,4 • 17,4	• 21 • 21	• 8,0 • 8,0	• 8 • 8				
Ancillary Parameters (2008, 2009) • TOC • Grain size • *Clostridium perfringens*	• 9,9 • 9,9 • 9,9	• 18 • 18 • 18	• 17,16 • 17,16 • 17,16	• 33 • 33 • 33	• 8,8 • 8,8 • 8,8	• 16 • 16 • 16				
SPI (2008, 2009)	183, 183	366					69, 69	138		
Hard-bottom Slides Video (min)									828, 828 460, 460	1656 920

Table 10. Processing and Storage of Field Samples taken on Boston Harbor Benthic Surveys.

Activity	Task 5.1 Harbor Infaunal Survey	Task 5.2 Harbor Reconnaissance Survey (SPI)
Stations	9 (T01–T08 and C019, see Table 2)	61 (T01–T08, C019, R02–R53, see Table 2)
Weather/sea state/ bottom depth	Record general conditions; record bottom depth to nearest 0.5 m	As for Task 5.1
Marine mammals	Note incidental observations	As for Task 5.1
Sampling: Gear	0.04-m^2 Ted Young-modified Van Veen grab sampler	Sediment profile camera
Sampling: Measurements	Record penetration depth to nearest 0.5 cm and sediment volume to nearest 0.5 L	Record prism penetration (0.5 cm)
Sampling: Sediment texture	Describe qualitatively	NA
Sampling: aRPD depth	Record visual estimate of aRPD to nearest 0.5 cm	Visual estimate
Faunal Samples: Number	3 at each station	3 images at each station
Faunal Samples: Processing	Rinse over 300-µm-mesh sieve; fix in 10% buffered formalin	Check counter
Faunal Samples: Storage	Clean, labeled plastic jars; ambient temperature	NA
Chemistry (Ancillary) /Microbiology Samples (All): Number	1 at each station	NA
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 ~500 mL for grain size	NA
Chemistry Samples (Ancillary): Storage[1]	Clean, labeled glass jar. Freeze TOC at -20°C; refrigerate grain size. Holding time is 28 days for both TOC and grain size.	NA
Microbiology Samples: Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~25 mL subsample	NA
Microbiology Samples: Storage[1]	Sterile sample bottle; preserve with $Na_2S_2O_3$, refrigerate at 4°C.[2] Holding time not defined.	NA

[1]Sediment samples collected in 2008 and 2009 will be shipped to DLS for testing. Grain size samples will then be sent by DLS to the Azimuth Geo Services, Austin, Texas, for analysis. Microbiology samples will be sent to BAL Laboratory, Cranston, RI, for analysis of *Clostridium perfringens*.

[2]*C. perfringens* may be stored frozen, but then must not be thawed until analyses are performed.

Table 11. Field Processing and Storage of Samples taken on Outfall Benthic Surveys.

Activity	**Task 6.1** **Nearfield Benthic Survey**	**Task 6.2** **Farfield Benthic Survey**	**Task 6.3** **Nearfield SPI Survey**	**Task 6.4** **Nearfield Hard-bottom Survey**
Stations	2008: 13 (Table 4) 2009: 12 (Table 4)	2008: 4 (Table 4) 2009: 4 (Table 4)	23 (Table 3)	18 waypoints on 6 transects (T1, T2, T4, T6, T7, T8) plus 5 single waypoints: T9, T10, T11, T12, diffuser #44 (Table 5)
Weather/sea state/ bottom depth	Record general conditions; record bottom depth to nearest 0.5 m	As for Task 6.1	As for Task 6.1	As for Task 6.1
Marine mammals	Note incidental observations	As for Task 6.1	As for Task 6.1	As for Task 6.1
Sampling: Gear	Ted Young-modified Van Veen grab sampler	Ted Young-modified Van Veen grab sampler	Digital video camera coupled to digital sediment profile camera	ROV equipped with video and 35-mm (or digital) cameras
Sampling: Measurements	Record penetration to nearest 0.5 cm and sediment volume to nearest 0.5 L	As for Task 6.1	Record prism penetration	Record ROV position, depth, heading
Sampling: Sediment texture	Describe qualitatively	As for Task 6.1	Estimate from images (see Section B2.2.3)	Not Applicable (NA)
Sampling: apparent RPD depth	Record visual estimate (0.5 cm)	As for Task 6.1	Estimate from images (see Section B2.2.3)	NA
Faunal Samples/Images: Number	2008: 3 each at stations NF12, NF17, FF10, FF13, 1 each at NF05, NF07, NF08, NF09, NF16, NF18, NF19, NF22, NF23 (Table 3) 2009: 3 each at stations NF12, NF17, FF12, NF24; 1 each at NF02, NF04, NF10, NF13, NF14, NF15, NF20, NF21 (Table 3)	2008: 3 each at stations FF04, FF05, FF07, FF09 (Table 3) 2009: 3 each at stations FF01A, FF06, FF11, FF14 (Table 3)	3 each station	20 min video, 36 still photos per waypoint
Faunal Samples/Images: Processing	Rinse over 300-µm-mesh sieve; fix in 10% buffered formalin	As for Task 6.1	Check counter; preview images within 3 business days of survey completion (see section B2.2.3)	Develop film on board. Save video to DVD
Faunal Samples/Images: Storage	Clean, labeled plastic jar; ambient temperature	As for Task 6.1	CD	DVD
Chemistry/ microbiology Samples: Number in 2008	2 each at NF12, NF17, FF10, and FF13, and 1 each at remaining 9 stations for *C. perfringens*, TOC, grain size, metals, and organics	2 each at stations FF04, FF05, FF07, FF09 for *C. perfringens*, TOC and grain size, metals, and organics	NA	NA

Table 11. (continued)

Activity	Task 6.1 Nearfield Benthic Survey	Task 6.2 Farfield Benthic Survey	Task 6.3 Nearfield SPI Survey	Task 6.4 Nearfield Hard-bottom Survey
Chemistry/ microbiology Samples: Number in 2009	2 each at NF12, NF17 for organics, metals, C. perfringens, TOC, and grain size; 2 each at FF12, NF24 and 1 each at NF02, NF04, NF10, NF13, NF14, NF15, NF20, NF21 for C. perfringens, TOC, and grain size only (Table 3)	2 each at FF01A, FF06, FF11, FF14 for C. perfringens, TOC, and grain size only (Table 3)	NA	NA
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 6.1	NA	NA
Chemistry Samples (Organics): Storage[1]	Clean labeled 250 ml (8 oz) glass jar with Teflon-lined screw 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 6.1	NA	NA
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 6.1	NA	NA
Chemistry Samples (Metals): Storage [1]	Clean, 125 ml (4 oz. plastic labeled I-Chem© jar; freeze (-20° C); holding time is 6 months to preparation; Hg holding time is 28 days to preparation.	As for Task 6.1	NA	NA
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 ~500 mL for grain size.	As for Task 6.1	NA	NA
Chemistry Samples (Ancillary): Storage[1]	Clean, labeled, wide-mouth glass jar (125 ml (4 oz) for TOC and 500 ml (16 oz) for grain size); freeze TOC, refrigerate grain size. Holding time is 28 days for both TOC and grain size	As for Task 6.1	NA	NA
Microbiology Samples: Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~25 mL subsample	As for Task 6.1	NA	NA
Microbiology Samples: Storage[1]	Sterile sample bottle; preserved with $Na_2S_2O_3$, refrigerate at 4°C[2], holding time not defined.	As for Task 6.1	NA	NA

[1]Sediment samples collected in 2008 and 2009 will be shipped to DLS for testing. Grain size samples will then be sent by DLS to the Azimuth Geo Services, Austin, Texas, for analysis. Microbiology samples will be sent to BAL Laboratory, Cranston, RI, for analysis *of Clostridium perfringens*.

[2]*C. perfringens* may be stored frozen, but then must not be thawed until analyses are performed.

B2.2.1 *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). The numbers of grab samples to be collected at each station for macrofaunal and/or chemical analyses are listed in Tables 4, 10, and 11.

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 that 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 A7.1.2). 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 aRPD will be visually estimated. The aRPD depth 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 an odor of hydrogen sulfide is detected, then the sample has no measurable aRPD 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 out toward the investigator. This action creates a vertical profile that can be examined and allows the aRPD to be measured to the nearest millimeter. Alternatively, the same ruler may 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 aRPD. Both methods will be used on the MWRA biological sampling cruises to estimate aRPD 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 12). 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 analysis.

Precautions will be taken during the deployment and retrieval of the grab sampler to prevent contamination of samples between stations. Sampling for infauna, 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* 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, 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 Battelle 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.

Table 12. Values used to Convert Grab Penetration Depth to Sediment Volume.

Grab Penetration Depth (cm)	Sediment Volume (L) 0.04-m^2 Grab	Sediment Volume (L) 0.10-m^2 Grab
3.5–4.0	1.0	
5.0	1.5	
6.0–6.5	2.0	
7.0	2.25	4.5
7.5	2.5	5.5
8.0	2.75	6.5
8.5–9.0	3.0	7.5
> 9.5 (over penetration) 0.04-m^2 grab	3.25	8.0
10		9.0
11		9.5
12		10.0
>15 (over penetration) 0.1-m^2 grab		11.0

B2.2.2 *Grab Sample Shipboard Processing*

At harbor grab 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 portion retained on the screens will be transferred to labeled jars and fixed in 10% buffered formalin. Sample jars will be Nalgene or other sturdy plastic jars with screw-capped lids. Each sample jar will be filled no more than half full of material. The jar will be gently turned around on its side to distribute the formalin evenly throughout the sample. The technician sieving each sample will be identified by his or her initials in the survey log. 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 corroded 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 250 mL (8 oz) glass jar with a Teflon-lined screw cap. About 100 mL of sample for metals analysis will be placed into an acid-cleaned, plastic, 125 mL (4 oz) I-Chem® jar (Prasse *et al*. 2007) jar. Approximately 50- and 500-mL subsamples for TOC and grain size will be placed into separate 125 mL (4 oz) and 500 mL (16oz) wide-mouth glass jars, respectively. These samples will be labeled and refrigerated at 1−4°C. A subsample of ~25 ml to be used for *Clostridium perfringens* analysis will be placed into a sterile sample bottle, labeled, and refrigerated or frozen until analysis. These samples will be delivered to DLS within 24 hours of survey completion.

No holding times for sediment samples are specified under the sampling/analysis protocols specified by NOAA for the National Status & Trends Mussel Watch Project. 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 (for organics and metals analysis) 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.

B2.2.3 *Sediment Profile Image Collection*

The sediment profile camera system consists of a 5.2-megapixel digital 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. The digital camera is also equipped with a video feed that is used to send images to the surface via cable so that prism penetration can be monitored in real time. The camera/prism system is mounted in a cradle that is secured to a larger frame, which ensures that the prism penetrates the sediment at a 90° angle. In addition, the camera frame supports a video-plan camera mounted to view the surface of the seabed. Prior to every field deployment, all essential items are gathered and tested for proper operation.

A winch is used to lower the entire assembly at a steady rate to the seafloor. Images from the video-plan camera are relayed to the surface via the video cable and permit the camera operator to see the seafloor and know exactly when the camera has reached the bottom. The camera operator then can view the prism penetration and choose exactly when to record sediment profile images. Each time the camera is on the bottom, a series of 2–4 photographs is taken, generally within the first 12 seconds after bottom contact. This sampling protocol helps to ensure that at least one usable photograph is produced during each lowering of the camera. After the required number of replicates, the camera assembly is returned to the ship. The date, time, station, water depth, photo number, and estimated camera penetration are recorded in a field log, with each touchdown of the camera also marked as an event on the NAVSAM©.

The digital camera produces a 14.1-megabyte RGB image that is then recorded to either an IBM 1-gigabyte microdrive or solid-state memory cards. The video signal (from the video-plan camera mounted on the frame) showing the surface of the seafloor is recorded on mini-DVD digital videotape for later review. The combination of video and digital images will ensure accurate and reliable collection of SPI data. The video contributes the real-time assessment component, whereas the still images provide high-resolution detail for full image analysis in the laboratory. The digital images are directly comparable with historic profile camera data collected with 35-mm film.

The sediment profile images will be reviewed within three business days of survey completion to provide a “quick look” analysis. 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 aRPD
- General benthic successional stage
- Other major, readily discernable patterns

Within one week of completion of the rapid review, the results will be communicated to MWRA via an e-mail summary of the survey.

B2.2.4 *Hard-bottom Videotapes and Still Images Collection*

The annual ROV survey of the nearfield hard-bottom environment will examine a series of waypoints along transects (Figure 5). For HOM6, the ROV to be used will be an Outland Technology "Outland 1000" equipped with an UWC-360D, low-light, dual camera on 360° tilt. One video camera will record color (480 line, 0.01 lux) and a second camera will record black and white (600 line, 0.003 lux). Still photographs will be taken by a 35-mm camera (a digital camera may be substituted) mounted on the frame. This system has been used successfully since the 2005 hard-bottom survey. 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 20–30 minutes of video footage will be recorded along randomly selected headings. Along this route, still photographs will be taken as randomly as possible until 36 images have been acquired. At waypoints including an outfall diffuser, approximately 50% of the effort will be devoted to 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 recording and 35-mm slide (or digital) exposure will be recorded as an "event" on the NavSam© system. The time that is displayed on the video monitor (and recorded on the DVD and 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, DVD, CD, and any duplicated media. Each roll of film will be labeled immediately after processing and 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 the same location is filmed 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 (or still digital images) provide high-resolution for a more detailed analysis. The still photographs also allow direct comparison with the historical hard-bottom data.

B3. SAMPLE HANDLING AND CUSTODY

B3.1 Sample Handling

Handling of sediment samples while in the field, including storage requirements, is described in Tables 10 and 11 above.

Following each benthic survey, the infaunal samples, stored in sturdy coolers, will be driven by a team member to the ENSR office in Woods Hole where they will be readied for shipping. These samples, preserved in 10% formalin, can be shipped by FedEx ground or 2-day express delivery. The lids on the plastic sample jars will be taped and the jars inserted into large zip-locked or tied plastic bags lined with absorbent padding. ENSR will ship all sediment grab samples obtained on the harbor benthic (Task 5.1) and outfall benthic (Tasks 6.1 and 6.2) surveys for benthic faunal analysis to Cove Corporation in Lusby, Maryland, where the samples will be transferred to ethanol, and the organisms picked from the samples and sorted into major taxonomic groups. All acceptable infaunal samples will be processed.

The sediment chemistry samples collected during the harbor benthic (Task 5.1) and outfall benthic (Tasks 6.1 and 6.2) surveys must be kept cold or frozen as described in Tables 10 and 11. Following the completion of the joint surveys, an ENSR survey team member will hand carry the sediment chemistry samples directly to MWRA's DLS in Winthrop, Massachusetts. The survey team will keep DLS informed as to the expected delivery time and laboratory personnel will be asked to stay until the samples are received (Yong Lao, MWRA, pers. comm.). All samples will be kept on ice in coolers during transport. If circumstances dictate that the samples must be shipped to DLS, they will be shipped by FedEx Overnight Express. In that case, the samples that were frozen after collection will be placed on dry ice with protective layers of foam or bubble wrap to ensure that they remain intact and frozen during shipment.

B3.2 Sample Custody

B3.2.1 *Sample Tracking*

Sample custody will be tracked through sample labels (Figure 6), station logs (Figure 7), and chain of custody (COC) forms (Figure 8).

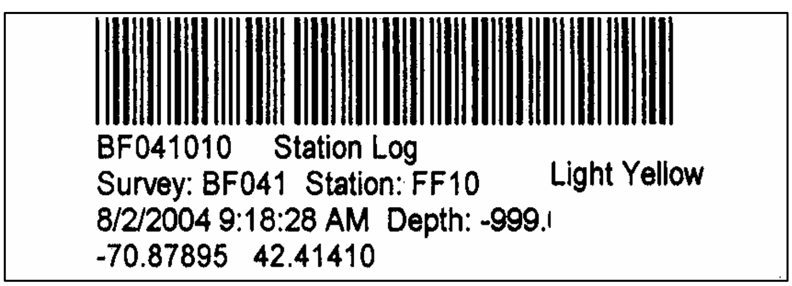

Figure 6. Example of an Infaunal Sample Label.

STATION LOG
For Benthic Sediment Grab Samples
Project Name: MWRA Harbor and Outfall Monitoring – Contract S453B

SURVEY: **BC081** STATION ID: **NF24** TIME ON STATION:____________________ STATION DEPTH (M):____________________DATE:______________________		Weather:___________________________ Recorded By:___________________________
Comments	Sample ID Label	Field Measurements
		Grab Size: 0.04-m² 0.1-m²
		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-m² 0.1-m²
		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-m² 0.1-m²
		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-m² 0.1-m²
		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 7. Example of a Station Log Form.

MWRA Harbor and Outfall Monitoring Program

Contract No. OP-44B

Example of Sample Custody Form

Today's Date : 08/01/06 9:30:00 AM

Chain-of-Custody # : BC061-TC-0006
Survey ID : BC061
Analysis ID : TC
Analysis Description : TOC

Laboratory : Department of Laboratory Services
MWRA
190 Tafts Avenue
Winthrop, MA 02152
Dr. Yong Lao
Ph: (617) 660-7800
FAX: (617) 660-7960

Bottle ID :	Bottle ID :	Sampling Date :	Station ID :	Ck 1	Ck 2	Ck 3	Ck 4
	BC0610E1TC1	08/01/06 10:06:39 AM	FF10				
	BC0610ECTC1	08/01/06 10:47:50 AM	FF10				
	BC0610EETC1	08/01/06 10:59:23 AM	FF10				
	BC0610F6TC1	08/01/06 11:35:14 AM	NF08				
	BC0610F8TC1	08/01/06 11:47:34 AM	NF08				
	BC0610FATC1	08/01/06 12:12:44 PM	NF08				
	BC061100TC1	08/01/06 12:48:56 PM	NF24				
	BC061101TC1	08/01/06 12:56:47 PM	NF24				
	BC061102TC1	08/01/06 1:06:20 PM	NF24				
	BC061106TC1	08/01/06 1:27:23 PM	NF22				
	BC061107TC1	08/01/06 1:36:57 PM	NF22				
	BC061108TC1	08/01/06 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 8. Example of a Chain-of-Custody Form.

There will be two formats for sample labels. For infaunal samples and media generated by the hard-bottom survey, the format used during the HOM4 and HOM5 monitoring programs will be used. For infaunal samples, 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 BF061, with "BF" indicating that it is a farfield benthic survey, "06" 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 infaunal sample 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 13 for the two letter codes).

For sediment chemistry samples that will be processed by MWRA's DLS, a second format will be used. DLS will generate *Container-IDs* using the Laboratory Information Management System (LIMS), the data management program used by DLS. Where there are multiple grabs per station, different *Container-IDs* will be assigned to each replicate; however, the location codes will be the same and replicates can be matched using the collection time, which is recorded on the sample bottle at the time of collection. These sample IDs will be e-mailed to Battelle prior to the survey and will be loaded into the NavSam© software program prior to the survey by Battelle Data Management. The *Container-ID* format consists of an 8-digit number followed by a hyphen and two more digits. The first eight characters of the Container-ID are the Sample ID. The first two digits denote the year. The last two digits denote the analysis that will be performed. The Battelle loading operation will tell NavSam© which C*ontainer-ID* corresponds to which specific analysis.

The NavSam© software produces two labels (Figure 6) for each bottle, one for the bottle and the second to be affixed to the Station Log (Figure 7). All data reporting will be keyed to MWRA'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 7) 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, aRPD, and general descriptions. These sheets will remain in the survey logbook and will be maintained in the project files. During field collection, COC forms (Figure 8) 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 unacceptable grabs will be placed on the back of the station logs.

Table 13. Analysis Codes Used in Bottle ID.

Analysis Code	Description	Laboratory
RS	Rapid SPI Analysis	Diaz
FA	Infauna	Cove/ENSR
SP	SPI Data	Diaz
BV	Benthic Hard-bottom Video	Hecker
BP	Benthic Hard-bottom Photos	Hecker

B3.2.2 *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. COC forms generated by the NavSam© system (Figure 8) will accompany the samples. One complete (copied) set of the infauna COC forms will be included in each shipping container and the original COC forms will be returned to ENSR after the samples have been logged in at Cove. After the samples are sorted, Cove will return the appropriate specimens to ENSR for identification using its own COC transfer forms (Appendix B).

Sediment chemistry samples will be in the custody of an ENSR survey team member from collection until they are transferred to DLS.

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 form 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. The custodian will verify that the custody seals on the cooler are intact and include this information in the laboratory tracking system. The laboratory sample custodian will then 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, and complete and sign the COC form so that transfer of custody of the samples is complete. Any discrepancies between sample labels and transmittal forms, the condition of the samples upon receipt, and any unusual events or deviations from the QAPP will be documented in detail on the COC, and the ENSR Task Manager and Project Manager notified. Copies of completed custody forms will be faxed back to the ENSR Task Manager, Stacy Doner, within 24 hours 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 and verification that the custody seals were intact, will follow by mail within one week. The signed original custody forms will be retained in the ENSR project files.

All original SPI field data sheets and associated media (video and digitally formatted media) will be generated by and remain in the custody of the senior scientist from Diaz and Daughters. Similarly, all original data from the yearly ROV surveys will be generated and maintained by Dr. Hecker of Hecker Environmental.

B3.2.3 *Sample Archival Policies*

The types of materials that may be archived under this contract include sample residues, a reference collection, and other infaunal specimens. Infaunal sample residues will be held until the data report is accepted by MWRA, and then may be discarded. Reference collection specimens will be retained for the duration of the project and then returned to MWRA or another designated laboratory. Reference collection specimens 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. Other infaunal specimens may be retained by the contracting laboratory indeterminately as there is no contractual obligation regarding those specimens.

B4. ANALYTICAL METHODS

The parameters to be measured during the various benthic monitoring tasks can be characterized as macrobiological and sedimentological (habitat properties) (Table 14). Macrobiological parameters are based on (1) the species-level identifications of the soft-bottom infauna and (2) identifications of epibenthic macrofauna seen in the hard-bottom study; these parameters include community measures such as abundance (or percent cover), numbers of species, and diversity. The general nature of the infaunal community is measured during the SPI studies, which also generate information about sediment geophysical properties, including sediment grain size and other sediment habitat properties.

B4.1 Soft-bottom Infaunal Analysis

At Cove Corporation, samples will be rinsed with fresh water over 300-µm-mesh screens to remove any broken-up mud casts and transferred to 70−80% ethanol for sorting and storage (Cove 2008, Appendix D). 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 aliquots of the sample will be placed in glass dishes, and all organisms, including anterior fragments of polychaetes, will be removed and sorted to major taxonomic categories such as polychaetes, arthropods, and mollusks. Sorting will be done under a dissecting microscope.

After samples have been completely 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. Identifications will be made to the lowest practical taxonomic level, usually species. Dr. James A. Blake (ENSR) will provide general oversight of the taxonomy of the soft-bottom fauna identified on this project. Primary taxonomic responsibilities are as follows:

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

Table 14. Benthic Survey Sample Analyses.

Parameter	Laboratory	Unit of Measurement	Method	Reference
Infaunal Analysis	Cove Corporation, ENSR	Count/species (# per grab)	ID and Enumeration	Section B4, this QAPP
Sediment Profile Images	Diaz and Daughters	Various (see Table 15)	Various	Section B4, this QAPP
Hard-bottom	Hecker Environmental	Various	Various	Section B4, this QAPP
Organic Analyses				
Polycyclic Aromatic Hydrocarbons (PAH)	DLS*	µg/kg dry wt.	GC/MS-SIM	Prasse *et al.* 2007
Polychlorinated Biphenyls (PCBs)	DLS	µg/kg dry wt.	GC/MS-SIM	Prasse *et al.* 2007
Pesticides	DLS	µg/kg dry wt.	GC/MS-SIM	Prasse *et al.* 2007
Metals Analyses				
Major Metals (Al, Fe)	DLS	% dry wt.	FAA	Prasse *et al.* 2007
Trace Metals (Ag, Cd, Ni, Pb) (Cr, Cu, Zn) (Hg) (Pb)	DLS	mg/kg dry wt.	GFA FAA CVAA GFA	Prasse *et al.* 2007
Ancillary Physicochemical and Microbiological Parameters				
TOC	DLS	%C by dry weight	Infrared detection	Prasse *et al.* 2007
Sediment Grain Size**	DLS	% dry weight	Folk (1974)	Prasse *et al.* 2007
Microbiology:*** *Clostridium perfringens*	DLS	Spores/g dry weight	Emerson and Cabelli (1982)	Prasse *et al.* 2007

* MWRA's Department of Laboratory Services
** Sediment grain size will be analyzed by Azimuth Geo Services, Austin, Texas.
***_C. perfringens_ will be analyzed by BAL Laboratory, Cranston, RI.

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

MWRA has established a project-specific reference collection, which will be used by project taxonomists to ensure comparability of the taxonomic identifications performed under HOM6 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.

As taxa not previously identified during the program are encountered, they 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 or its designee upon submission of the final reference collection status report in June 2010.

B4.2 Sediment Profile Image Analysis

Dr. Robert Diaz of Diaz and Daughters will perform the SPI analysis. After field collection, analysis will continue with a reanalysis of the plan-view video previously examined in the field (section B.2.2.3). A visual analysis including the same parameters as estimated from the video SPI will be made for the still images. The final rapid "quick look" analysis based on this review of both video and still images will be completed within three days of the completion of field work.

Each image file will be labeled with station and replicate data. The first analytical step is accomplished by visually examining the images and recording all observed features into a preformatted, standardized spreadsheet file. The parameters to be measured are summarized in Table 15 and discussed in more detail in Appendix E. Further details about these analyses can be found in the standardized image analysis procedures of Viles and Diaz (1991).

The videotapes also are analyzed visually, with all observed features also recorded into a preformatted, standardized spreadsheet. Adobe Photoshop™ is used to preprocess the images (*e.g.*, 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 of each image is 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 Excel. SPI results, in the form of an Excel spreadsheet generated by the image-analysis program, will be delivered to Battelle for loading into the database loading application.

Table 15. Parameters Measured from Sediment Profile Images.

Parameter	Units	Method[1]	Description
Sediment Grain Size	Modal phi interval	V	An estimate of sediment types present. Determine by 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.
Methane/Nitrogen Gas Voids	Number	V	Count
Epifauna	—	V	If present, note and identify
Tubes Type Density	 — Number	 V V	 Identify as amphipod or polychaete Estimate number (none, few, some, many)
Surface Features Pelletal Layer Bacterial Mats	 — —	 V V	 Note if present If present, note color
Infauna Visible Infauna Burrow Structures Feeding (Oxic) Voids Successional Stage	 Number — Number —	 V V V V	 Count, identify Count Count Identify
Organism Sediment Index	—	CA	Derived from RPD, Successional Stage, Voids (Rhoads and Germano 1986)

[1] V: Visual measurement or estimate
CA: Computer analysis

B4.3 Hard-bottom DVDs, Videotapes, 35-mm Slides, and Digital Images

The 35-mm film will be mounted, labeled (cruise, date, roll number, frame number, and waypoint), and scanned onto CDs immediately after the cruise. If still images are acquired digitally, those files will be transferred onto a laptop during the cruise and onto CDs immediately after the cruise. Slides and video will then be transferred to Dr. Barbara Hecker for analysis.

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

- Primary and secondary substrate
- Degree of sediment drape
- Estimated percent cover of crustose pink algae (coralline algae)
- Relative abundance of hydroids, spirorbid/barnacle complex, the red alga *Ptilota serrata*
- Occurrence and abundance of all recognizable taxa

Data collected from the still photographs are coded using a mix of alpha and numeric codes and entered directly into a computer using a customized Access loading application. At this point the data are stored in a condensed database. At the completion of slide analysis, the database is run through a customized program to produce an exceptions report that highlights invalid data parameters and then through another program to produce an expanded database in Excel format. Summaries for each waypoint are then generated and proofread. If errors are found, the photographs are rechecked and the database is corrected. The Access loading application is then transferred to Battelle for data management.

The video footage will be viewed by Drs. Barbara Hecker and Pamela Neubert for habitat characteristics and heterogeneity (substrate types, sediment drape, and habitat relief) and for biotic components. The data from the video will be entered on data sheets. After viewing the slides from each waypoint, the video data sheets will be updated with regard to degree of sediment drape, relative amount of coralline algae, and relative amount of spirorbids and/or barnacles—all parameters that are exceptionally difficult to determine from the video footage alone. This permits cross-referencing between the greater areal coverage of the video and the higher visual resolution of the stills. The video data will then be entered into the customized Access database (loading applications) that is then run through a program that produces an exceptions report and another program that produces an Excel database for data proofing. The Access database is then transferred to Battelle for data management.

B5. QUALITY CONTROL

B5.1 Sampling

B5.1.1 *Navigation*

Navigation will be performed using Battelle's sampling and navigation computer (NavSam©) software and computer system. An operator expert in this system will be provided by Battelle and accompany all surveys.

<u>Accuracy and Precision</u>
For HOM6, the Battelle onboard sampling and navigation computer (NavSam©) software uses the differential Global Positioning System (dGPS) for station positioning. The reporting units for the dGPS navigation are degrees, the range is coastal, and accuracy and precision are both 1.8 X 10^{-5} degrees (Libby *et al.* 2008).

Comparability

All sampling positions will be comparable to positions obtained by previous MWRA monitoring activities as well as by other researchers that have used or are using dGPS at these stations. The station locations listed in Tables 2, 3, and 5 are targets and at each sampling station the vessel is positioned as close to the target coordinates as possible. A station radius of up to 30 m is acceptable for benthic sediment sampling and the display on the NavSam© computer screen is set to show a radius of 30 m around the target station coordinates (six 5-m rings) to facilitate complying with this requirement. For the hard-bottom surveys, the start and end points of each transect are recorded together with the exact position of each still photograph. Upon arriving at station, the *Event* key on the navigation computer is pressed to record station arrival time. The 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.

Completeness

Battelle's navigation software system outputs navigation positions at intervals of 2 seconds. The software system will display all position fixes and save these fixes in an electronic file during sampling operations. The time interval requirement for obtaining positions during sampling for this project is 1 minute. Thus, even if a few bad data streams from the dGPS navigation system to the computer are experienced, the software will provide enough position fixes within each 1-minute period for 100% collection. During transit between stations, the software system will save vessel coordinates in an electronic file every 5 minutes. These data quality requirements and assessments for navigational data are also described in the water column monitoring QAPP (Libby *et al.* 2008).

B5.1.2 *Grab Sampling*

All sediment samples to be used for faunal analyses 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, a dedicated grab sample, collected by the 0.04-m^2 grab sampler, will provide adequate quantities of sediment for grain size, TOC, and microbiology. Sediment samples for physical and chemical analyses will be collected with a Kynar-coated 0.1-m^2 Ted Young-modified Van Veen grab. 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
- 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 acceptable at the discretion of the chief scientist. Mild over-penetration may be acceptable 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 of the grab

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

B5.1.2.1 *Benthic Infauna*

Accuracy, Precision, and Representativeness
There will be no subsampling. Consequently, the accuracy, precision, and representativeness of the sampling will depend upon the factors discussed above under Section A7.1.2.

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 reported for all years. 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 specified in the HOM6 contract for each survey. The entire sample will be sieved and all material retained on the 300-µm-mesh screen will be fixed for analysis.

B5.1.2.2 *Sediment*

Accuracy, Precision, and Representativeness
These qualities will be assured by the sampling scheme (see B.5.1.1 Grab Sampling above) and by ensuring that samples are well homogenized and subsampled and preserved following methods detailed in Section B2.2.2.

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 specified in the HOM6 contract for each survey.

B5.1.3 *Sediment Profile Imagery*

The DQOs for the field collection of the SPI will be met by following several procedures. Proper assembly and operation of the surface video and digital camera SPI system will ensure that images obtained are clear and of high quality. Real-time monitoring of the surface video will permit some degree of evaluation of the potential quality of the deployment. Prior to every field deployment, all video/SPI components are assembled 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 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 digital SPI camera) will be monitored in real time on deck via the video monitor.

Accuracy, Precision, and Representativeness
Accuracy and precision will be ensured by using properly functioning equipment and real-time monitoring of images as described above to acquire clear and analyzable images. 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 dGPS for navigation will allow re-occupation of previously sampled sites.

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

Completeness
To ensure that all required images are collected at all planned stations, the digital image 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.

B5.1.4 *Hard-bottom ROV Survey*

The DQOs for the field collection of the hard-bottom survey will be met by adhering to the following measures. Real-time viewing of video images during the surveys will ensure that the images will be of sufficient quality to achieve the objectives of the survey. DVD and EHG (extra high grade) magnetic videotapes (VHS format) will be used for this project. All equipment will be cleaned and checked thoroughly before deployment.

Accuracy, Precision, and Representativeness
Accuracy and precision will be ensured by using properly functioning equipment and real-time monitoring of images as described above to acquire analyzable images. Hard-bottom transects and waypoints to be recorded and photographed are those that were selected by MWRA to be representative of the hard-bottom habitats in the vicinity of the outfall.

Comparability
The field methods used will be similar to those followed in previous surveys. The same transects as those occupied since the beginning of the program will be followed; this design was only slightly modified by the deletion of two stations (T4, stations 1 and 3) in 2003 and the addition of two stations (T11-1 and T12-1) in 2005. All transects will be occupied so that the nature of the epifauna and sedimentary environment in the hard-bottom area can be compared to that recorded on previous surveys.

Completeness
All requisite transects (and their waypoints) will be recorded on DVD and videotape and photographed. Approximately 20 minutes of video and images from a full roll of film (36 exposures) will be collected at

each waypoint. In the event that a digital camera system is substituted for the film camera, 36 digital still images will be collected at each waypoint. ROV operations will be monitored by watching the video in real time during the survey. The DVDs and videotapes will be checked in the field to ensure that the video images are recorded. The still photographs, if film is used, will be developed in the field as they are collected to make sure that the camera is functioning properly and that the images are of high quality.

B5.2 Laboratory Activities

B5.2.1 *Infaunal Analysis*

<u>Accuracy</u>
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.

<u>Precision</u>
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 QC analysis. Samples will be divided into batches of approximately 10 samples. 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.

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

<u>Completeness</u>
All samples collected are scheduled for analysis. At those stations where three replicates will be collected, loss of one sample will still permit data to be obtained for that station. One hundred percent completeness is expected.

<u>Comparability</u>
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 the MWRA Reference Collection. 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 the ENSR Marine and Coastal Center and turned over to the MWRA, or the MWRA's designee, at the end of the project.

B5.2.2 *Sediment Profile Image Analysis*

<u>Accuracy</u>
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. Once the system is on and functioning, a standardized scale slide is measured to ensure that the linear measurements made on the profile images are accurate.

Precision

Even with the most careful control, there may be variations in lighting that cause subtle color differences among images. To correct this problem, the first and last picture taken each field day is of a standard color card (JOBO brand) 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. Color variations then can be accounted for during the computer image analysis.

Completeness

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 performed for the MWRA program. However, slight variation in the manner in which the operator examines the slide may occur. This may result in a slight variation of image areas analyzed within and between slides. To control for operator error, 10% of all slides will be reanalyzed and the results compared to previous results. If any discrepancies with the original analysis are found then all images will be checked and reanalyzed.

Representativeness

Representativeness is defined by the stations selected in the baseline.

B5.2.3 *Hard-bottom Video and 35-mm Slide (or Digital Still Image) Analysis*

Accuracy and Precision

Each slide (or digital image) will be projected and analyzed by Dr. Barbara Hecker. Data to be collected for each still image includes: primary and secondary substrate type, degree of sediment drape, estimated percent cover of coralline algae, estimated relative abundance (*i.e*., rare, few, common, abundant, or very abundant) of hydroids, spirorbid/barnacle complex, *Ptilota serrata*, and counted abundance of other identifiable biota. Degree of sediment drape and percent cover of coralline algae will be determined by Drs. Barbara Hecker and Pamela Neubert. 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 (*e.g*., anemone, fish).

Video footage will be examined by Drs. Barbara Hecker and Pamela Neubert for a 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 low 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; Williams *et al*. 2005) to allow comparisons between the previously collected baseline data and the monitoring data to be made. The method of analysis of the still photographs is identical to that used previously and allows direct comparisons. The method of analysis for the video images is similar enough to previous studies to permit 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 (1) strength of tidal currents determining the direction in which the ROV can maintain a heading, (2) mobility of the ship during station occupation due to surface currents and wind, (3) bottom visibility (moving in a down-current direction frequently causes reduced visibility due to sediment clouds), (4) bottom topography (going over every boulder could keep the ROV too far off bottom), (5) tether length (the ROV could be at the end of the tether before the requisite footage has been collected), and (6) the requirement that the ROV be a requisite distance from the bottom in order to acquire usable still photographs. Within these constraints, representative visual images of each area will be obtained.

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 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.

B5.2.4 *Sediment Chemistry*

All sediment samples scheduled to be analyzed for organic contaminants and metals in 2008 and 2009 will be analyzed by MWRA's DLS. The DQOs for the DLS are provided in Prasse *et al.* (2007).

B5.2.5 *Physicochemical and Microbiological Parameters*

Sediment samples collected in 2008 and 2009 will be analyzed for TOC by DLS; the DQOs for TOC testing are provided in Prasse *et al.* (2007).

In 2008 and 2009, sediment grain size and *Clostridium perfringens* analyses will be performed by Azimuth Geo Services and BAL Laboratory, respectively, under contract to DLS. DQOs for grain size and *Clostridium* analyses are provided in Prasse *et al.* (2007).

No field-collected QC samples, including field duplicates, or equipment and field blanks for sediment chemistry are required by the MWRA, nor have they been in past harbor and outfall monitoring programs. Adequate sediment is collected for the analytical laboratories to perform the required MS/MSD analyses.

B6. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

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

B6.1 Laboratory Equipment

Microscopes used for sorting of faunal samples and taxonomic identification of specimens are cleaned and maintained as needed.

For HOM6, no analytical laboratory instruments are covered by this QAPP. For details of laboratory equipment testing, inspection, and maintenance pertinent to the sediment chemistry analyses performed by DLS on samples collected during HOM6, see Prasse *et. al.* (2007) and updates as issued by DLS.

B6.2 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. This check 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.

Proper system functioning (*e.g.*, penetration of prism, flash from digital SPI camera) will be monitored in real time on deck via the video monitor. Any misfires or improper camera operation can then 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 digital cameras will be carried on each survey.

B6.3 Hard-bottom ROV Video and 35-mm or Digital Cameras

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

B7. INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

B7.1 Navigation Equipment

Details of the calibration procedures and preventative maintenance for the navigation equipment can be found in the Water Column Monitoring QAPP (Libby *et al.* 2008).

B7.2 Laboratory Equipment

For HOM6, no analytical laboratory instruments are covered by this QAPP. For details of laboratory instrument and equipment calibration schedules pertinent to the sediment chemistry analyses performed by DLS on the samples collected during HOM6, see Prasse *et. al.* (2007) and updates as issued by DLS.

B8. INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

For HOM6, critical supplies for field activities will be the responsibility of the chief scientist and NavSam© operator (Table 16).

Table 16. Supplies, Acceptance Criteria, and Responsibility for Critical Field Supplies.

Critical Supplies and Consumables	Inspection Requirements and Acceptance Criteria	Responsible Individual
Jars for infaunal samples	Visually inspected for cracks, breakage, and cleanliness. May be reused.	Chief Scientist
Sample bottles for sediment chemistry delivered by DLS	Visually inspected upon receipt for cracks, breakage, and cleanliness. Must be accompanied by certificate of analysis.	Chief Scientist
Chemicals and reagents	Visually inspected for proper labeling, expiration dates, appropriate grade.	Chief Scientist
Sampling equipment	Visually inspected for obvious defects, damage, and contamination.	Chief Scientist
Navigation instruments	Functional checks to ensure proper calibration and operating capacity.	NavSam© Operator

If unacceptable supplies or consumables are found, then the Chief Scientist will initiate corrective action. Corrective measures may include repair or replacement of measurement equipment, and/or notification to vendor and subsequent replacement of defective or inappropriate materials. All actions will be documented in the project files.

B9. NONDIRECT MEASUREMENTS

Nondirect data (historical reports, maps, literature searches, and previously collected analytical data) may be used in the preparation of synthesis reports (Task 11). These data may come from sources such as

- Prior MWRA harbor and outfall monitoring program results
- Results of other MWRA studies including water quality monitoring and flux study data
- Pertinent data collected by other agencies, such as USGS bathymetry data and NOAA weather records, as appropriate

B10. DATA MANAGEMENT

Figure 9 illustrates the benthic monitoring data processing strategy for data entry into the MWRA EM&MS and accessing the data for various reports. The data from the program will be compared by MWRA to the caution and warning threshold parameters included in the MWRA Contingency Plan (MWRA 2001).

B10.1 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 CD-ROM backups of all electronic data generated each day. Each CD 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 "Set 2" will be generated. The backup disks will be in the custody of the Battelle field manager. The original will be delivered to the ENSR project manager. Field data will receive a quality assurance review at Battelle prior to delivery the project Data Manager, Greg Lescarbeau.

ENSR, Battelle, and all other laboratories (except Ocean's Taxonomic Services) involved in this project will produce electronic data under this task. Each laboratory is responsible for the internal custody of their electronic data until they are forwarded to the ENSR laboratory task manager. After the data packages are checked for completeness, the electronic files, loading applications for infauna and hard-bottom, and an Excel spreadsheet for SPI data, will be delivered to Battelle for loading as described in Section B10.3 below.

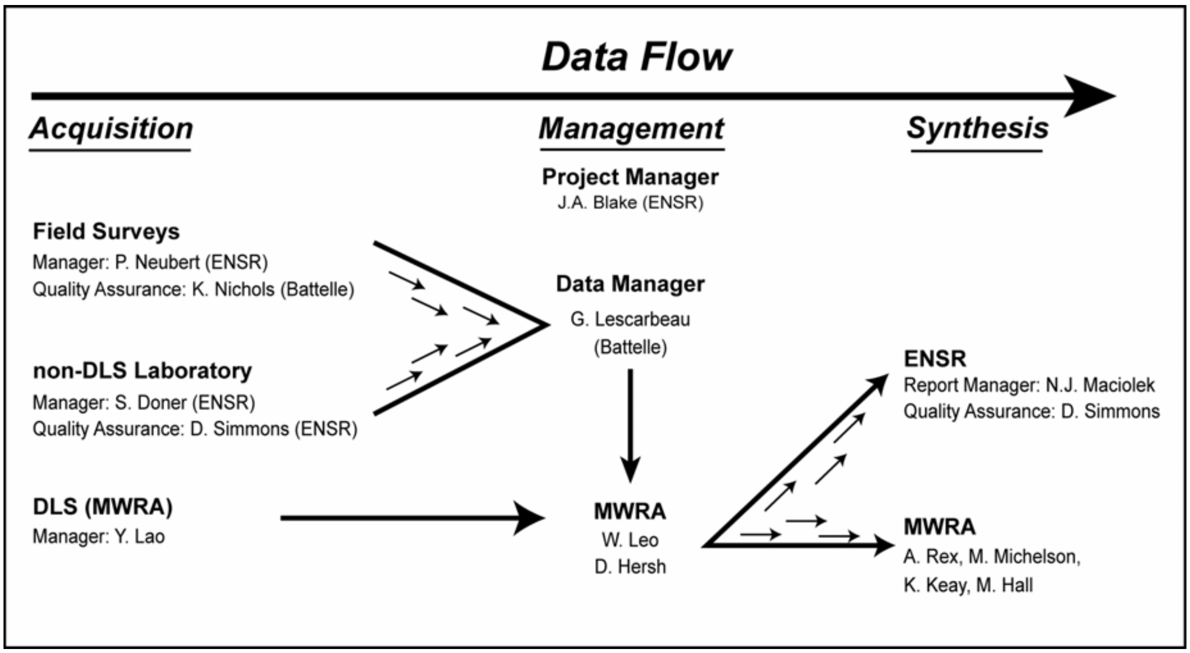

Figure 9. Overview of the Data Management Strategy for Benthic Monitoring

B10.2 Laboratory Data and Data Reduction

All data generated by ENSR or other benthic team laboratories will be either electronically transferred from the instrument or manually read from the instrument display (optical field of a microscope or video monitor) and entered into a loading application provided by the Battelle Data Management team or other appropriate database format (Excel spreadsheet in the case of SPI data). Data entered into laboratory notebooks or data sheets will be manually entered into the loading application.

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. For HOM6, only the SPI data discussed below requires some manipulation before being submitted to the Battelle Data Management team. All data reduction will be performed electronically, either by the instrument software or in a spreadsheet, and will be validated according to procedures described in Section D2.

The format for final data submission is described below. All laboratory replicates except chemistry will be reported as mean sample values and all field replicates will be reported as individual sample values. For chemistry, the first replicates value will be reported.

B10.2.1 *Infaunal Analysis*

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

B10.2.2 *Sediment Chemistry Analysis*

No sediment chemistry analyses will be performed as part of this contract. Details regarding DLS's data reduction procedures are provided in Prasse *et al.* (2007).

B10.2.3 *SPI Analysis*

After visual and computer image analyses are completed, a standard set of parameters (Table 10) taken from both analyses is combined and tabulated into an Excel spreadsheet for delivery to Battelle.

SPI data are used to summarize environmental conditions through the calculation of the Organism-Sediment Index (OSI). The OSI (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) denotes habitats that have little or no dissolved oxygen, no apparent evidence of surface or subsurface fauna, 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 17. For SPI data collected from the nearfield, RPD values will be compared by MWRA to the threshold levels (MWRA 2001, Appendix A).

B10.2.4 *Hard-bottom Analysis*

There is no manipulation of hard-bottom data prior to the submission of the hard-bottom data loading application.

Table 17. 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

B10.3 Analytical Data Sets Submitted to Battelle for Loading into the MWRA Database

All benthic laboratory data to be loaded into the EM&MS will be submitted to Battelle by ENSR in electronic format. The field data will be available for loading by Battelle directly from the computer on the ship. Battelle will provide a loading application to the laboratories conducting the infaunal and hard-bottom analyses. To increase data quality and data flow efficiency, the loading application will include the collection data. SPI data will be delivered as an Excel spreadsheet generated by the laboratory’s image analysis software; these data will be uploaded into the database loading application at Battelle. Formats for delivering electronic data to MWRA are included in the HOM6 contract. The current delivery formats are available from the data task managers at Battelle (Greg Lescarbeau) or at MWRA (Wendy Leo). Battelle’s data management staff will process all data into the appropriate HOML format as defined in the contract and deliver these data to ENSR for review. These submissions then will be delivered by ENSR to MWRA via email in the absence of the HOML application. Once the HOML application goes online, ENSR will submit data electronically through the application.

B10.3.1 *Navigation and Sample Collection Data*

Navigation and sample collection data will be processed on-board the survey vessel and will be ready for loading upon arrival at Battelle. A database application developed as part of the NavSam© system will query the on-board database tables for the fields necessary to populate the *Event, Station, Sample,* and *Bottle* tables. The data will be submitted to EM&MS in the HOML format. All database constraints developed by MWRA will be applied to the tables so that the data are checked during insertion.

B10.3.2 *Laboratory Analytical Data*

The data reporting procedure for analytical data will begin with the Battelle Data Management team. Field collection data will be delivered to the Battelle data manager as an Access database. Sample IDs and analytical protocols will be extracted from this database and used to populate a loading application specific for each analytical laboratory. A separate loading application will be prepared for each data deliverable.

Loading applications for the benthic infaunal and hard-bottom analytical laboratories will be sent to those laboratories by Battelle for data entry. When data contributors (Cove, ENSR, and Hecker Environmental) open the database, they will be presented with a form that already contains the Sample IDs and spaces to enter data, either by using pull-down menus or by direct entry (Figure 11). All data entries are constrained by the rules of EM&MS. Errors are caught on entry and fixed by the data contributor. Primary keys, a field or set of fields that uniquely identify each record stored in the table, are in place so that duplication cannot occur.

B10.3.2.1 *Benthic Infaunal Laboratories (Cove Corporation and ENSR)*

Users of the benthic infaunal loading application will not see a form populated with all the species names, but must choose the proper species code from a pull-down list (Figure 10). Selection of the proper code automatically enters the 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, including data submitted by Ruff Systematics and Oceans Taxonomic Services, into the application, perform another QC check, and transmit the loaded database to Battelle.

B10.3.2.2 *Sediment Chemistry Laboratory (MWRA's DLS)*

Sediment chemistry data will be loaded into DLS' LIMS (Prasse *et al.* 2007) and transferred to EM&MS by MWRA ENQUAD database staff using established procedures for checking, surrogate correction, and transfer. Users will communicate to DLS the formats required for their analytical procedures.

B10.3.2.3 *Hard-bottom-Analytical Laboratory (Hecker Environmental)*

Users of the hard-bottom loading application see a form that uses a combination of pull-down menu choices (for example, substrate type) plus a direct entry table for species codes and abundance. After an extensive QC check, this loaded application is also transmitted to Battelle.

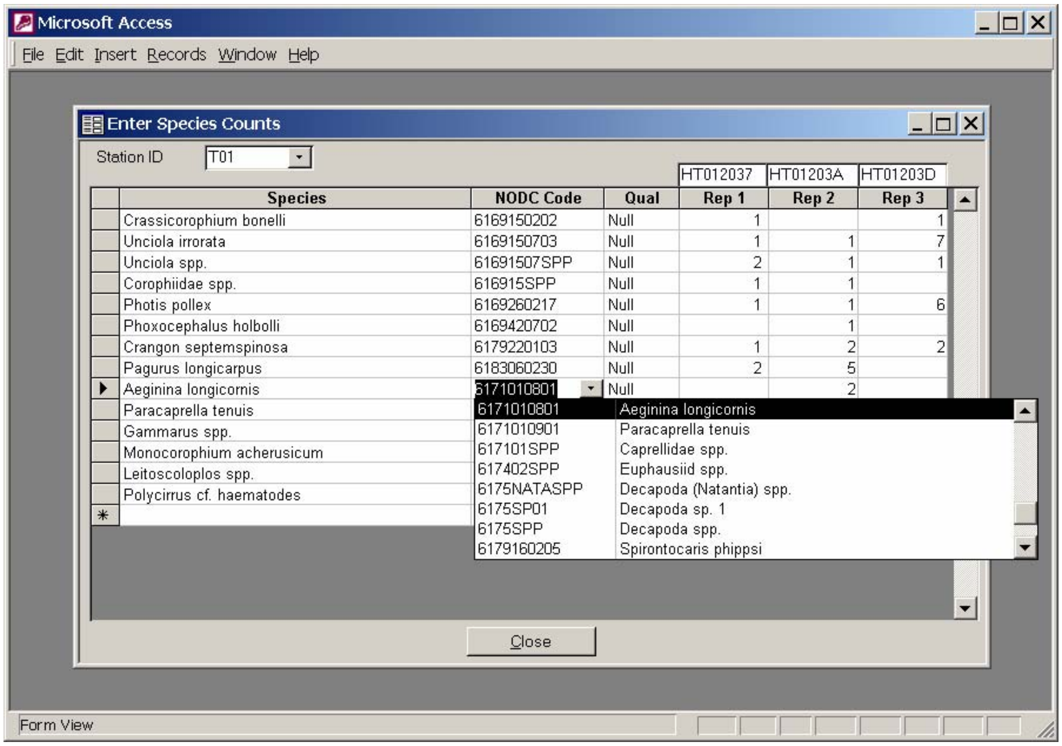

Figure 10. Example of Loading Application Data Entry Form

B10.3.2.4 *Sediment Profile Imaging Analysis Laboratory (Diaz & Daughters)*

Battelle will retain the SPI loading application and populate the application, including qualifiers, using data from the Excel spreadsheet submitted to ENSR by the SPI analytical laboratory. Data tables generated by the SPI loading application will be sent to ENSR for review prior to submission of the database to MWRA.

B10.3.3 *Loading Application Functions and Database Codes*

The loading application provides the laboratory with many functions, including QC checks (SPI only), hardcopy and exceptions reports, and analysis summary. The hardcopy data report function allows the laboratory to create a hardcopy report to check for entry errors and to include as part of the data deliverable to ENSR, Battelle, and MWRA. The QC checks are comprised of the applicable sections of EM&MS and constraints scripts. The exceptions report checks the data that were expected against the results loaded. The data contributor must account for any entries in the exception report. The analysis summary report produces a report of the number of analyses by analyte. A copy of this report is included with the data deliverable to MWRA and with the invoice for the analyses.

Completed loading applications (for infauna and hard-bottom data) and the SPI data spreadsheet are sent initially to ENSR for review along with the QA statement, QA/QC corrective action log, and hardcopy report. The completed loading applications and SPI data spreadsheet are then transmitted electronically to Battelle data management along with a hardcopy report of the data. Battelle will process the electronic data and provide ENSR with comma separated variable (CSV) files in the HOML format along with the electronic output of database checks, summary statistics, any notes on loading issues, any outstanding data issues (*e.g.*, sampling coordinates outside contract target range) and documentation on any missing or 's' qualified data. ENSR will deliver the CSV files and the electronic output of the checks via e-mail to MWRA in the absence of the HOML application. Once the HOML application goes on-line, the CSV files will be submitted electronically by Battelle data management and the exception report delivered to ENSR for inclusion in the hardcopy deliverable. ENSR's deliverable for data sets will include a cover letter and data documentation provided in both hardcopy and electronically. The cover letter will include any issues discovered during loading, missing and 's' qualified data, outstanding data issues, planned versus collected tally, measured versus reported tally, and HOML exceptions (when available). Data documentation will include the QA statement.

Within the loading application, the data entered by the laboratory are translated into the correct codes and inserted into database tables that match the structure used by EM&MS. Table 18 shows the qualifiers that may be used with the infaunal, hard-bottom, and SPI results. Table 19 shows the parameters and database codes applicable only to the SPI analysis.

Table 18. Data Qualifiers

Qualifier	Description	Value Reported?
	Value is not qualified	Yes
A	Value above maximum detection limit, e.g. too numerous to count or beyond range of instrument – For SPI this means that the value (i.e. RPD depth) was greater than the penetration depth of the prism.	Yes – The average penetration depth is entered here
e	Results not reported, value given is NULL, see comments field – For SPI this means no image, blank slide.	No
P	Present but uncountable, value given is NULL – For SPI this means that the value could not be estimated from the image.	Yes
p	Lab sample bottles mislabeled - caution data use	Yes
q	Possibly suspect/invalid and not fit for use. Investigation pending.	Yes
s	Suspect/Invalid. Not fit for use	Yes
w	This datum should be used with caution, see comment field	Yes

The hard-bottom codes are listed in Table 20. The hard-bottom PARAM_CODEs and the infaunal abundance SPEC_CODEs are too numerous to list; 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 database manager when requested by Battelle data management.

Additional database codes used for the benthic monitoring task are included in Table 21. A comprehensive list of parameters and database codes for sediment chemical and physicochemical analytes can be requested from the MWRA EM&MS Database Manager, Ms. Wendy Leo. The laboratory will have the ability to add additional codes to describe their results but the new qualifiers will be highlighted in the exceptions 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 has the responsibility for maintaining the code list for the EM&MS.

Table 19. Parameters and Database Codes for SPI Analysis.

Parameter	Param_code	Meth_ Code	Unit_ code	Gear_code
Number of water-filled spaces in sediment that appear to be abandoned feeding voids	ANOXIC_VOID_NUM	WILL02		HULCHER_DIGI
Average penetration	AVG_PEN	WILL02	cm	HULCHER_DIGI
Average depth of the apparent color redox potential discontinuity layer	AVG_RPD	WILL02	cm	HULCHER_DIGI
Number of burrows	BURR_NO	WILL02		HULCHER_DIGI
Number of gas filled spaces in sediment resulting from methanogenesis	GAS_VOID_NUM	WILL02		HULCHER_DIGI
Sediment grain size	GRN_SZ	WILL02		HULCHER_DIGI
Organism-Sediment Index	OSI	WILL02		HULCHER_DIGI
Number of active, water-filled spaces in sediment resulting from sub-surface feeding activity of infauna	OXIC_VOID_NUM	WILL02		HULCHER_DIGI
Maximum penetration depth of camera	PEN_MAX	WILL02	cm	HULCHER_DIGI
Minimum penetration depth of camera	PEN_MIN	WILL02	cm	HULCHER_DIGI
Maximum depth of the apparent color redox potential discontinuity layer	RPD_MAX	WILL02	cm	HULCHER_DIGI
Surface relief across the 15 cm width of the face plate. Calculated as (PEN_MAX – PEN_MIN)	SR	WILL02	cm	HULCHER_DIGI
Infaunal worms counted	SUB_FAUNA_WORMS	WILL02		HULCHER_DIGI
Estimated infaunal successional stage	SUCC_STG	WILL02		HULCHER_DIGI
Features on the sediment surface	SURFACE_FEATURES	WILL02		HULCHER_DIGI
Amphipod tube	TUBE_AMPH	WILL02		HULCHER_DIGI
Polychaete tube	TUBE_POLY	WILL02		HULCHER_DIGI

Table 20. Database Codes[1] for Hard-bottom Analysis.

Type of Data[2]	Code Type	Code	Description
still image	COMMENT_CODE	0	No comment
still image	COMMENT_CODE	01	Partial picture
still image	COMMENT_CODE	02	Matting of sediment drape
still image	COMMENT_CODE	03	Coralline algae being sedimented over
still image	COMMENT_CODE	04	Shell hash
still image	COMMENT_CODE	05	ROV very high
still image	COMMENT_CODE	06	Faunal association
still image	COMMENT_CODE	07	Kodak moment
still image	COMMENT_CODE	08	Poor quality, not usable for counts
still image	COMMENT_CODE	09	Rocks partially buried
still image	COMMENT_CODE	10	Garbage
still image	COMMENT_CODE	11	Too close
still image	COMMENT_CODE	12	Ripples
still image	COMMENT_CODE	13	Lobster trap
still image	COMMENT_CODE	14	High suspended matter
still image	COMMENT_CODE	15	Fogged camera lens
still image	COMMENT_CODE	16	Bad development
still image	COMMENT_CODE	17	Massive settlement of post-juvenile barnacles
still image	COMMENT_CODE	18	Die-off of massive settlements of post-juvenile barnacles
still image	COMMENT_CODE	19	Sediment drape estimated from other images.
still image	COMMENT_CODE	20	Disturbed bottom (1st used in 2007)
still image	SUBSTRATE_CODE (PRIMARY + SECONDARY)[3]	b	Boulders
still image	SUBSTRATE_CODE	c	Cobbles
still image	SUBSTRATE_CODE	cc	Consolidated clay
still image	SUBSTRATE_CODE	cp	Cobble pavement
still image	SUBSTRATE_CODE	d	Diffuser
still image	SUBSTRATE_CODE	db	Diffuser base
still image	SUBSTRATE_CODE	di	Diffuser indent
still image	SUBSTRATE_CODE	dp	Diffuser port
still image	SUBSTRATE_CODE	ds	Diffuser side
still image	SUBSTRATE_CODE	dt	Diffuser top
still image	SUBSTRATE_CODE	g	Gravel
still image	SUBSTRATE_CODE	gp	Gravel pavement

[1] Parameter codes (type of organism) are too numerous to list; they are in the database.
[2] In some cases the meaning of the codes varies depending on the type of data for which it is used.
[3] In the still images, the primary substrate code denotes the most abundant substrate, and the secondary substrate code denotes the second most abundant substrate.

Type of Data[2]	Code Type	Code	Description
still image	SUBSTRATE_CODE	mm	Man made rocks
still image	SUBSTRATE_CODE	mx	Mix
still image	SUBSTRATE_CODE	null	No substrate code given
still image	SUBSTRATE_CODE	rr	Riprap
still image	SUBSTRATE_CODE	s	Sediment (sand)
still image	SED_DRAPE_CODE	c	Clean
still image	SED_DRAPE_CODE	h	Heavy
still image	SED_DRAPE_CODE	l	Light
still image	SED_DRAPE_CODE	lm	Moderately light
still image	SED_DRAPE_CODE	m	Moderate
still image	SED_DRAPE_CODE	mh	Moderately heavy
still image	SED_DRAPE_CODE	vl	Very light
analysis of still image	VALUE_CODE[4]	a	Abundant
analysis of still image	VALUE_CODE	c	Common
analysis of still image	VALUE_CODE	f	Few
analysis of still image	VALUE_CODE	r	Rare
analysis of still image	VALUE_CODE	va	Very abundant
video	SUBSTRATE CODE[5]	b	Boulders
video	SUBSTRATE CODE	b+c	Boulders and cobbles, more boulders
video	SUBSTRATE CODE	b+mx	Boulders and mix, more boulders
video	SUBSTRATE CODE	c	Cobbles
video	SUBSTRATE CODE	c+b	Cobbles and boulders, more cobbles
video	SUBSTRATE CODE	c+mx	Cobbles and mix, more cobbles
video	SUBSTRATE CODE	c+ob	Cobbles and occasional boulders
video	SUBSTRATE CODE	cp	Cobble pavement
video	SUBSTRATE CODE	cp+b	Cobble pavement and boulders, more boulders
video	SUBSTRATE CODE	cp+g	Cobble pavement and gravel, more cobble
video	SUBSTRATE CODE	cp+gp	Cobble pavement and gravel pavement, more cobble
video	SUBSTRATE CODE	cp+mx	Cobble pavement and mix, more cobble pavement
video	SUBSTRATE CODE	cp+ob	Cobble pavement and occasional boulders

[4] Most taxa are reported as percent cover or number of individuals, but some are reported using these relative abundance classifications.
[5] In the video images, the substrate codes are used in combination to denote the range of substrates encountered.

Type of Data[2]	Code Type	Code	Description
video	SUBSTRATE CODE	d+rr	Diffuser and riprap
video	SUBSTRATE CODE	gp+c	Gravel pavement and cobbles, more gravel pavement
video	SUBSTRATE CODE	mx	Mix
video	SUBSTRATE CODE	mx+cp	Mix and cobble pavement, more mix
video	SUBSTRATE CODE	mx+rr	Mixed and riprap
video	RELIEF_CODE	h	High
video	RELIEF_CODE	l	Low
video	RELIEF_CODE	l-lm	Low to moderately low
video	RELIEF_CODE	lm	Moderately low
video	RELIEF_CODE	l-m	Low to moderate
video	RELIEF_CODE	lm-m	Moderately low to moderate
video	RELIEF_CODE	m	Moderate
video	RELIEF_CODE	mh	Moderately high
video	RELIEF_CODE	m-h	Moderate to high
video	RELIEF_CODE	mh-h	Moderately high to high
video	RELIEF_CODE	m-mh	Moderate to moderately high
video	SED_DRAPE_CODE	c	Clean
video	SED_DRAPE_CODE	c-l	Clean to light
video	SED_DRAPE_CODE	c-m	Clean to moderate
video	SED_DRAPE_CODE	c-vl	Clean to very light
video	SED_DRAPE_CODE	h	Heavy
video	SED_DRAPE_CODE	l	Light
video	SED_DRAPE_CODE	l-h	Light to heavy
video	SED_DRAPE_CODE	l-lm	Light to moderately light
video	SED_DRAPE_CODE	lm	moderately light
video	SED_DRAPE_CODE	l-m	Light to moderate
video	SED_DRAPE_CODE	l-mh	Light to moderately heavy
video	SED_DRAPE_CODE	lm-h	Lightly moderate to heavy
video	SED_DRAPE_CODE	lm-m	Moderately light to moderate
video	SED_DRAPE_CODE	m	Moderate
video	SED_DRAPE_CODE	mh	Moderately heavy
video	SED_DRAPE_CODE	m-h	Moderate to heavy
video	SED_DRAPE_CODE	mh-h	Moderately heavy to heavy
video	SED_DRAPE_CODE	m-mh	Moderate to moderately heavy
video	SED_DRAPE_CODE	vh	Very heavy
video	SED_DRAPE_CODE	vl	Very light
video	SUSP_MATTER_CODE	h	High
video	SUSP_MATTER_CODE	mh	Moderate to high
video	SUSP_MATTER_CODE	vh	Very high
analysis of video	VALUE	a	Abundant
analysis of video	VALUE	c	Common
analysis of video	VALUE	f	Few
analysis of video	VALUE	r	Rare
analysis of video	VALUE	va	Very abundant

Table 21. Descriptions of Other Database Codes used in HOM6 Benthic Monitoring.

Field Name	Code	Description
ANAL_LAB_ID	COV	Cove Corporation.
ANAL_LAB_ID	DIL	MWRA Dept of Lab Services Central Lab
ANAL_LAB_ID	ENSR	ENSR Marine and Coastal Center
DEPTH_UNIT_CODE	m	Meters
DEPTH_UNIT_CODE	cm	Centimeters
GEAR_CODE	HULCHER _DIGI	Hulcher Model Minnie Sediment Profile Camera System with Digital Camera
GEAR_CODE	VV01	0.1-m^2 Young-Modified Van Veen Grab
GEAR_CODE	VV04	0.04-m^2 Young-modified Van Veen Grab
INSTR_CODE	MICR	Microscope
INSTR_CODE	RULER	Measurement by ruler
MATRIX_CODE	SED	Sediment
METH_CODE	ENUM	Enumeration
METH_CODE	WILL02	Williams *et al.* 2002 Benthic QA Plan
SAMP_VOL_UNIT_CODE	L	Liter
UNIT_CODE	0.04 m^2	Units associated with a Van Veen grab, gear_type of VV04
UNIT_CODE	cm	Centimeters
VAL_QUAL	A	Value above maximum detection limit, *e.g.*, too numerous to count or beyond range of instrument
VAL_QUAL	F	Abundance recorded for a fraction or portion of the sample collected
VAL_QUAL	P	Present but uncountable, value given is NULL
VAL_QUAL	a	Usable non-detect result; not detected at or above the method detection limit (MDL). Database value input as null or negative. DETECT_LIMIT is the MDL.
VAL_QUAL	d	Accuracy does not meet data quality objectives.
VAL_QUAL	e	Results not reported, value given is NULL. Explanation in COMMENTS field
VAL_QUAL	p	Lab sample bottles mislabeled - caution data use.
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	w	This datum should be used with caution, see comment field.
SPEC_QUAL	G	Fragment
SPEC_QUAL	J	Juvenile (unspecified stage)
SPEC_QUAL	X	Complex

B10.4 Loading Analytical Data into the Harbor and Outfall Studies Database

Data submissions from ENSR will consist of final electronic spreadsheets (SPI) or final loading applications as discussed above. The submissions will be logged in upon receipt at Battelle and a copy of the login will be maintained on file under the login id. Data will be loaded into a temporary table space by striking a button on the application. A transfer script will copy the data into the proper table in Battelle's copy of the HOML. Data will receive a QA review by Battelle prior to electronic submission to ENSR. Any issues will be corrected in the database and the script output will be supplied to MWRA and ENSR upon request. A check script will be run on the database prior to export of a dataset to ensure that all data conform to QC checks and database constraints. Any issues will be sent to the Battelle Data Manager and ENSR Project Manager via e-mail. Any irresolvable issues in the database as a result of QC checks (*e.g.*, stations more than specified distance from target) will also be submitted to MWRA with the data export.

B10.5 Data Report Quality Control Checks

Based on data received from ENSR and loaded successfully in the EM&MS database, MWRA will perform the range checks as defined in Table 22 and submit a draft Data Report to ENSR. ENSR will comment on the draft report and MWRA will finalize it, taking ENSR's comments into consideration.

Table 22. Data Report Quality Control Checks – Benthic Area

Parameter	Nearfield	Farfield	Harbor
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		
SPI	Range check each quantitative variable. Min, Max, Avg. by variable for event.		

C. ASSESSMENT AND OVERSIGHT

C1. ASSESSMENT AND RESPONSE ACTIONS

This section identifies the number, frequency, and type of planned assessment activities that will be performed to assure implementation of this QAPP for HOM6 benthic monitoring. These activities will be overseen by the ENSR QA Officer, Ms. Debra Simmons.

C1.1 Assessments

C1.1.1 *Field Sampling Readiness Reviews*

Each field survey plan (Section A9.4.2) will include checklists for required supplies and equipment. Examples are shown in Tables 23 and 24.

C1.1.2 *Field Sampling Technical System Audit*

The Project QA Officer and/or ENSR Survey Task Leader will be responsible for periodic internal Technical Surveillance Audits (TSAs) to verify that field sampling procedures and measurements are properly followed. The internal field audit checklist (Table 25) will include examination of the following:

- Field sampling records
- Sample collection, handling, and packaging procedures
- QA procedures
- Chain-of-custody
- Sample documentation

Results of internal field TSAs will be documented in the QA reports to the ENSR project manager. (Section C2).

C1.1.3 *Fixed Laboratory Technical System Audits*

System audits are performed as described in each laboratory's QA manual for internal auditing. Laboratory audits may be conducted by ENSR at project start up and then periodically as part of its analytical subcontractor monitoring program. The laboratory audit checklist (Table 26) will review the following:

- QA organization and procedures
- Personnel training and qualifications
- Sample log-in procedures
- Sample storage facilities
- Analyst technique
- Adherence to laboratory SOPs and this QAPP
- Compliance with QA/QC objectives
- Instrument calibration and maintenance
- Facility security
- Waste management
- Data recording, reduction, review, reports, and archival
- Cleanliness and housekeeping

Table 23. Harbor Traditional Survey Supply Checklist

Survey Item	Ordered	Need to Order for Next Survey
☐ formalin (+MSDS Safety sheet)		
☐ sieves (4, 300micron)		
☐ metal pans (2)		
☐ glass bowls for homogenizing (2)		
☐ filter units (2)		
☐ hoses		
☐ connections		
☐ filters		
☐ squirt bottles		
☐ forceps, spoons		
☐ Borax		
☐Solvents: Ethanol + hazardous waste container		
☐electrical tape, clear packing tape		
☐ scissors		
☐ funnels		
☐ pens/pencils		
☐ ruler		
☐ syringes		
☐ hose (siphon)		
☐ Grabs- (2), 0.04-m^2 van Veen		
☐ 1 wooden stand		
☐ holder for each grab (2)		
☐ wooden discs for the bottom of the grab (2)		
☐ weights for the grab		
☐ Sieve Tables (2)		
☐ Buckets (4)		
☐ bucket rockers (2)		
☐ Containers:		
☐ Infauna (various)_______________		
☐ TOC (4 oz glass jars (125 ml))__________________		
☐ GS (8 oz glass jars (250 ml))____________________		
☐ *C. perfringens* (sterile sample bottle)___________		
☐survey logbook		
☐ soap and brush for cleaning the grab		
☐ zip ties in various sizes		
☐ Coolers for sample transport		
☐ Blue ice for the *C. perfringens* samples		
☐ Spare belts for the water pump		

Table 24. Field Safety and Equipment Checklist for HOM6.

FIELD SAFETY AND EQUIPMENT CHECKLIST

FIELD SAFETY CHECKLIST

Date of Survey_______________

Project No. _________________

Type of work:
- Sample collecting
  - Landbased ☐
  - Waterbased ☐
- Mooring operations ☐
- Dive operations ☐
- Towed sampling ☐
- Navigation ☐
- Other:____________ ☐

Type of sample collected:
- Water ☐
- Sediment ☐
- Sludge ☐
- Raw sewerage ☐
- Dredge materials ☐
- Living organisms ☐
- Marine debris ☐
- Electronic data ☐
- Other:____________

	Y	N
*Do samples impose a health risk?	☐	☐
If yes, what kind of hazard:		
Chemical	☐	☐
Biological	☐	☐
Radioactive	☐	☐
Other ____________		
Specify Hazard:______________		
* (or fixatives / additives used w/ samples)		
Is there a spill response plan?	☐	☐
Is one necessary?	☐	☐
Are immunizations necessary?	☐	☐
Will electrical equipment be used by staff?	☐	☐
Will electrical equipment be used on deck?	☐	☐
Will ground fault interrupt (GFI) be used?	☐	☐
Will elecrtrical equipment be checked-out before survey?	☐	☐

List type of sampling equipment to be used:
____

	Y	N
Do all members of the survey party have appropriate field experience?	☐	☐
Is training necessary before the survey?	☐	☐
Will there be lifting of heavy objects?	☐	☐
Are all members of survey party familiar with safe lifting practices?	☐	☐

Reviewed and approved

Task Leader____________________ Date_________

Chief Scientist__________________ Date_________

Dept Manager__________________ Date_________

FIELD SAFETY EQUIPMENT CHECKLIST

Check equipment needed for survey

	Tech Staff	Lab Staff
Hard Hats**		
Work Vests**		
Life Raft		
EPIRB		
First Aid Kit		
Cold Weather Suits		
Safety Glasses		
Work Gloves		
Tyvek Suits		
Radiation Detector		
Respirators		
Air Hood		
Face Shields		
Lab Coats		
Eye Wash		
Flash Lights		
Spill Response Kit		

** Required for surveys using vessels

Survey Party, Battelle Staff	ENSR Staff
_______________	_______________
_______________	_______________
_______________	_______________
_______________	_______________
_______________	_______________
_______________	_______________
_______________	_______________

Table 25. Example of Internal Field TSA Checklist

Project: **Site Location:** **Auditor:**	
1. Was project-specific training held?	
2. Are copies of project plan (SAP, QAPP) on site and available to personnel?	
3. Are samples being collected in accordance with the project plan?	
4. Do the numbers and locations of samples conform to the project plan?	
5. Are sample locations staked or otherwise marked?	
6. Are samples labeled in accordance with the project plan?	
7. Is equipment decontamination in accordance with the project plan?	
8. Is field instrumentation being operated and calibrated in accordance with the project plan?	
9. Are samples being preserved and containerized in accordance with the project plan?	
10. Are QC samples in accordance with the types, collection procedures, and frequencies specified in the project plan?	
11. Are chain-of-custody procedures and documents in conformance with the project plan?	
12. Are field records complete, accurate, up-to-date, and in conformance to good recordkeeping procedures?	
13. Are modifications to the project plan being communicated, approved, and documented appropriately?	
Additional Comments:	
Auditor:	**Date:**

Table 26. Example of Laboratory Audit Checklist

Project: **Facility Location:** **Auditor:**	
Is there a written QA Program Plan/Manual?	
Is there a designated QA Officer?	
Are facilities and equipment adequate to perform the analyses of interest?	
Review procedures and engineering controls for minimizing cross contamination.	
Review most recent interlaboratory performance evaluation sample results and recent Agency audits.	
Review SOP system. Review techniques for conformance to approved SOPs.	
Are personnel qualified and trained? Is there a formal training program and are records of training and proficiency maintained?	
Is there a designated sample custodian? Is there a sample inspection checklist? Are sample log-in procedures defined in an SOP?	
Is the laboratory area secure?	
Review internal chain-of-custody procedures.	
Are instruments operated and calibrated in accordance with SOPs? Are records of calibration maintained?	
Is equipment maintained according to written protocols? Are routine and non-routine maintenance procedures documented?	
Are samples being analyzed in conformance to the cited methods?	
Are QC samples and checks being performed at the frequencies stated in the cited methods?	
Are records complete, accurate, up-to-date, and in conformance to good recordkeeping procedures?	
How are project-specific requirements communicated to the bench level?	
Review data reduction, review, and reporting processes.	
Review data archival process (paper and electronic).	
Review audit and corrective action program.	
Additional Comments:	
Auditor:	**Date:**

Preliminary results of the systems audit will be discussed with the Laboratory management staff. A written report that summarizes audit findings and recommends corrective actions will be prepared and submitted to the Laboratory Director for response and to the ENSR Project Manager. The results of the audit, including resolution of any deficiencies, will be included in the QA reports to management, as described in Section C2.

C1.1.4 *Performance Evaluation Sample Assessment*

Proficiency testing for infaunal taxonomic analyses is accomplished through regular communication and inter-calibration of infaunal samples among laboratories.

C1.1.5 *Data Technical System Audits*

Tabular data reported in deliverables and associated raw data generated by ENSR will be audited under the direction of the Project QA Officer for 100% of the packages received as part of the data validation process (Section D.1). Raw data will be reviewed for completeness and proper documentation. For electronically acquired navigational data, Battelle will verify that computer software used to process the data has been validated. Other electronically acquired data will be verified by ENSR. 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 QAPP-prescribed formats; no other formats will be acceptable. During the time that 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 ENSR Database Task Manager and must be accompanied by a signed QA statement that describes the types of audits and reviews conducted, the results, any outstanding issues that could affect data quality, and a narrative of activities.

C1.2 Assessment Findings and Corrective Action Responses

All technical personnel share responsibility for identifying and resolving problems encountered in the routine performance of their duties. Issues that affect the schedule, cost, or performance of Tasks 1–12 will be reported to Dr. James A. Blake, ENSR's Project Manager. He will be accountable to MWRA and to ENSR management for overall conduct of the Harbor and Outfall Benthic Monitoring Project, including the schedule, costs, and technical performance. Dr. Blake will be responsible for identifying and resolving problems that (1) have not been addressed in a timely manner or successfully at a lower level, (2) influence multiple components of the project, or (3) require consultation with ENSR management or with MWRA. He will be responsible for evaluating the overall impact of the problem on the project and for discussing corrective actions with the MWRA Benthic Monitoring Project Area Manager. He will also identify and resolve problems that necessitate changes to this QAPP. Problems identified by the QA Officer will be reported to him and corrected as described in Section C2.

Corrective action is the process of identifying, recommending, approving, and implementing measures to counter unacceptable procedures or out-of-limit QC performance that can affect data quality. Corrective action can occur during field activities, laboratory analyses, data validation, and data assessment. All corrective action proposed and implemented should be documented in the QA reports to management (Section C2). Corrective action should only be implemented after approval by the ENSR Project Manager, or his designee.

C1.2.1 *Field Corrective Action*

Corrective action in the field may be needed when the sample frequency is changed (*i.e*., more/fewer samples, sample locations other than those specified in the QAPP), or when sampling procedures and/or field analytical procedures require modification due to unexpected conditions. The field team may identify the need for corrective action. The MWRA Deputy Project Manager, ENSR Project Manager, and Project QA Officer will approve the corrective measure. The Chief Scientist will ensure that the field team implements the corrective action.

Corrective action resulting from internal field audits will be implemented immediately if data may be adversely affected due to unapproved or improper use of approved methods. The QA auditor will identify deficiencies and recommend corrective action to the Chief Scientist. The Chief Scientist and field team will perform implementation of corrective actions. Corrective action will be documented in QA reports to the project management team (Section C2).

Corrective actions will be implemented and documented as follows in the field record book.

- A description of the circumstances that initiated the corrective action
- The action taken in response
- The final resolution
- Any necessary approvals
- Effectiveness of corrective action

No staff member will initiate corrective action without prior communication of findings through the proper channels. If at any time a corrective action issue which directly impacts the project DQOs is identified, the MWRA Project Manager will be notified.

C1.2.2 *Laboratory Corrective Action*

Corrective action in the laboratory is specified in laboratory SOPs and may occur prior to, during, and after initial analyses. Conditions, such as broken sample containers, may be identified during sample log-in or analysis. Following consultation with laboratory analysts and supervisory personnel, it may be necessary for the subcontractor QA Manager to approve the implementation of a corrective action. If the problem makes it impossible to achieve project objectives, the ENSR Laboratory Task Manager will be notified, who will in turn notify the ENSR Project Manager. The ENSR Project Manager will communicate with the MWRA Benthic Monitoring Project Area Manager and other members of the project team, as necessary. The MWRA Benthic Monitoring Project Area Manager will also be notified in those cases where the nonconformance affects the achievement of the project DQOs.

These corrective actions will be performed prior to release of the data from the laboratory. The corrective action will be documented in both the laboratory's corrective action files, and in the narrative data report generated by the laboratory. If the corrective action does not rectify the situation, the laboratory will contact the ENSR Laboratory Task Manager, who will determine the action to be taken and inform the appropriate personnel.

C1.2.3 *Corrective Action during Data Validation and Data Assessment*

The need for corrective action may be identified during either data validation or data assessment. Potential types of corrective action may include resampling by the field team or reanalysis of samples by the laboratory. These actions are dependent upon the ability to mobilize the field team and whether the data to be collected are necessary to meet the required QA objectives. If the data validator or data assessor identifies a corrective action situation that impacts the achievement of the project objectives, the ENSR Project Manager will be responsible for informing the appropriate personnel, including the MWRA Benthic Monitoring Project Area Manager.

C2. REPORTS TO MANAGEMENT

QA reports will be prepared by the ENSR Project QA Officer and submitted on an as-needed basis to the ENSR Project Manager. QA reports will document any problems identified during the sampling and analysis programs and the corrective measures taken in response. The QA reports will include:

- All results of field and laboratory audits
- Problems noted and actions taken during data validation and assessment
- Significant QA/QC problems, recommended corrective actions, and the outcome of corrective actions

A summary of QA issues, audit findings, and significant nonconformances will be included in the status reports to the MWRA.

D. DATA VALIDATION AND USABILITY

This section details the QA activities that will be performed to ensure that the collected data are scientifically defensible, properly documented, of known quality, and meet project objectives. Two steps are completed to ensure that project data quality needs are met:

- Data verification/validation
- Data usability assessment

D1. DATA REVIEW, VERIFICATION, AND VALIDATION

D1.1 Field Data

The field data verification includes verification of sampling design, sample collection procedures, and sample handling. Field data will be reviewed daily by the ENSR Chief Scientist and Battelle NavSam© Operator to ensure that the records are complete, accurate, and legible and to verify that the sampling procedures are in accordance with the protocols specified in the QAPP (refer to Section D2.1 for the specific elements reviewed).

D1.2 Laboratory Data

Prior to the release of any data from the laboratory, the data will be reviewed and approved by laboratory personnel. The review will consist of a tiered approach (Section D2.2) that will include reviews by the person performing the work, by a qualified peer, and by supervisory and/or QA personnel.

Validation of the analytical data produced by DLS is not included in the scope of this contract.

D1.3 Data Management

The review process will include verification of manually entered data, QC checks associated with loading applications and script checks prior to exporting the data to MWRA. Detailed descriptions of these processes are included in Sections B10 and D2.

D2. VALIDATION AND VERIFICATION METHODS

D2.1 Field Data

Field records will be reviewed by the Chief Scientist and Battelle NavSam© operator to ensure that:

- Logbooks and standardized forms have been filled out completely and that the information recorded accurately reflects the activities that were performed
- Records are legible and in accordance with good recordkeeping practices, *i.e.*, entries are signed and dated, data are not obliterated, changes are initialed, dated, and explained
- Equipment calibration, sample collection, handling, preservation, storage, and shipping procedures were conducted in accordance with the protocols described in the QAPP, and that any deviations were documented and approved by the appropriate personnel

D2.2 Laboratory Data

As a part of data validation, each benthic team laboratory will ensure that:

- The QC checks specified in Sections A7 and B5 were conducted and met the acceptance criteria
- 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

Once data have been generated and compiled in the laboratory, Senior Scientists in each laboratory 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 any samples during shipment or analysis will be documented in the dataset package submitted to the MWRA and noted in the database.

D2.3 Data Management

Laboratory analytical data will be submitted to ENSR for review prior to the electronic submission to Battelle. Data provided electronically to facilitate data handling will be verified against the hard copy data.

A review of the electronic data as generated by Battelle will be performed by the ENSR Laboratory Task Manager or Project Manager before results are submitted to MWRA. This review will serve to verify the completeness of the dataset submission and to ensure that project requirements are met for the analyses performed.

Upon receipt, MWRA will load the data into their EM&MS system, and prepare a data report. ENSR will review this report to verify that all data have been entered correctly in the EM&MS database.

D2.4 Project Deliverables

Upon completion of the verification/validation process, a dataset package will be prepared for submittal to MWRA. This documentation will include the following elements required for HOM6 benthic monitoring and as listed in Section A9.4.

- Cover letter describing any problems
- List of problems encountered and corrective action taken
- List of samples/images planned vs. collected, or measurements planned vs. reported
- Quality Assurance Statement including a checklist of QA actions, and notes on deviations and corrective actions (electronic and signed hard copy)
- Table(s) of data submitted
- Exceptions report showing results of checks (for data sets submitted via the HOML application)

D3. RECONCILIATION WITH USER REQUIREMENTS

This element describes how the verified/validated project data will reconcile with the project DQOs, how data quality issues will be addressed, and how limitations on the use of the data will be reported and handled. The purpose of this section is to indicate the methods by which it will be ensured that the data collected for this investigation fall in line with the DQOs as described in Section A7 of this QAPP. To meet these DQOs, a combination of qualitative evaluations and statistical procedures will be used to check the quality of the data. These procedures will be used by the laboratory generating the data, by qualitative review by ENSR, and by statistical review by the Battelle Data Management Team.

The data generated must meet the MWRA's needs as defined in the project DQOs defined in Section A7 of this QAPP. The primary objectives for assessing the usability of the data are to ensure that (1) data denote conditions in Boston Harbor and Massachusetts and Cape Cod Bays, (2) all datasets are complete and defensible, and (3) data are of the quality needed to meet the overall objectives of the MWRA.

D3.1 Comparison to Measurement Criteria

D3.1.1 *Precision and Accuracy Assessment*

The accuracy and precision of the data generated during this program will be assessed by comparison to the DQOs specified in Section A7. Data that fail to meet the data quality criteria may necessitate sample reprocessing, analysis of archival material, sample recollection, or flagging of the data, depending on the magnitude of the nonconformance, logistical constraints, schedule, and cost.

D3.1.2 *Completeness Assessment*

Completeness is the ratio of the number of valid sample results to the total number of results planned for collection. The goal of this program is to generate valid, usable data. However, in environmental sampling and analysis, some data may be lost due to sampling location logistics, or field or laboratory errors. The overall completeness goal for the HOM6 Benthic Monitoring Program is 100% of planned samples to be collected and analyzed. The ENSR Laboratory Task Manager will assess the completeness of the overall data generation against the project goals. Following completion of the sampling, analysis, and data review, the percent completeness will be calculated and compared to the project objectives stated in Section A7.2 using the following equation.

$$\% \text{ Completeness} = \frac{\text{Number of valid/usable results obtained}}{\text{Number of valid/usable results planned}} \times 100$$

If this goal is not met, data gaps may exist that will require evaluation to determine the effect on the intended use of the data. Sample re-analysis, analysis of archived material, and/or re-collection of the sample may be appropriate depending on criticalness of the missing data, logistical constraints, cost, and schedule.

Representativeness

Representativeness expresses the degree to which data accurately and precisely denote a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition within a defined spatial and/or temporal boundary.

Representativeness of the field data will be assessed by verifying that the sampling program was implemented as proposed and that proper sampling techniques were used.

The assessment of representativeness in the laboratory will consist of verifying that the proper analytical procedures and appropriate methods were used.

D3.2 Overall Assessment of Environmental Data

Data assessment will involve an evaluation to determine if the data collected are of the appropriate quality, quantity, and representativeness for the purposes required by the MWRA. This evaluation will be performed by the ENSR Project Manager in concert with other users of the data. Data generated in association with QC results that meet these objectives will be considered usable. Data that do not meet the objectives and/or the data validation criteria might still be usable. This assessment may require various statistical procedures to establish outliers, correlations between data sets, adequate sampling location coverage, etc., in order to assess the effect of qualification or rejection of data. The effect of the qualification of data or loss of data deemed unacceptable for use, for whatever reason, will be discussed and decisions made on corrective action for potential data gaps.

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APPENDIX A

Standard Operating Procedures (SOPs)

SOP-04 Calculation of Baseline and Test Values for the Benthic Diversity Indices and Opportunists at the MWRA Outfall Nearfield.

SOP-34 Calculation of the Annual Threshold Values for Sediment Toxic Contamination

SOP-35 Calculation of the Annual Threshold Value for Redox Potential Discontinuity Depth in Sediment

CALCULATION METHOD FOR BASELINE AND TEST VALUES FOR THE BENTHIC DIVERSITY INDICES AND OPPORTUNISTS AT THE NEARFIELD

Author(s): Suh Yuen Liang
Last Updated: October 13, 2004
Purpose: Calculation method for baseline and test values for the benthic diversity indices and opportunists at the nearfield.

Revision History:
Original: January 9, 2002
Revision 1: October 13, 2004 -

a) Reduced station sets for even and odd year used in revised monitoring program (MWRA, 2004), are now used to calculate baseline and post-discharge results.
b) Modified the merge list to reflect the recent species consolidation implemented in the database and the new merges per Ken Keay, Nancy Maciolek, Jim Blake, and Isabelle Williams.

The contingency plan threshold comparisons for the nearfield benthic diversity indices and percent opportunists are performed each year. The diversity indices include total species, log-series alpha, Shannon-Wiener H', and Pielou's J'. The nearfield averages of the benthic diversity indices and benthic opportunists are compared to the thresholds to determine if there is an exceedance. The table below shows the caution thresholds for the benthic diversity indices and benthic opportunists for testing on even and odd years.

	Parameter	Threshold ID	Caution Level	Warning Level	Baseline Years	Baseline Method
Even Years	Total species	SBDTOTMAXE	82.00	-	1992-2000	Central 95th percentile of annual means.
		SBDTOTMINE	48.41	-		
	Fisher's log-series alpha	SBDLOGMAXE	16.47	-		
		SBDLOGMINE	9.99	-		
	Pielou's J'	SBDPJMAXE	0.68	-		
		SBDPJMINE	0.58	-		
	Shannon-Wiener H'	SBDSWHMAXE	4.14	-		
		SBDSWHMINE	3.37	-		
Odd Years	Total species	SBDTOTMAXO	79.95	-	1992-2000	Central 95th percentile of annual means.
		SBDTOTMINO	46.52	-		
	Fisher's log-series alpha	SBDLOGMAXO	15.17	-		
		SBDLOGMINO	9.95	-		
	Pielou's J'	SBDPJMAXO	0.66	-		
		SBDPJMINO	0.56	-		
	Shannon-Wiener H'	SBDSWHMAXO	3.91	-		
		SBDSWHMINO	3.30	-		
All years	Benthic Opportunists	SBO	10%	25%	NA	NA

Table 1: Benthic diversity indices and percent opportunist thresholds.

Data Source (Data from EM&MS database):

- The benthic infaunal data and sample information are obtained from the ABUNDANCE and SAMPLE tables.
- Taxa are classified as “good” (GOOD_BAD = ‘G’, generally, identified to species), “bad” (GOOD_BAD = ‘B’, identified only to a higher taxonomic level) or “worse” (GOOD_BAD = ‘W’, non-infaunal taxa) in the INFAUNA_REF table. Species classified as “worse” are excluded from calculation. “Worse” refers to pelagic, epifaunal, or colonial species.

Data To Be Used In The Analysis:

- For even year thresholds, the following stations are used for baseline calculations and threshold testing: NF12, NF17, FF10, FF13, NF05, NF07, NF08, NF09, NF16, NF18, NF19, NF22, NF23, NF01, NF03, NF06, NF11. (Note NF01, NF03, NF06, and NF11 were sampled only in 1992.)
- For odd year thresholds, the following stations are used for baseline calculations and threshold testing: NF01, NF02, NF03, NF04, NF06, NF10, NF11, NF12, NF13, NF14, NF15, NF17, NF20, NF21, FF12, NF24. (Note NF01, NF03, NF06, and NF11 were sampled only in 1992.)
- There is one survey event in August each year, except that there are surveys in May and August 1992. Survey S9202 in May 1992 is excluded from the baseline calculations because the time of data collection and the sampling method are inconsistent with all other surveys.
- Data qualified as suspect/invalid (VAL_QUAL contains ‘s’) and investigation pending (VAL_QUAL contains ‘q’) are not used.
- Include only “good” species for benthic diversity index calculations, as defined in INFAUNA_REF table, with the following exceptions:
    1. Treat *Turbellaria* spp. 3901SPP as good
    2. Treat *Micrura* spp. 43030205SPP as good
- Include both “good” and “bad” species for calculating the percent benthic opportunists.
- Do not merge taxa in each sample with the following exceptions:
    1. Merge *Turbellaria sp. 1* (3901SP01) with *Turbellaria spp.* (3901SPP)
    2. Merge *Turbellaria sp. 2* (3901SP02) with *Turbellaria spp.* (3901SPP)
    3. Merge *Pholoe tecta* (50020601TECT) with *Pholoe minuta* (5001060101)
    4. Merge Apistobranchus tullbergi (5001420101) with *Apistobranchus typicus* (5001420103)
    5. Merge *Maldane glebifex* (5001630302) with *Maldane sarsi* (5001630301)
    6. Merge *Euclymene cf. collaris* (5001631102CF) with *Euclymene collaris* (5001631102)
    7. Merge *Clymenura polaris* (5001631202) with *Clymenura sp.* A (50016312SP01)
    8. Merge *Proclea sp. 1* (50016817SP01) with *Proclea graffi* (5001681702)
    9. Merge Ascidacea (8401SPP) and *Molgula* spp. (84060301SPP) with *Molgula manhattensis* (8406030108)
    10. Merge *Ampharete baltica* (5001670216) with *Ampharete acutifrons* (5001670208)
    11. Merge *Nereis* spp. (50012404SPP) with *Nereis grayi* (5001240409)
    12. Merge Scaphopoda (56SPP) with *Dentalium entale* (5601010201)
    13. Merge *Chaetozone* spp. (50015004SPP), *Chaetozone* sp. 4 (500150043SP04), and *Chaetozone* sp. 5 (50015004SP05) with *Chaetozone setosa* (50015004MB).

- Do not merge genus spp. and species just because there is only one species found in that genus.

- The list of benthic opportunists includes the following:

Species	**Species Code**
Polydora cornuta	5001430448
Capitella capitata complex	5001600101
Capitella spp.	50016001SPP
Streblospio benedicti	5001431801
Mulinia lateralis	5515250301
Ampelisca macrocephala	6169020101
Ampelisca abdita	6169020108
Ampelisca vadorum	6169020109

Data Aggregation:

- Calculate the benthic diversity indices and percent opportunists for each sample. These are defined as follows:

  S = total distinct “good” species in the sample
  N = total number of “good” individuals in the sample
  N(*i*) = total number of “good” individuals in *i*th species
  Sa = total distinct opportunist species in the sample
  Na = total number of individuals (include “good” and “bad” species) in the sample

  1. Total species = S

  2. Log series alpha = N * (1-x))/x
     where:
     x is defined by (x-1)/x*ln(1-x) = S/N,
     and is determined numerically with a look up table in which x varies from 0 to 1 in increments of 0.000001

  3. Shannon-Wiener H' $= -\sum_{i=1}^{S} [(N(i)/N) \cdot \log_2(N(i)/N)]$

  4. Pielous J' $= H'/\log_2(S)$

  5. Benthic opportunists = (Sa/Na)*100%

- All samples within a station are treated as independent measurements so there is no data aggregation within a station.

- Calculate the yearly means of benthic diversity indices and percent opportunists using all samples from each year.

Baseline Calculation:

- The distribution of the nine yearly means for each benthic diversity index was determined to be normal using Kolmogorov-Smirnov (Lilliefors Significance Correction) and Shapiro-Wilk tests for normality.
- The central 95th percentiles for these thresholds were calculated using:
  Upper threshold = baseline mean + 1.96*(baseline standard deviation)
  Lower threshold = baseline mean - 1.96*(baseline standard deviation)
- Benthic opportunist threshold is not based on baseline values.

Threshold Testing:

- For each post-discharge even year, the average for the one (August) survey from the even year station set is compared against the caution and/or warning thresholds for even years in table 1. Likewise, for each post-discharge odd year, the average from the odd year station set is compared against the caution and/or warning thresholds for odd years in table 1. If the average of any benthic diversity index is greater than the upper threshold or smaller than the lower threshold, there is an exceedance for that year. If the average of benthic opportunists is greater than the threshold, there is an exceedance for that year.

References:
MWRA. 2004. Massachusetts Water Resources Authority effluent outfall ambient monitoring plan Revision 1, March 2004. Boston: Massachusetts Water Resources Authority. Report ms-092. 65 p.

Written by:	______________________ Suh Yuen Liang	__________ Date
Data Group Manager:	______________________ Wendy Leo	__________ Date
MWRA Scientist Responsible for benthic studies	______________________ Kenneth Keay	__________ Date

CALCULATION METHODS FOR ANNUAL THRESHOLD VALUES FOR SEDIMENT TOXIC CONTAMINATION

Author(s): Wendy Leo, Doug Hersh
Last Updated: April 3, 2002

Revision History:

This memo summarizes the methods used to calculate the baseline values of sediment contaminants and to compare the nearfield average to the threshold.

There are 26 thresholds related to toxic contaminants in sediments, based on NOAA Effects Range-Median sediment guidelines. The thresholds for DDT, PCB, LMWPAH, HMWPAH, and total PAH are based on the sum of concentrations of several chemicals.

Parameter	Threshold ID	Testing area	Caution Level	Warning Level	Units	Baseline Years	Averaging Method
acenaphthene	STNANP	Nearfield	-	500	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
acenaphthylene	STNAPTH	Nearfield	-	640	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
anthracene	STNARC	Nearfield	-	1100	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
benz(a)-anthracene	STNBAA	Nearfield	-	1600	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
benzo(a)pyrene	STNBAP	Nearfield	-	1600	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
chrysene	STNCHR	Nearfield	-	2800	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
dibenzo(a,h)-anthracene	STNDBA	Nearfield	-	260	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
fluoranthene	STNFLT	Nearfield	-	5100	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
fluorene	STNFLU	Nearfield	-	540	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
naphthalene	STNNAP	Nearfield	-	2100	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
phenanthrene	STNPHN	Nearfield	-	1500	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
pyrene	STNPYR	Nearfield	-	2600	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
sum HMWPAH	STNHPAH	Nearfield	-	9600	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
sum LMWPAH	STNLPAH	Nearfield	-	3160	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
total PAH	STNTPAH	Nearfield	-	44792	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
p,p'-DDE	STNDDE	Nearfield	-	27	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
total DDT	STNTDDT	Nearfield	-	46.1	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
total PCB	STNTPCB	Nearfield	-	180	ng/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean

Table 1: Sediment Contamination Thresholds (continued on next page).

Parameter	Threshold ID	Testing area	Caution Level	Warning Level	Units	Baseline Years	Baseline Method
cadmium	STNCD	Nearfield	-	9.6	ug/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
chromium	STNCR	Nearfield	-	370	ug/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
copper	STNCU	Nearfield	-	270	ug/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
lead	STNPB	Nearfield	-	218	ug/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
mercury	STNHG	Nearfield	-	0.71	ug/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
nickel	STNNI	Nearfield	-	51.6	ug/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
silver	STNAG	Nearfield	-	3.7	ug/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean
zinc	STNZN	Nearfield	-	410	ug/g dry	1992-2000 (data avail. only in 1992-1995, 1999)	Arithmetic mean

Table 1: Sediment Contamination Thresholds (continued).

Data Source (Data from EM&MS database):

- Laboratory data from the Massachusetts Bay Soft Bottom Monitoring study for the parameters shown in table 2 for the various groups are used. These data are stored in the ANALYTICAL_RESULTS table with supporting data in the BOTTLE and SAMPLE tables.
- Nearfield stations are specified as station IDs beginning with 'N', plus stations FF10, FF12, and FF13.
- There is one survey event each year, in August.

Threshold	Group (Group Code)	Parameter Code	Parameter Description	Parameter Abbreviation
acenaphthene	STNANP	83-32-9	ACENAPHTHENE	
acenaphthylene	STNAPTH	208-96-8	ACENAPHTHYLENE	
anthracene	STNARC	120-12-7	ANTHRACENE	
benz(a)anthracene	STNBAA	56-55-3	BENZ(A)ANTHRACENE	
benzo(a)pyrene	STNBAP	50-32-8	BENZO(A)PYRENE	
chrysene	STNCHR	218-01-9	CHRYSENE	
dibenzo(a,h)anthracene	STNDBA	53-70-3	DIBENZO(A,H)ANTHRACENE	
fluoranthene	STNFLT	206-44-0	FLUORANTHENE	
fluorene	STNFLU	86-73-7	FLUORENE	
naphthalene	STNNAP	91-20-3	NAPHTHALENE	
phenanthrene	STNPHN	85-0108	PHENANTHRENE	
pyrene	STNPYR	129-00-0	PYRENE	

Table 2: Sediment Contaminants included in each Threshold (continued on next page).

Threshold	Group (Group Code)	Parameter Code	Parameter Description	Parameter Abbreviation
sum HMWPAH	STNHPAH	56-55-3	BENZ(A)ANTHRACENE	
		50-32-8	BENZO(A)PYRENE	
		MWRA86	BENZO(B)/BENZO(K)FLUORANTHENE	
		205-99-2	BENZO(B)FLUORANTHENE	
		192-97-2	BENZO(E)PYRENE	
		191-24-2	BENZO(G,H,I)PERYLENE	
		207-08-9	BENZO(K)FLUORANTHENE	
		MWRA70	C1-CHRYSENES	
		MWRA69	C1-FLUORANTHRENES/PYRENES	
		MWRA4	C2-CHRYSENES	
		MWRA83	C2-FLUORANTHENES/PYRENES	
		MWRA71	C3-CHRYSENES	
		MWRA84	C3-FLUORANTHENES/PYRENES	
		MWRA72	C4-CHRYSENES	
		218-01-9	CHRYSENE	
		53-70-3	DIBENZO(A,H)ANTHRACENE	
		206-44-0	FLUORANTHENE	
		193-39-5	INDENO(1,2,3-C,D)PYRENE	
		198-55-0	PERYLENE	
		129-00-0	PYRENE	
sum LMWPAH	STNLPAH	83-32-9	ACENAPHTHENE	
		208-96-8	ACENAPHTHYLENE	
		120-12-7	ANTHRACENE	
		92-52-4	BIPHENYL	
		MWRA68	C1-DIBENZOTHIOPHENES	
		MWRA65	C1-FLUORENES	
		MWRA64	C1-NAPHTHALENES	
		MWRA67	C1-PHENANTHRENES/ANTHRACENES	
		MWRA5	C2-DIBENZOTHIOPHENES	
		MWRA6	C2-FLUORENES	
		MWRA7	C2-NAPHTHALENES	
		MWRA57	C2-PHENANTHRENES/ANTHRACENES	
		MWRA9	C3-DIBENZOTHIOPHENES	
		MWRA66	C3-FLUORENES	
		MWRA10	C3-NAPHTHALENES	
		MWRA52	C3-PHENANTHRENES/ANTHRACENES	
		MWRA11	C4-NAPHTHALENES	
		MWRA54	C4-PHENANTHRENES/ANTHRACENES	
		132-64-9	DIBENZOFURAN	
		127330-66-9	DIBENZOTHIOPHENE	
		86-73-7	FLUORENE	
		91-20-3	NAPHTHALENE	
		85-0108	PHENANTHRENE	

Table 2: Sediment Contaminants included in each Threshold (continued on next page).

Threshold	Group (Group Code)	Parameter Code	Parameter Description	Parameter Abbreviation
total PAH	STNTPAH	83-32-9	ACENAPHTHENE	
		208-96-8	ACENAPHTHYLENE	
		120-12-7	ANTHRACENE	
		56-55-3	BENZ(A)ANTHRACENE	
		50-32-8	BENZO(A)PYRENE	
		MWRA86	BENZO(B)/BENZO(K)FLUORANTHENE	
		205-99-2	BENZO(B)FLUORANTHENE	
		192-97-2	BENZO(E)PYRENE	
		191-24-2	BENZO(G,H,I)PERYLENE	
		207-08-9	BENZO(K)FLUORANTHENE	
		92-52-4	BIPHENYL	
		MWRA70	C1-CHRYSENES	
		MWRA68	C1-DIBENZOTHIOPHENES	
		MWRA69	C1-FLUORANTHRENES/PYRENES	
		MWRA65	C1-FLUORENES	
		MWRA64	C1-NAPHTHALENES	
		MWRA67	C1-PHENANTHRENES/ANTHRACENES	
		MWRA4	C2-CHRYSENES	
		MWRA5	C2-DIBENZOTHIOPHENES	
		MWRA83	C2-FLUORANTHENES/PYRENES	
		MWRA6	C2-FLUORENES	
		MWRA7	C2-NAPHTHALENES	
		MWRA57	C2-PHENANTHRENES/ANTHRACENES	
		MWRA71	C3-CHRYSENES	
		MWRA9	C3-DIBENZOTHIOPHENES	
		MWRA84	C3-FLUORANTHENES/PYRENES	
		MWRA66	C3-FLUORENES	
		MWRA10	C3-NAPHTHALENES	
		MWRA52	C3-PHENANTHRENES/ANTHRACENES	
		MWRA72	C4-CHRYSENES	
		MWRA11	C4-NAPHTHALENES	
		MWRA54	C4-PHENANTHRENES/ANTHRACENES	
		218-01-9	CHRYSENE	
		53-70-3	DIBENZO(A,H)ANTHRACENE	
		132-64-9	DIBENZOFURAN	
		127330-66-9	DIBENZOTHIOPHENE	
		206-44-0	FLUORANTHENE	
		86-73-7	FLUORENE	
		193-39-5	INDENO(1,2,3-C,D)PYRENE	
		91-20-3	NAPHTHALENE	
		198-55-0	PERYLENE	
		85-0108	PHENANTHRENE	
		129-00-0	PYRENE	
p,p'-DDE	STNDDE	75-55-9	P,P-DDE	4,4'-DDE
total DDT	STNTDDT	MWRA33	O,P-DDD	2,4'-DDD
		MWRA34	O,P-DDE	2,4'-DDE
		789-02-6	O,P-DDT	2,4'-DDT
		72-54-8	P,P-DDD	4,4'-DDD
		75-55-9	P,P-DDE	4,4'-DDE
		50-29-3	P,P-DDT	4,4'-DDT

Table 2: Sediment Contaminants included in each Threshold (continued on next page).

Threshold	Group (Group Code)	Parameter Code	Parameter Description	Parameter Abbreviation
total PCB	STNTPCB	34883-43-7	2,4'-DICHLOROBIPHENYL	CL2(8)
		37680-65-2	2,2',5-TRICHLOROBIPHENYL	CL3(18)
		7012-37-5	2,4,4'-TRICHLOROBIPHENYL	CL3(28)
		41464-39-5	2,2',3,5'-TETRACHLOROBIPHENYL	CL4(44)
		35693-99-3	2,2',5,5'-TETRACHLOROBIPHENYL	CL4(52)
		32598-10-0	2,3',4,4'-TETRACHLOROBIPHENYL	CL4(66)
		32598-13-3	3,3',4,4'-TETRACHLOROBIPHENYL	CL4(77)
		37680-73-2	2,2',4,5,5'-PENTACHLOROBIPHENYL	CL5(101)
		32598-14-4	2,3,3',4,4'-PENTACHLOROBIPHENYL	CL5(105)
		31508-00-6	2,3',4,4',5-PENTACHLOROBIPHENYL	CL5(118)
		57465-28-8	3,3',4,4',5-PENTACHLOROBIPHENYL	CL5(126)
		38380-07-3	2,2',3,3',4,4'-HEXACHLOROBIPHENYL	CL6(128)
		35065-28-2	2,2',3,4,4',5'-HEXACHLOROBIPHENYL	CL6(138)
		35065-27-1	2,2',4,4',5,5'-HEXACHLOROBIPHENYL	CL6(153)
		35065-30-6	2,2',3,3',4,4',5-HEPTACHLOROBIPHENYL	CL7(170)
		35065-29-3	2,2',3,4,4',5,5'-HEPTACHLOROBIPHENYL	CL7(180)
		52663-68-0	2,2',3,4',5,5',6-HEPTACHLOROBIPHENYL	CL7(187)
		52663-78-2	2,2',3,3',4,4',5,6-OCTACHLOROBIPHENYL	CL8(195)
		40186-72-9	2,2',3,3',4,4',5,5',6-NONACHLOROBIPHENYL	CL9(206)
		2051-24-3	DECACHLOROBIPHENYL	CL10(209)
cadmium	STNCD	7440-43-9	CADMIUM	Cd
chromium	STNCR	7440-47-3	CHROMIUM	Cr
copper	STNCU	7440-50-8	COPPER	Cu
lead	STNPB	7439-92-1	LEAD	Pb
mercury	STNHG	7439-97-6	MERCURY	Hg
nickel	STNNI	7440-02-0	NICKEL	Ni
silver	STNAG	7440-22-4	SILVER	Ag
zinc	STNZN	7440-66-6	ZINC	Zn

Table 2: Sediment Contaminants included in each Threshold (continued).

Data To Be Used In The Analysis:

- Baseline calculations and threshold testing are performed on the entire nearfield.
- All data from years in which all stations were sampled are included. Exceptions are specified in the following:
  1. Data qualified as suspect/invalid (VAL_QUAL contains 's'), investigation pending (VAL_QUAL contains ‘q’), and (VAL_QUAL contains ‘e’), above maximum detection limit (VAL_QUAL=’A’) are not used. There are no ‘s’ or ‘q’ qualified data in the current data set.
  2. Data qualified as below detection limit ('a' qualifier) are treated as zero values.

Data Aggregation:

- Laboratory analytical replicates, if any, are first averaged (bottle averages).
- All sediment chemical measurements within a station are treated as independent measurements so there is no data aggregation within a station. This is consistent with how the faunal data are analyzed and thresholds calculated.
- Annual averages for each parameter are calculated by averaging across all nearfield samples (or bottles) for a given year for each parameter.

- The annual values for DDT, PCB, and LMWPAH, HMWPAH, and total PAH are calculated by summing the annual averages of the parameters listed in table 2.

Baseline Calculation:

- The threshold is based on NOAA sediment guidelines, rather than baseline values. However, the threshold testing script can be run for any year in which the nearfield was sampled. Note that in August 2000 only a subset of nearfield stations were sampled for contaminants, so those data are not included in the baseline computations and caution must be used if comparing them to baseline or discharge averages of all nearfield data.

Threshold Testing (STN.SQL):

- For each post-discharge year, the nearfield average is compared against the caution threshold in table 1. If the nearfield average is greater than the threshold, there is an exceedance for that year.

Written by:	______________________ Wendy Leo	__________ Date
Data Group Manager:	______________________ Wendy Leo	__________ Date
MWRA Scientist Responsible for sediment contaminant threshold	______________________ Kenneth Keay	__________ Date

CALCULATION METHODS FOR ANNUAL THRESHOLD VALUE FOR REDOX POTENTIAL DISCONTINUITY DEPTH IN SEDIMENT

Author(s): Suh Yuen Liang
Last Updated: October 19, 2001

Revision History:

This memo summarizes the methods used to calculate the baseline value of redox potential discontinuity (RPD) depth in sediment.

Param_code	Threshold ID	Testing area	Caution Level (cm)	Warning Level (cm)	Baseline Years	Baseline Method
AVG_RPD	SRPD	Nearfield	1.18	-	1992-2000 (data available only in 1992, 1995, 1997, 1998 through 2000)	Arithmetic mean

Table 1: Sediment RPD Thresholds.

Data Source (Data from EM&MS database):

- Apparent RPD data are obtained from the SED_PROF_PARAM and SED_PROF_IMAGE table.
- Nearfield stations are specified as station IDs beginning with 'N', plus stations FF10, FF12, and FF13.
- There is one survey event each year. All events were conducted in August, except that the event S9702 in 1997 was done in August and October.

Data To Be Used In The Analysis:

- Baseline calculations and threshold testing are performed on all nearfield.
- All RPD data from all baseline years are included. Exceptions are specified in the following:
  3. Data qualified as suspect/invalid (VAL_QUAL contains 's'), investigation pending (VAL_QUAL contains ‘q’), and (VAL_QUAL contains ‘e’) are not used. There are no ‘s’ or ‘q’ qualified data in the current data set.
  4. For data qualified as above maximum detection limit (VAL_QUAL=’A’), the prism penetration value (PARAM_CODE=’AVG_PEN’) is used as a surrogate for RPD value.

Data Aggregation:

- All RPD measurements within a station are treated as independent measurements so there is no data aggregation within station. This is consistent with how the faunal data are analyzed and thresholds calculated.

- The yearly mean is calculated using all nearfield measurements from each year.

Baseline Calculation:

- The average of the six yearly means is the baseline mean.
- Caution threshold is 0.5* baseline mean.

Threshold Testing:

- For each post-discharge year, the annual average is compared against the caution threshold in table 1. If the annual average is smaller than the threshold, there is an exceedance for that year.

Written by:	Suh Yuen Liang	Date
Data Group Manager:	Wendy Leo	Date
MWRA Scientist Responsible for redox potential discontinuity depth	Kenneth Keay	Date

APPENDIX B

Data Forms

Cove Corporation
Diaz and Daughters
Barbara Hecker/Hecker Environmental
ENSR Marine & Coastal Center

Cove Corporation Sorting QC Sheet **Page ___ of ___**

Client: MWRA (HOM5 Project)	**Study Site:**	**Sampling Date:**
QC Sample:	**Lab. Serial No.:**	**Sample Id.:**
Sorter:		**Batch No.:**

I. Number of Organisms Found in QC Inspection

Taxon	Count	Taxon	Count

II. Evaluation of QC Sample

Total number of organisms present in sample:	Total number of organisms found in QC audit:
Percent error calculation:	Pass ☐ Fail ☐
Date & initials of sorter performing the QC resort:	
Date & initials of taxonomist recording the number of organisms missed:	
Has this batch previously failed a QC check? Yes ☐ No ☐	
Was the sample residue properly labeled with internal and external labels? Yes ☐ No ☐	
Were all specimen vials of the QC sample properly labeled? Yes ☐ No ☐	

Cove Corporation

Sample Batch Listing Sheet Page ___ of ___

Client & Project Name: MWRA (HOM5 Project)	**Study Site:**
Taxonomist:	**Sampling Date:**

I. BATCHES OF SAMPLES

Batch No.	Batch No.	Batch No.	Batch No.
1)	1)	1)	1)
2)	2)	2)	2)
3)	3)	3)	3)
4)	4)	4)	4)
5)	5)	5)	5)
6)	6)	6)	6)
7)	7)	7)	7)
8)	8)	8)	8)
9)	9)	9)	9)
10)	10)	10)	10)

II. QC EVALUATION

QC Results	Batch No.	Batch No.	Batch No.	Batch No.
QC Sample				
Serial No.				
QC Date				
QC Inspector				
Percent Error				

III. COMMENTS CONCERNING SAMPLE PROCESSING

(initialize & date all entries -- continue on back if necessary)

Necessary Remedial Action:
Comments:

Chain of Custody Record Page ___ of ___

Cove Corporation, 10200 Breeden Road, Lusby, MD 20657
TEL 410-326-4577, FAX 410-326-4767

Client & Project Name: MWRA (HOM5 Project)	**Destination:**
Study Site & Sampling Date:	
Project Description: macrobenthic sample processing	

Rep.	No. of Vials	Serial No.	Survey Date	Sta. – Rep.	No. of Vials	Serial No.	Survey Date

Total Number of Samples

Relinquished by (Signature)	Date	Method of Shipment	Received By (Signature)	Date	Method of Shipment
Relinquished by (Signature)	Date	Method of Shipment	Received By (Signature)	Date	Method of Shipment

Cove Corporation
Species Abundance Data Sheet **Page ___ of ___**

Client: MWRA	**Project Name:** HOM5 Project	**Study Site:**
Taxonomist & Id. Date:		**Sampling Date:**

Station:		Sample Id.	Sample Id.	Sample Id.
Species	Code	Lab. Ser. No.	Lab. Ser. No.	Lab. Ser. No.
		Rep. 1	Rep. 2	Rep. 3

Cove Corporation Identification QC Sheet Page ___ of ___

Client: MWRA (HOM5 Project)	**Study Site:**	**Sampling Date:**
QC Sample:	**Lab. Serial No.:**	**Sample Id.:**
Taxonomist:		**Batch No.:**

I. TYPE I ERRORS (taxa incorrectly enumerated)

Taxon	QC Count	Original Count	Taxon	QC Count	Original Count
Total number of enumeration errors					

II. TYPE II ERRORS (taxa incorrectly identified)

III. TYPE III ERRORS (taxa not recorded or recorded on the wrong line of the data sheet)

Taxon	Number	Taxon	Number
Total number of recording errors			

IV. EVALUATION OF QC SAMPLE

Total number of organisms present in sample:	Total number of errors detected in QC audit:
Identification QC error:	Pass ☐ Fail ☐
Reidentified by:	Date Reidentified:
Necessary Remedial Action:	
Comments:	

Diaz and Daughters
Sediment Profile Image Analysis
Spreadsheet

Client________________
Project Name__________

Study Site______________
Sampling Date___________

		PEN.	PEN.	PEN	Sur		RPD	RPD	RPD		MAX	SURFACE	AMPHIPOD	WORM
STATION	Rep	Min	Max	ave	Rel	Qual	Max	Qual	ave	GRAIN SIZE	GRAIN SIZE	FEATURES	TUBES	TUBES

Page 1 of 2

Diaz and Daughters
Sediment Profile Image Analysis
Spreadsheet

Client____________________

Project Name______________

Study Site______________

Sampling Date___________

		SURFACE FAUNA	SUB. FAUNA		OXIC	ANAEROBIC	GAS	SUCC.			
STATION	Rep	OTHER	WORMS	BURROWS	VOIDS	VOIDS	VOIDS	STAGE		OSI	REMARKS

Hecker Environmental Data Record Form

Roll #:		**Station:T - WP**	**Date**:
Frame #	**Time**	**Depth (ft)**	**Comments**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
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35			
36			

ENSR SPECIES ABUNDANCE DATA SHEET **Page __ of __**

Client: MWRA (HOM6) **Study Site:** Mass Bay **Sampling Date:** ____________

Taxonomist:

Station:		Sample ID	Sample ID	Sample ID
Species	Code	cc#	cc#	cc#
		Rep. 1	Rep. 2	Rep. 3

APPENDIX C

Right Whale Guidance Protocol

Right whale guidance protocol
for vessels operated/contracted by the Commonwealth of Massachusetts

Introduction

The northern right whale is the most endangered large whale in the world. In the western North Atlantic, there are approximately 300 to 350 right whales left. Massachusetts coastal waters are part of the range of the northern right whale, and most Cape Cod Bay has been designated a Critical Habitat for the whale under the federal Endangered Species Act because it serves as a feeding and nursery ground for right whales in the late winter and early spring. The Great South Channel, which lies east of Cape Cod, has also been designated in part as Critical Habitat because of its importance to the right whale as a feeding area in late spring and into the summer. It has been determined that the most significant human-induced causes of mortality are ship strikes and entanglements in fishing gear.

Purpose and Applicability

This protocol applies to all vessels owned or operating under contract to the Commonwealth and is intended to provide guidance for proper operational procedures in the event that such vessels encounter right whales. Vessels operating in the designated Critical Habitat areas (Cape Cod Bay or the Great South Channel) should be especially vigilant from mid-winter to mid-summer when the whales are likely to be present.

Sightings of Right Whales

Reports of right whale sightings should be made to NOAA Fisheries Sighting Advisory System (SAS). Tim Cole, the SAS coordinator, can be reached at 508-495-2087 and the SAS pager number is 978-585-8473. Please report your name, agency and phone numbers at which you can be contacted. Also include the vessel's name, the date, time and location of the sighting, the numbers of whales sighted and any other comments that may be of importance. If possible, photograph or videotape the whale, especially if the animal is entangled or has evidence of a ship-strike. Photographs of entangled whales should be sent to the attention of Dr. Charles Mayo at the Center for Coastal Studies, P.O. Box 1036, Provincetown, MA 02657. Otherwise, photographs should be sent to the Beth Pike of the New England Aquarium’s Right Whale Research team at Central Wharf, Boston, MA 02110. She can be reached at 617-226-2143. Please remember that Massachusetts’ Right Whale Conservation Regulations (322 CMR 12.00) establish a 500-yard buffer zone around any right whale.

Physical Contact with a Whale

If a vessel owned by the Commonwealth of Massachusetts or under contract with the Commonwealth of Massachusetts comes into physical contact with any whale, the incident should be noted in the vessel's logbook. The vessel's logbook entry should include the time and location of the incident, weather and sea conditions, vessel speed, the species of whale struck if known, the nature of any injuries to the crew and/or the whale any damage to the vessel. Also record the name of any other vessels in the area that may have witnessed or can provide information about the incident. A copy of the vessel's log for the entire trip should be submitted to the Massachusetts Director of the Division of Marine Fisheries, the Massachusetts Director of the Division of Law Enforcement, the Massachusetts Secretary of Environmental Affairs and the National Marine Fisheries Service, Northeast Region office in Gloucester.

If the whale is incapacitated or appears to have life-threatening injuries, immediately call the Center for Coastal Studies, entanglement hotline at 800-900-3622 or via their pager at 508-803-0204 and the

Massachusetts Environmental Police Communications Center at 800-632-8075 or 617-626-1665 once the vessel is safe and secure. Stay with the whale until the Coast Guard or Center for Coastal Studies arrives on scene.

Entanglements

Upon encountering an entangled right whale, immediately call the Center for Coastal Studies' (CSC) entanglement hotline at 800-900-3622 or via the CSC pager at 508-307-5300 and the Massachusetts Environmental Police Communications Center at 800-632-8075 or 617-626-1665. Do not attempt to remove any debris from the whale, stay on station with the whale, and follow at a safe distance. As relocating an entangled whale can be extremely difficult, staying on station and following the whale are crucial. However, if following the whale is not possible, contact the Coast Guard and/or the Center for Coastal Studies and note the last direction the animal was heading as well as any other pertinent information that would assist in relocating the whale.

Stranded Whales

Immediately report stranded right whales to the Stranding Network; 617-973-5247 (pager) or, as a second resort, 617-973-5246/6551. Connie Merigo and Howard Krum, New England Aquarium, Central Wharf, Boston, MA 02110 are the contacts for the Network.

QUICK REFERENCE

Sightings

Tim Cole, NOAA Fisheries Sighting Advisory System Coordinator: 508-495-2087 (work), 508-495-2393 (fax) and pager 508-585-8473

Photographs

Dan McKiernan, Acting Deputy Director, Massachusetts Division of Marine Fisheries, 251 Causeway Street, Suite 400, Boston, MA 02114. 617-626-1536
Beth Pike, Data Coordinator, Right Whale Research, New England Aquarium, Central Wharf, Boston, MA 02110. Work: 617-226-2143

Entangled whales

Center for Coastal Studies, entanglement hotline at 800-900-3622 or pager at 508-307-5300
Massachusetts Environmental Police Communications Center at 800-632-8075 or 617-626-1665.

Stranded or Injured Animals

The Stranding Network's hotline is 617-973-5247 (pager). As a second resort, call 617-973-5246/6551. The Cape Cod Stranding Network Phone number is 508-301-7859.

APPENDIX D

Cove Corporation Processing and Quality Control Procedures

COVE CORPORATION

(SPECIALISTS AT MACROBENTHIC SAMPLE PROCESSING)

Description of Macrobenthic Sample Processing and Quality Control Procedures

Prepared by

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Last Revision: May 30, 2008

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1.0 MACROBENTHIC SAMPLE PROCESSING PROCEDURES

This section describes macrobenthic sample processing procedures at Cove Corporation. This section is divided into four parts: (1) sample inventory and storage, (2) sample sorting, (3) sample identification and enumeration, and (4) sample biomassing. These laboratory procedures are designed to produce high quality data. It should also be noted that these laboratory procedures are based upon currently accepted practices in marine benthic ecology.

1.1 Sample Inventory and Storage

Sample processing begins with the reception of macrobenthic samples from the contractor. Upon receipt, each sample will be given a unique serial number so that the location and status of sample processing can be tracked at all times. All sample identification information (e.g., station code, replicate number, sample serial number, location of study site, date of collection, number and size of containers used for each sample, etc.) will be recorded into a computerized sample log book. Samples will also be checked against a master list of samples supplied by the contractor to be sure that they are properly labeled. In addition, the samples will be checked to assure that they are adequately preserved. The contractor will be immediately notified of any sample labeling or preservation problems.

Samples will be stored in storage shed where they will be protected from environmental extremes (i.e., they will be maintained at temperatures between 5° and 30°C). Stored samples will be periodically checked to be sure that an excessive amount of preservative has not evaporated from any of the samples.

During laboratory processing, samples will not be maintained in water for more than 48 hours. If sample sorting has not been completed within 48 hours, the sample will be re-preserved in an 80% ethanol solution for a period of 12 hours. This precaution will minimize microbial decomposition that could affect macroinvertebrate biomass measurements.

1.2 Sample Sorting

The first step of sample sorting is to initiate the sample tracking process. This process assures that the sample has been properly identified by cross referencing the outside sample label information with the sample serial number and station/replicate identification code that is listed in the sample log book.

The second step of sample sorting is to re-sieve the samples using a 0.5 mm sieve. The purpose of this step is to remove the preservative and fine sedimentary particles. Prior to re-sieving, sieves will be cleaned and back washed to prevent cross contamination of samples. Under a fume hood, the preservation fluid from the sample will be poured through a 0.5 mm sieve. The filtrate (i.e., preservation fluid) will be saved to re-preserve the sample residue once sorting is completed. The remaining portion of the sample in the sample container will be rinsed into the sieve using tap water. The sieve containing the sample will be placed in a washbasin and the basin will be partially filled with water. The sieve will be gently agitated to remove fine sedimentary particles from the sample. A gentle spray of water may also be used to help break up consolidated portions of the sample, but direct heavy jets of water will not be used. This washing procedure minimizes mechanical damage to soft-bodied organisms. After the washing procedure has been completed, the sample will be transferred into a labeled container in preparation for sorting. Sieves will be examined after the transfer to ensure that no organisms are entangled in the mesh.

The third step of sample sorting is to remove organisms from the samples. The objective of this step is to remove all organisms of interest from the sample matrix. The organisms of interest are macrobenthic invertebrates usually defined as those organisms retained on a 0.5 mm sieve. All macrofauna and significant body fragments will be removed from each sample. Meiofauna (e.g., harpacticoid copepods, nematodes, ostracods, etc.) and pelagic organisms (e.g., calanoid copepods, chaetognaths, jellyfish, etc.) will not be removed from the samples.

Sorting commences by pouring the sieved sample into white enamel or plastic trays for the initial removal of large size macroinvertebrates. Finer material will be transferred to a petri dish marked with grid lines for sorting using a dissecting microscope. Samples must be evenly distributed over the tray or dish and the water level must be low enough to prevent back and forth sloshing as the tray or dish is moved during sorting. Organisms will be sorted into screw-top vials and preserved in an 80% ethanol solution. Vials will be generated for the following categories: (1) annelids, (2) arthropods, (3) bivalves, (4) gastropods, (5) echinoderms, and (6) miscellaneous taxa. All vials will be labeled internally with the following information: (1) taxonomic category, (2) station code, (3) replicate number, (4) sample serial number, (5) study site, and (6) collection date. All vials from each sample will be bound together with rubber bands and stored in the specimen storage closet. In addition, the sorter will document the following information in the sample log book: (1) number of specimen vials generated for the sample, (2) date and time when sample sorting was completed, and (3) initials of the sorter who sorted the sample. The sample residue that remains after sorting will be transferred back to the sample container and re-preserved in an 80% ethanol solution. A log or batch list of all sorted samples will be kept for each sorter.

1.3 Sample Identification and Enumeration

The objectives of sample identification and enumeration are to accurately identify all organisms found in the sample to the lowest possible level and accurately count the number of individuals of each taxon. Because the identification of macrobenthic invertebrates requires specialized taxonomic training and a familiarity with current taxonomic literature, no single individual will be responsible for identifying all macroinvertebrate groups. Instead, each taxonomist will be responsible for particular groups. When difficult or problematic taxa are encountered, outside taxonomic experts will be consulted to help resolve identifications.

In general, identification of all specimens will be to the species level whenever possible. Nevertheless, certain taxa such as anthozoans, nemerteans, oligochaetes, and turbellarians are extremely difficult to identify and no attempt will be made to identify these taxa to a lower level. In addition, it is often not possible to identify juveniles and damaged or incomplete specimens to a species level. However, an attempt will be made to identify such specimens to a generic or family level.

To be counted, a specimen must have a critical part of the body present. For example, polychaetes, gastropods, and arthropods must have the head, bivalves the umbo, and echinoderms must have at least one-half of the central disk present. Specimens lacking these critical parts will be considered fragments and will not be counted.

All identifications will be performed using dissecting and compound microscopes. The sample identification and enumeration processing begins by retrieving a sample from the specimen storage closet. At that time, a species abundance data sheet will be started. The sample serial number, station code, and replicate number marked on the vials will be checked with that recorded on the sample tracking sheet as well as that recorded in the sample log book. In addition, the number of vials for the sample will be checked with that recorded in the sample log book.

Specimens from each vial will be rinsed into separate petri dishes. All vials will be visually inspected to be sure that all organisms have been rinsed from the vials. Each taxon will be identified (usually to the species level), counted, and put into separate vials as specified for each project. All vials will be labeled internally with the following information: (1) taxonomic name, (2) station code, (3) replicate number, (4) and sample serial number. All vials from each sample will be pooled together into a larger sized jar. The jar will be labeled both internally and externally with the following information: (1) station code, (2) replicate number, (3) sample serial number, (4) study site, and (5) collection date. All records on the species abundance or biomass data sheets will be made in waterproof ink. In addition, all entries will be initialized and dated by each taxonomist that performs identifications.

1.4 Sample Biomassing

Wet weight biomass measurements will be made for each taxon (typically major taxonomic groups) using an analytical balance with an accuracy of 0.1 mg. Biomass measurements will not be made until all specimens in a sample have been identified and have passed all quality control protocols. The balance will be calibrated twice each day using a computerized, internal calibration program. Prior to weighing, each taxon will be placed on absorbent paper toweling to blot dry. In an effort to obtain consistent weights, specimens will be blot-dried for two minutes. However, the time required for blot drying may be less for small, less numerous taxa (e.g., one individual of *Mediomastus ambiseta*). For large bivalves (>20mm), the shell will be opened and the preservation fluid will be drained before weighing.

2.0 QUALITY CONTROL PROCEDURES

This section describes Quality Control (QC) procedures for macrobenthic sample processing at Cove Corporation. This section is divided into three parts: (1) sorting quality control, (2) identification and enumeration quality control, and (3) biomass quality control. Cove Corporation's QC program is designed to assure that good laboratory practices are used throughout sample processing and that all macrobenthic samples are processed with a high degree of accuracy.

2.1 Sorting Quality Control

This subsection describes QC protocols for sample sorting and is divided into three parts: (1) sorting QC of experienced technicians, (2) sorting QC of newly hired technicians, and (3) sorting QC of low abundance samples.

2.1.1 Sorting Quality Control of Experienced Technicians

At least 10% of the samples sorted by each technician will be checked to detect any unacceptable sorting errors. Only senior technicians will perform the QC evaluations. (A senior technician is defined as having three or more years of sorting experience). Under no circumstances will the same individual who sorted the sample perform the QC evaluation. All samples sorted by each technician will be divided into batches of ten samples and a random selection of one sample from each batch will be checked. In most cases, a batch of samples is defined as ten consecutively sorted samples. By definition, at least 95% of all animals must be removed from a sample to pass the QC evaluation (i.e., the percent sorting error must be ≤5%). The following formula will be used to calculate the percent sorting error for each QC sample:

$$\frac{\text{number of animals found in QC inspection}}{\text{total number of animals present in sample}} \times 100 = \text{percent sorting error}$$

If a sample fails the QC evaluation, all remaining samples from the batch of samples will be resorted. In addition, technicians will be informed of any necessary corrective measures. This procedure will be repeated until the batch of samples passes the QC evaluation. A record of all sorting QC evaluations will be maintained for each technician. Residual material from all completed samples will be returned to the contractor or disposed of as requested.

An initial QC check will be performed when samples from a new geographical region are processed. This initial check will be performed before the regular QC procedure discussed above is implemented. This procedure simply involves checking the first few samples sorted by each technician to detect and correct any unacceptable sorting errors. The purpose of this initial check is to assure that all target animals are being extracted from the samples. This procedure is also considered to be a continuation of laboratory training for experience technicians, since new and/or unusual taxa are often missed when they are encountered for the first time.

2.1.2 Sorting Quality Control of Newly Hired Technicians

Cove Corporation also has a special training program for new technicians. During the first phase of the training program, a senior technician will closely monitor sample sorting. All portions of each sample will be re-sorted by the senior technician to make sure that the new technician is removing all target animals from the sample. Any problems detected by the senior technician will be discussed with the new technician. This process continues until the senior technician believes that the new technician can sort samples independently. During the second phase of the training program, new technicians sort samples independently. After they complete each sample, a senior technician resorts the sample and a percent sorting error for the sample will be calculated (see formula above). Again, any sorting deficiencies will be discussed with the new technician. New technicians must pass three consecutive QC evaluations before proceeding to the next phase of the training program. During the third and final phase of the training program, new technician sort samples independently in batches of ten samples. After each batch of samples is completed, a senior technician randomly selects and resorts one sample from the batch. If the sample fails the QC evaluation, the corrective measures discussed above will be implemented. If the new technician continually fails sorting QC evaluations, they will be retrained starting at the first phase of the training program.

2.1.3 Sorting Quality Control of Low Abundance Samples

A unique problem arises when samples with a low abundance are chosen for the QC evaluation. To illustrate this point, assume that a sample with 15 organisms was selected for the sorting QC check. There are only two possible outcomes. Either the sample was sorted perfectly (i.e., no organisms were missed) or the sample fails (i.e., even if only one organism was missed, the sorting error would be 6.6%). This example illustrates the inflexibility of using an arbitrary value to determine the pass/fail status of a batch of samples. In other words, the 6.6% sorting error in this example does not indicate that the sorting performance was poor. In fact, just the opposite is true. To this end, Cove Corporation has developed special guidelines governing low abundance samples. First, a low abundance sample is defined as “any sample having fewer than 60 organisms”. Second, any low abundance sample in which three or fewer organisms were missed is considered to pass the sorting QC evaluation even if the percent sorting error is >5%. Third, a special case of a low abundance sample is a sample in which no organisms present. Such samples are excluded from the sorting QC selection process simply because they would automatically pass the QC evaluation (provided that there really are no organisms present in the sample).

2.2 Identification and Enumeration Quality Control

In general, the same basic QC principles described in the previous section apply to species identifications. For example, at least 10% of the samples will be checked to detect any unacceptable identification and enumeration errors. Only senior taxonomists will perform the QC check. (A senior taxonomist is defined as having three or more years of taxonomic experience). QC samples will be selected in the same manner as described in the Sorting Quality Control section above. In addition, the same percent accuracy level[1] will be used to determine if a sample passes the QC evaluation and the same corrective measures will be implemented if a sample fails the QC evaluation. The following formula will be used to calculate the percent taxonomy error for each QC sample:

$$\frac{\text{total number of taxonomy errors}}{\text{total number of animals present in sample}} \times 100 = \text{percent taxonomy error}$$

Please note that in certain cases it may not be necessary to reprocess the entire batch of samples if only minor corrections are needed (e.g., name changes). When any misidentification is discovered, all previously identified samples containing that taxon will be rechecked. A record of all identification QC evaluations will be maintained. Specimens from all completed samples will be returned to the contractor or stored for a period of one year and then disposed of as requested.

Cove Corporation maintains a specimen reference collection of all identified taxa for each geographical region. The purpose of a reference collection is to assure that identifications throughout the project and among projects are consistent. A positive result of the QC program is the active discussion of taxonomic literature and comparison of species identifications among taxonomist. Thus, the identifications of most taxa as well as reference specimens will be constantly checked throughout sample processing.

2.3 Biomassing Quality Control

Many of the QC principles described in Sorting Quality Control section are also used to evaluate biomass measurements. For example, at least 10% of the samples will be checked to detect any unacceptable weighing errors. Only senior technicians will perform the QC check. QC samples will be selected in the same manner and the same corrective measures will be implemented if a sample fails the QC evaluation. However, there are some important differences. First, the definition of a biomass sample is different. A sample is defined as “the weight of one biomass group from a single macrobenthic grab sample”. Please note that biomass groups vary among projects. In some cases, it may compose all individuals of a particular macroinvertebrate group (e.g., annelida, arthropoda, bivalvia, gastropoda, etc.) or it may

[1]A strict 95% acceptance/rejection level is not used when a sample with a low abundance is selected for the taxonomy QC evaluation (see section 2.1.3). The same criteria described in section 2.1.3 also apply to taxonomy QC checks.

comprise all individuals of a single macroinvertebrate species (e.g., *Ampelisca abdita*, *Polydora cornuta*, or *Tellina agilis*). Second, the percent accuracy level that will be used to determine if a sample passes the QC evaluation is also different. Wet weight biomass values are difficult to reproduce (i.e., they are imprecise). For this reason, an 80% accuracy level will be used to determine if a sample passes the QC evaluation (i.e., the percent weighing error must be ≤20%). The following formula will be used to calculate the percent weighing error for each QC sample:

$$\frac{\left|\text{original weight - QC weight}\right|}{\text{QC weight}} \times 100 = \text{percent weighing error}$$

A record of all biomassing QC evaluations will be maintained for each technician.

As with sorting QC samples that possess a low number of individuals, high percent weighing errors can be calculated for QC samples with a low biomass. For this reason, any sample in which the difference between the original and QC measurement is ≤1 mg is considered to pass the biomass QC evaluation even if the percent weighing error is >20%.

3.0 DATA MANAGEMENT

This section describes how data is recorded and key punched into a computer. This section is divided into two parts: (1) data documentation and data entry and (2) quality control of data entry. Data quality control procedures at Cove Corporation are designed to assure that all data is entered into a computer with a high degree of accuracy.

3.1 Data Documentation and Data Entry

All data generated during laboratory sample processing will be recorded directly onto abundance and/or biomass data sheets. All data will be recorded in waterproof ink. In addition, all entries will be initialized and dated by the person recording information onto the data sheet. Data sheets will be linked to specific samples using the sample serial numbers that were assigned to each sample during the initial inventory of all macrobenthic samples.

Each macroinvertebrate taxon will be coded with a unique National Oceanographic Data Center (NODC) numerical code. Abundance and/or biomass data will be entered into a desktop computer using a customized data entry program. Electronic computer files of raw macro-benthic data are in an ASCII format, but they can be easily converted into text files or Excel spreadsheets. All abundance and/or biomass data will be reported on a per sample basis.

3.2 Quality Control of Data Entry

The accuracy of computerized data entry occurs in two phases. First, quality control checks are directly incorporated into the data entry program to assure that all taxa are properly coded and duplicate species entries are prevented. As an additional precaution, each line of data will be printed to the screen so that the scientific name and abundance of each taxon can be checked as data is entered. Second, all printouts of species abundance tables will be manually checked line by line to assure that all taxa are present and the abundance of each taxon has been correctly entered. In other words, 100% of the data will be rechecked for accuracy.

APPENDIX E

SPI PARAMETERS

Diaz and Daughters

The following paragraphs describe the parameters measured from the sediment profile images.

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 sediment 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, the prism penetration provides a means for assessing the relative sediment compaction between stations or different habitat types.

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 submerged aquatic vegetation (SAV), worm tubes, fecal pellets, epibenthic organisms, bacterial mats, algal mats, shells, mud clasts, and 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).

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