Quality assurance project plan (QAPP) for benthic monitoring: 2006–2007

Massachusetts Water Resources Authority

Environmental Quality Department

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COMBINED WORK QUALITY ASSURANCE PROJECT PLAN
FOR
BENTHIC MONITORING

for

Benthic Monitoring: 2006 – 2007

Tasks 17-20
MWRA Harbor and Outfall Monitoring Project
Contract No. OP-44B

Submitted to

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Environmental Quality Department
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Technical Report No. 2006-09

QUALITY ASSURANCE PROJECT PLAN (QAPP)

for

BENTHIC MONITORING: 2006 – 2007

Tasks 1-10

MWRA Harbor and Outfall Monitoring Project
Contract No. OP-44B

TITLE AND APPROVAL SHEET

Dr. James A. Blake ENSR Program Manager	Date
Dr. Pamela A. Neubert ENSR Deputy Program Manager	Date
Ms. Debra Simmons ENSR Quality Assurance Officer	Date
Dr. Michael Mickelson MWRA Project Manager	Date
Mr. Kenneth E. Keay MWRA Benthic Monitoring Project Area Manager	Date
Ms. Wendy Leo MWRA EM & MS Manager	Date

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Section A – PROJECT MANAGEMENT

A1 Introduction

This Quality Assurance Project Plan (QAPP) has been prepared to meet the requirement of Task 3.1 of the Massachusetts Water Resources Authority Contract OP-44B for Benthic Monitoring Services (Agreement II) for Harbor and Outfall Monitoring. This QAPP describes the objectives of each study, the technical activities to be performed at sea and in the laboratory (including shipboard processing and preservation of samples), data quality requirements and assessments, project management (organization and responsibilities of ENSR's staff and subcontractors), and a schedule of activities and deliverables. A full description of sample tracking, data processing, data quality control, and data reduction and analysis is included as well as the equations used to generate calculated values, and the types of quality control plots for each task area's data reports. This QAPP has been prepared in accordance with the USEPA QAPP format as presented in the *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R5 (EPA 2001) and the *EPA Guidance for Quality Assurance Project Plans*, EPA QA/G-5 (EPA 2002).

A2 Table of Contents

The table of contents includes sections, tables, figures, references, and appendices. Document control information is included in the header.

A3 Distribution List

Copies of this QAPP, and any subsequent revisions, will be distributed to the following personnel:

Andrea Rex, MWRA ENQUAD
Ken Keay, MWRA ENQUAD
Michael Mickelson, MWRA ENQUAD
Wendy Leo, MWRA EM & MS Manager
Yong Lao, MWRA DLS
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Rosanna Buhl, Battelle
Roy K. Kropp, Battelle
Alex Mansfield, Battelle
Robert Diaz, Diaz & Daughters
Barbara Hecker, Hecker Environmental
Nancy Mountford, Cove Corporation
Eugene Ruff, Ruff Systematics
Woollcott Smith, Independent Consultant
Russ Winchell, Ocean's Taxonomic Services

A4 Project/Task Organization

The Benthic (Sea-Floor) Monitoring tasks will be accomplished through the coordinated efforts of several organizations. 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.

Dr. Andrea Rex is the MWRA Director of Environmental Quality Department. Dr. Michael Mickelson is the MWRA Project Manager. Mr. Ken Keay is the MWRA Deputy Project Manager and is the Project Area Manager for the Benthic (Sea-Floor) Monitoring. Ms. Wendy Leo is the MWRA Environmental Monitoring and Management System (EM&MS) Database Manager. Dr. Yong Lao is the point of contact for the MWRA Department of Laboratory Services (DLS) that will be responsible for all sediment chemistry laboratory analyses. These MWRA managers will be informed of all matters pertaining to work described in this QAPP.

Dr. James A. Blake is the ENSR Program Manager responsible for ensuring that products and services that meet MWRA's expectations are delivered in a timely and cost-effective manner and for the overall performance of this project. He is responsible for ensuring that data collection and interpretation are scientifically defensible and for responding to technical challenges as they arise. Mr. Donald P. Galya is the Principal-in-Charge and 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. Dr. Pamela A. Neubert is ENSR's Deputy Program Manager. She is also the task manager for all field operations. Ms. Debra Simmons is the ENSR Quality Assurance Officer for the project and is responsible for reviewing the QAPP, survey and data reports, and the harbor and outfall synthesis reports. She also reviews QA Statements submitted by subcontractors for quality, completeness, and adherence to the QAPP. Ms. Hedy Lopes will serve as ENSR's contracting officer and will address any contractual or legal issues that might arise during the course of the project. Ms. Kathleen Harvey is ENSR's Health & Safety Officer and will ensure that strict health and safety procedures are followed during project, especially for field surveys and sample handling. Ms. Isabelle P. Williams is the task manager for laboratory analyses and the resultant databases. She will develop the draft 2006–2007 Benthic Monitoring QAPP under the guidance of Ms. Simmons. Dr. Nancy Maciolek is task manager and editor in charge of the harbor and outfall synthesis reports.

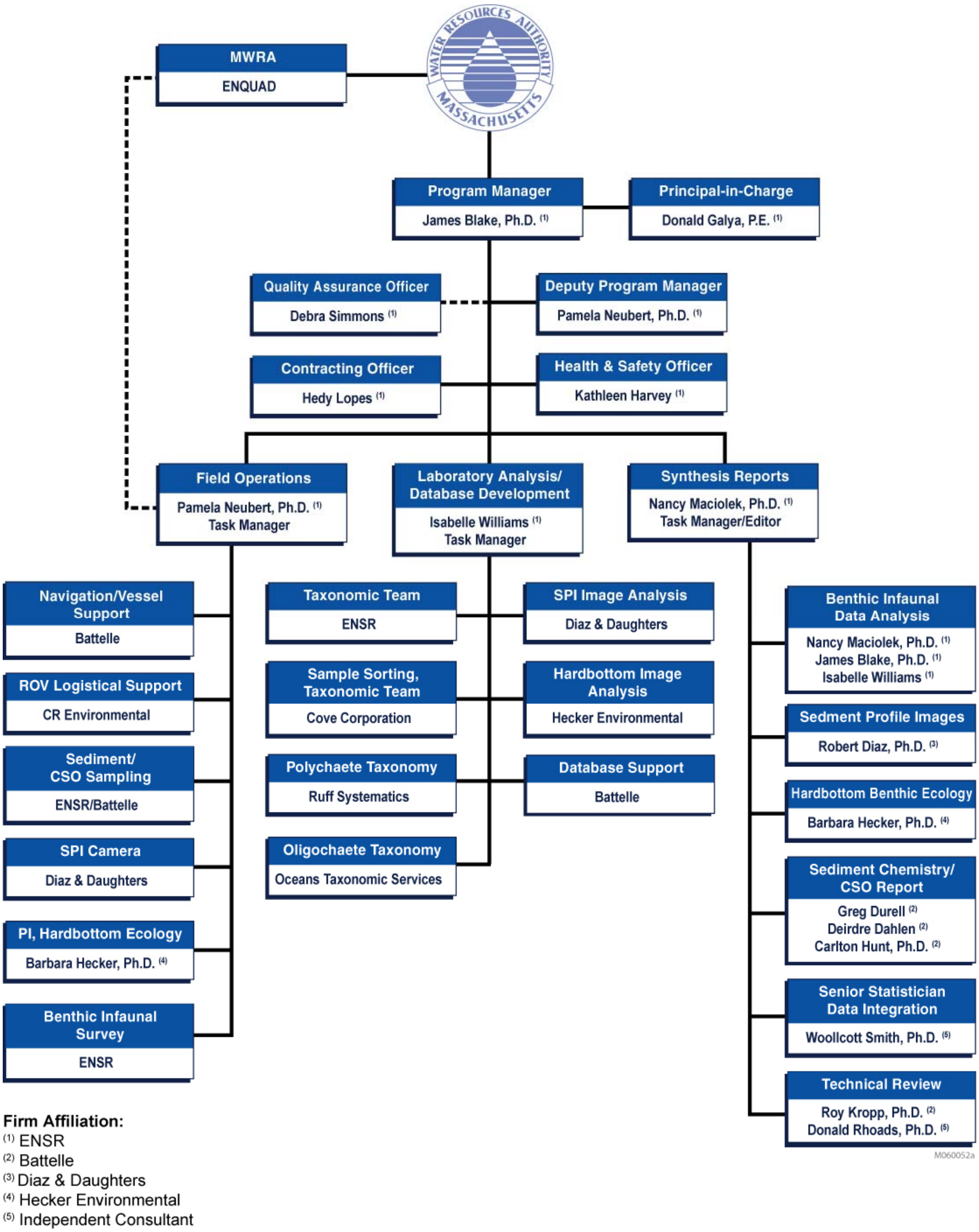

Figure 1. Benthic Monitoring Task Organization.

Technical oversight for the Benthic (Sea-Floor) Monitoring will be provided by a team of Senior Scientists gathered together by ENSR and Battelle. ENSR will be responsible for the biological aspects of benthic monitoring with Dr. James A. Blake having overall responsibility for the biological components. Supporting Dr. Blake for benthic infaunal biology are Dr. Nancy Maciolek (ENSR), Ms. Isabelle Williams (ENSR), Ms. Nancy Mountford and Mr. Timothy Morris (Cove Corporation), Mr. Eugene Ruff (Ruff Systematics), and Mr. Russell Winchell (Ocean's Taxonomic Services). Support for benthic biological and ecological processes determined by sediment profile imagery and hard-bottom community observations will be provided by Dr. Robert Diaz (Diaz and Daughters) for Sediment Profile Imagery and Benthic Ecology; and Dr. Barbara Hecker (Hecker Environmental) and Dr. Pamela Neubert (ENSR) for hard-bottom community analysis.

Providing Dr. Blake with support in report preparation and review and database management are senior consultants providing expertise in statistics, ecology, sediment chemistry, geology, and database management. Dr. Donald Rhoads (Consultant) will assist Dr. James Blake in the technical reviewer of the harbor synthesis report. Dr. Roy K. Kropp (Battelle) will be technical reviewer for the outfall synthesis report. Dr. Woollcott Smith (Consultant) will serve as senior statistician for all aspects of the benthic monitoring program. Battelle has overall responsibility for review and synthesis of sediment chemistry analytical results. Dr. Carlton Hunt (Battelle) and Ms. Deirdre Dahlen (Battelle) are co-principal investigators and authors responsible for the chemistry chapter of the harbor and outfall synthesis reports. Mr. Gregory Durell (Battelle) is the lead author for the 2006 CSO sediment/harbor contaminant report (Task 9.3). Battelle is also providing database support with Mr. Gregory Lescarbeau as the database specialist who will oversee the data loading to MWRA.

Navigational support for all benthic field programs is being provided by Battelle. Mr. Alex Mansfield is the Battelle Field Manager responsible for navigational 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. Mr. John H. Ryther, Jr. is providing vessel support and equipment logistics for the hard-bottom survey (Task 6.4).

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

A5 Problem Definition/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

Table 1. Personnel Responsibilities and Contact Information for HOM5 Program.

Name/ Affiliation	Address	Project Area Assignment	Contact Information
MWRA			
Dr. Andrea Rex	Environmental Quality Department MWRA Charlestown Navy Yard 100 First Ave. Boston, MA 02129	Director of Environmental Quality Department	Ph: 617-788-4708 Fx: 617-788-4889 andrea.rex[at]mwra.state.ma.us
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Mr. Ken Keay		Deputy Project Manager; Benthic Monitoring Project Area Manager	Ph: 617-788-4742 Fx: 617-788-4889 kenneth.keay[at]mwra.state.ma.us
Ms. Wendy Leo		EM&MS Database Manager	Ph: 617-788-4743 Fx: 617-788-4889 wendy.leo[at]mwra.state.ma.us
Dr. Yong Lao	Department of Laboratory Services MWRA 190 Tafts Avenue Winthrop, MA 02152	DLS Project Manager ; Primary point of contact for HOM5 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		Task Leader –- Infaunal Benthic Data Analysis and Synthesis Reports; Task Manager/Editor – Benthic Data Analysis and Synthesis Reports QAPP Development; Polychaete Taxonomy – Consultant; **(Tasks 1, 3, 7, 8, and 9)**	Ph: (508) 457-7900 Fx: (508) 457-7595 nmaciolek[at]ensr.aecom.com
Ms. Isabelle P. Williams		Task Manager – Infaunal Benthic Data; QA Documentation and Transmission; QAPP Development Support; Co-chief Scientist – Field Surveys Task Leader – Benthic Faunal Analysis; Reference Collection; Benthic Taxonomic Analysis, Crustaceans, Molluscs, Misc. Fauna; **(Tasks 1, 3, 4, 5, 6, and 7)**	Ph: (508) 457-7900 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 dsimmons[at]ensr.aecom.com

Name/ Affiliation	Address	Project Area Assignment	Contact Information
Battelle			
Dr. Carlton D. Hunt	Battelle Duxbury Operations 397 Washington St. Duxbury, MA 02332	Co-Principal Investigator, Sediment Chemistry; **(Task 9)**	Ph: (781) 952-5374 Fx: (781) 934-2124 huntc[at]battelle.org
Ms. Deirdre Dahlen		Co-Principal Investigator, Sediment Chemistry; **(Task 9)**	Ph: (781) 952-5253 Fx: (781) 934-2124 dahlend[at]battelle.org
Mr. Gregory Durell		Lead Author – CSO/Harbor Sediment Contaminant Report for 2006; **(Tasks 9 and 10)**	Ph: (781) 952-5233 Fx: (781) 934-2124 durell[at]battelle.org
Mr. Gregory Lescarbeau		Manager, Database Support; **(Task 4)**	Ph: (781) 952-5293 Fx: (781) 934-2124 lescarbeaug[at]battelle.org
Mr. Alex Mansfield		Battelle Field Manager; **(Tasks 5 and 6)**	Ph: (781) 952-5329 Fx: (781) 934-2124 mansfielda[at]battelle.org
Dr. Roy K. Kropp	Battelle Marine Sciences Laboratory 1529 West Sequim Bay Road Sequim, WA 98382	Technical Review, Synthesis Reports; **(Task 9)**	Ph: (360) 681-3610 Fx: (360) 681-3681 roy.kropp[at]pnl.gov
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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Mr. R. Eugene Ruff	Ruff Systematics 4227 S. Meridian – Suite C Puyallup, WA, 98373-3603	Benthic Taxonomic Analysis, Polychaetes; Lab QA **(Task 7)**	Ph: (253) 770-7007 Fx: (253) 841-2934 wormworks[at]qwest.net
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			
Dr. Donald C. Rhoads	22 Widgeon Rd. Falmouth, MA, 02540	Consultant/Technical Reviewer – Benthos **(Task 9)**	Ph: (508) 448-9588 dhrhoads[at]aol.com
Dr. Woollcott Smith	Temple University 1810 North 13th St. 203-O Speakman Hall (006-00) Philadelphia, PA, 19122-6083 Box 86 West Tisbury, MA 02575 Martha's Vineyard, MA	Statistical Support –Benthic Data Analysis; Analysis and Integration of Benthic Monitoring Results **(Tasks 9 and 10)**	Temple office Ph: (251) 204-6873 Fx: (215) 204-1501 wksmith[at]temple.edu Martha's Vineyard Ph: (508) 693-9168 Fx: --- smith4[at]vineyard.net

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 9.5 mi 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% is screened and disinfected. As of the end of 2004, 63 CSO's remained in Boston Harbor and its tributaries (Coughlin 2005). By 2008, ongoing projects will reduce the number of CSO outfalls to fewer than 50, with an estimated discharge of 0.4 BGY, of which 95% will be treated by screening and disinfection (Rex *et al.* 2002).

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.

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 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) is an attachment to the Memorandum of Agreement among the National Marine Fisheries Service, USEPA, and MWRA. 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

The studies included in the monitoring plan (MWRA 1991, 1997b, 2004) are more extensive than necessary to calculate the Contingency Plan threshold values or to meet the NPDES permit requirements (MWRA 2004). Relocating the outfall raised concerns about potential effects of the discharge on the offshore benthic (bottom) environment. These concerns 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. Extensive information collected over a nine-year baseline period and a five-year post-diversion period has allowed a more complete understanding of the bay system and has provided data to explain any changes in the parameters of interest and to address the question of whether MWRA's discharge has contributed to any such changes.

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

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

A5.3.1 *Scope*

The scope of the benthic task includes (1) monitoring the recovery of the benthic communities in Boston Harbor and (2) obtaining data on the communities and sediment quality at sites in Massachusetts Bay and Cape Cod Bay in 2006 and 2007.

The principal aim of the harbor studies is documentation of continuing recovery of benthic communities in areas of Boston Harbor in response to decreases in wastewater discharges; for example, reductions in combined sewer overflow (CSO) releases. Recent reports have indicated that some infaunal community changes are consistent with those expected with habitat improvements (Kropp *et al*. 2000, Kropp *et al*. 2001, Maciolek *et al*. 2004, 2005). 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 (0S8 km from the outfall), where changes in water and sediment quality were predicted to occur following initiation of the discharge. Farfield areas (typically >8 km from the outfall), which serve primarily as reference areas for the nearfield, are also examined as part of the monitoring studies. Such sites can become monitoring stations if the discharge is shown to affect sites distant from the diffuser.

A5.3.2 *Objectives*

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. Monitoring of the outfall is required by MWRA's discharge permit. Harbor monitoring of CSO impacts is required by CSO discharge permits. Additional objectives are to provide data that will be used to:

- Evaluate response against contingency plan thresholds
- Determine ecologically meaningful changes with statistical rigor and evaluate these changes as possible responses of benthic communities to cessation of discharges in Boston Harbor or to the continuation of treated wastewater discharges through the outfall diffuser
- Continue to develop an understanding of the dynamics and status of the ecosystems

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

These objectives are addressed in four major tasks as defined in the MWRA Benthic Monitoring Agreement II (see tasks 4-7 below). Two tasks focus on sampling activities that will take place in Boston Harbor, Massachusetts Bay, and Cape Cod Bay. One task concentrates on the analysis of the collected faunal samples and benthic images. The purpose of the fourth task is to produce interpretations and syntheses of the faunal, chemical, and sedimentary data collected during each year.

Harbor Benthic Surveys (Task 5) include traditional sediment grab-sampling to collect samples for characterization of the physical, chemical (TOC), and biological status of surficial sediments at nine stations throughout Boston Harbor (Williams *et al*. 2005) and an extensive reconnaissance survey using sediment profile images (SPI) (Williams *et al*. 2005). Samples will be collected in 2006 to detect the effects of CSOs on local sediment quality; the last focused CSO survey was conducted in 2002 (Lefkovitz *et al*. 2006).

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 (Williams *et al*., 2005). 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 (Williams *et al*. 2005). A reference collection of all soft-bottom taxa (identified and unidentified specimens) collected will be stored, maintained, and compiled throughout the project (Williams *et al*. 2005).

Synthesis Reports (Task 8) include the preparation of two annual (harbor and outfall) reports that interpret all activities carried out under Tasks 5–7 to evaluate the current status of benthic communities in the nearfield and farfield of Massachusetts and Cape Cod Bays and Boston Harbor. A third report, prepared only in 2006, will evaluate sediment contamination in Dorchester Bay from combined sewer overflows and long-term changes in concentrations of contaminants in Boston Harbor sediments. These synthesis reports will include data on sedimentary characteristics and contaminants provided by MWRA's Department of Laboratory Services.

The present status and variability of the benthic environmental quality within the harbor and Massachusetts bays system will be evaluated by examination of the interrelationships among the examined biological and sedimentary parameters. Critical to this component of the monitoring program is the use of statistical and numerical methods to evaluate benthic habitat and community changes and to identify possible causes. These synthesis reports will add to an understanding of the ecosystem and should address MWRA needs for assessing the adequacy of the monitoring program to detect meaningful change and for management decisions on the need for mitigation.

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. CSO stations will be sampled in 2006.

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 9.2). 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 2006 and 2007 (Table 2, Figure 2).

The Boston Harbor CSO study (Task 5.3), to be conducted in August 2006, is a continuation of the MWRA's CSO studies that were performed in 1990, 1994, 1998, and 2002 (Lefkovitz *et al*. 2006). The CSO sediment studies provide information on improvements in sediment quality in Boston Harbor after CSO upgrades. Sediments will be collected from all 17 stations (Table 2, Figure 3) that were sampled in 2002, and will be analyzed for selected contaminants. These CSO stations include all nine infaunal grab stations mentioned above and eight additional CSO stations, seven within Dorchester Bay and one (SWEX3) in the Outer Harbor. The analytical results will be compared to those obtained during the four previous CSO studies and the 1997 harbor contaminant (Blake *et al*. 1998) study.

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.

A6.2 Outfall Studies

The Outfall Benthic Surveys provide quantitative measurements of benthic community structure and patterns of contaminant concentrations in the sediments of Massachusetts and Cape Cod Bays. Baseline data was collected yearly in August from 1992 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. Outfall studies conducted under this task will provide the data required for a quantitative assessment of the effects of discharged effluent on benthic infaunal communities (Task 9.1) 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).

Table 2. Target Locations for Harbor Traditional and Reconnaissance Stations

Station	Latitude	Longitude	Depth (m)
Traditional Stations (all will be included in the 2006 CSO survey)			
T01	42°20.95′N	70°57.81′W	4.9
T02	42°20.57′N	71°00.12′W	6.8
T03	42°19.81′N	70°57.72′W	8.7
T04	42°18.60′N	71°02.49′W	3.2
T05A	42°20.38′N	70°57.64′W	17.5
T06	42°17.61′N	70°56.66′W	6.6
T07	42°17.36′N	70°58.71′W	5.9
T08	42°17.12′N	70°54.75′W	11.3
C019	42°21.55′N	71°02.72′W	9.4
Reconnaissance Stations			
R02	42°20.66′N	70°57.69′W	13.8
R03	42°21.18′N	70°58.37′W	4.5
R04	42°21.52′N	70°58.78′W	7.2
R05	42°21.38′N	70°58.68′W	5.7
R06	42°19.91′N	70°57.12′W	10.9
R07	42°20.85′N	70°58.53′W	5.6
R08	42°20.66′N	70°59.50′W	2.6
R09	42°20.80′N	71°00.98′W	11.6
R10	42°21.32′N	71°02.20′W	12.8
R11	42°19.28′N	70°58.48′W	7.3
R12	42°19.10′N	70°58.47′W	6.1
R13	42°19.03′N	70°58.84′W	6.7
R14	42°19.25′N	71°00.77′W	7.0
R15	42°18.92′N	71°01.15′W	3.2
R16	42°18.95′N	70°57.68′W	8.0
R17	42°18.29′N	70°58.63′W	8.1
R18	42°17.33′N	70°57.67′W	8.0
R19	42°16.92′N	70°56.27′W	9.2
R20	42°19.49′N	70°56.10′W	11.2
R21	42°18.53′N	70°56.78′W	8.7
R22	42°18.02′N	70°56.37′W	9.4
R23	42°17.63′N	70°57.00′W	10.8
R24	42°17.78′N	70°57.51′W	7.4
R25	42°17.48′N	70°55.72′W	7.3
R26	42°16.13′N	70°55.80′W	7.0

Table 2. (continued)

Station	Latitude	Longitude	Depth (m)
R27	42°16.83′N	70°54.98′W	6.0
R28	42°16.90′N	70°54.52′W	7.0
R29	42°17.38′N	70°55.25′W	11.0
R30	42°17.43′N	70°54.25′W	5.0
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	6.0
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	2.0
R41	42°18.67′N	71°01.50′W	4.0
R42	42°19.18′N	71°01.50′W	2.0
R43	42°18.40′N	71°00.13′W	3.0
R44	42°20.62′N	71°00.13′W	9.3
R45	42°19.70′N	70°58.05′W	6.8
R46	42°17.46′N	70°55.33′W	10.5
R47	42°20.67′N	70°58.72′W	6.5
R48	42°17.61′N	70°59.27′W	5.9
R49	42°16.39′N	70°54.49′W	6.1
R50	42°16.50′N	70°53.92′W	6.1
R51	42°15.80′N	70°56.53′W	5.3
R52	42°15.71′N	70°56.09′W	5.2
R53	42°16.15′N	70°56.27′W	6.0
Remaining CSO Stations			
DB01	42°19.48'N	71°02.75'W	3.0
DB03	42°19.30'N	71°00.86'W	5.0
DB04	42°19.68'N	71°02.22'W	4.0
DB06	42°19.39'N	71°02.25'W	2.0
DB10	42°17.50'N	71°02.33'W	2.0
DB12	42°18.97'N	71°01.29'W	5.0
DB14	42°17.92'N	71°02.73'W	2.0
SWEX3	42°19.76'N	70°59.56'W	8.0

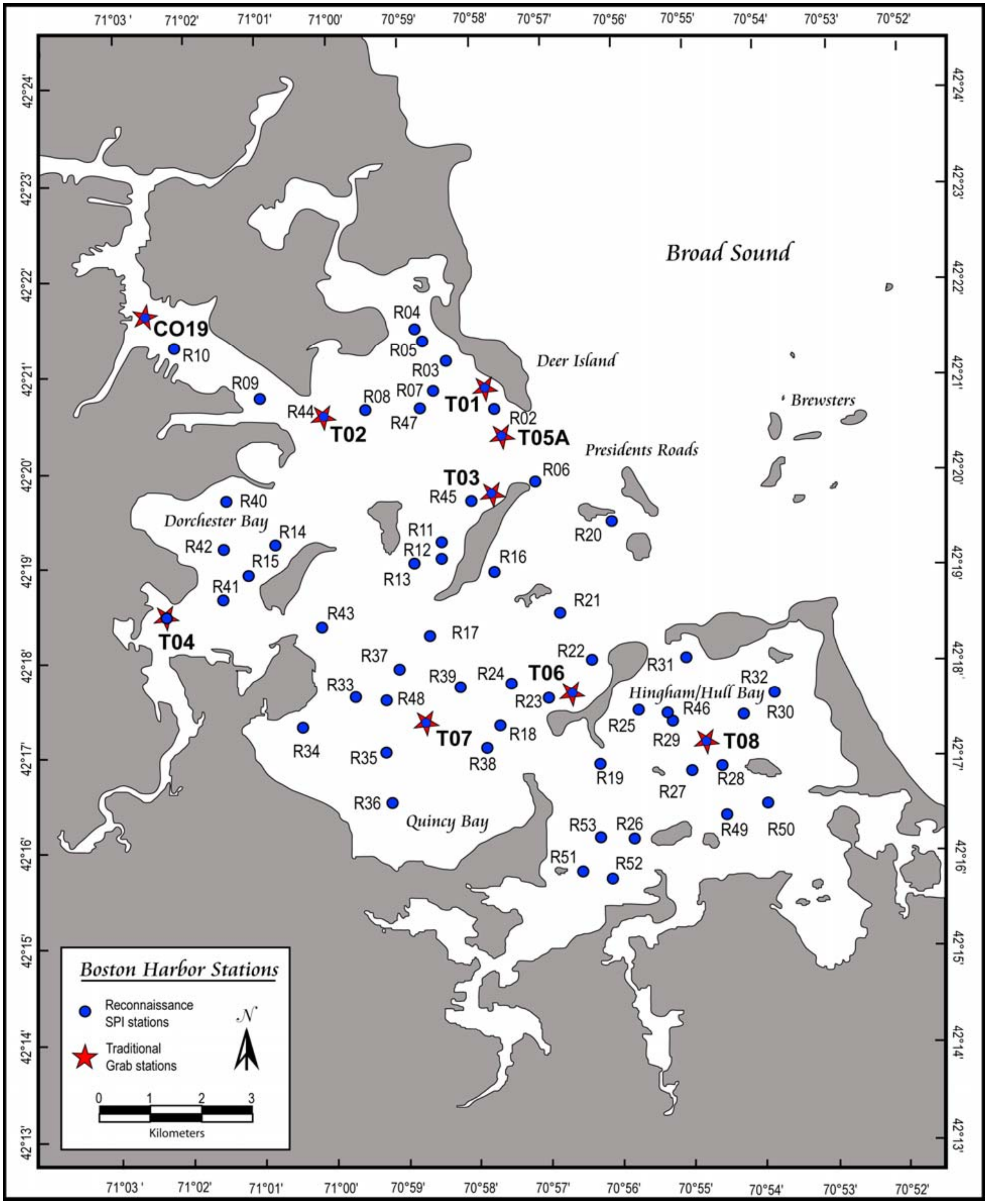


Figure 2. Locations of Boston Harbor Grab and Reconnaissance Stations.

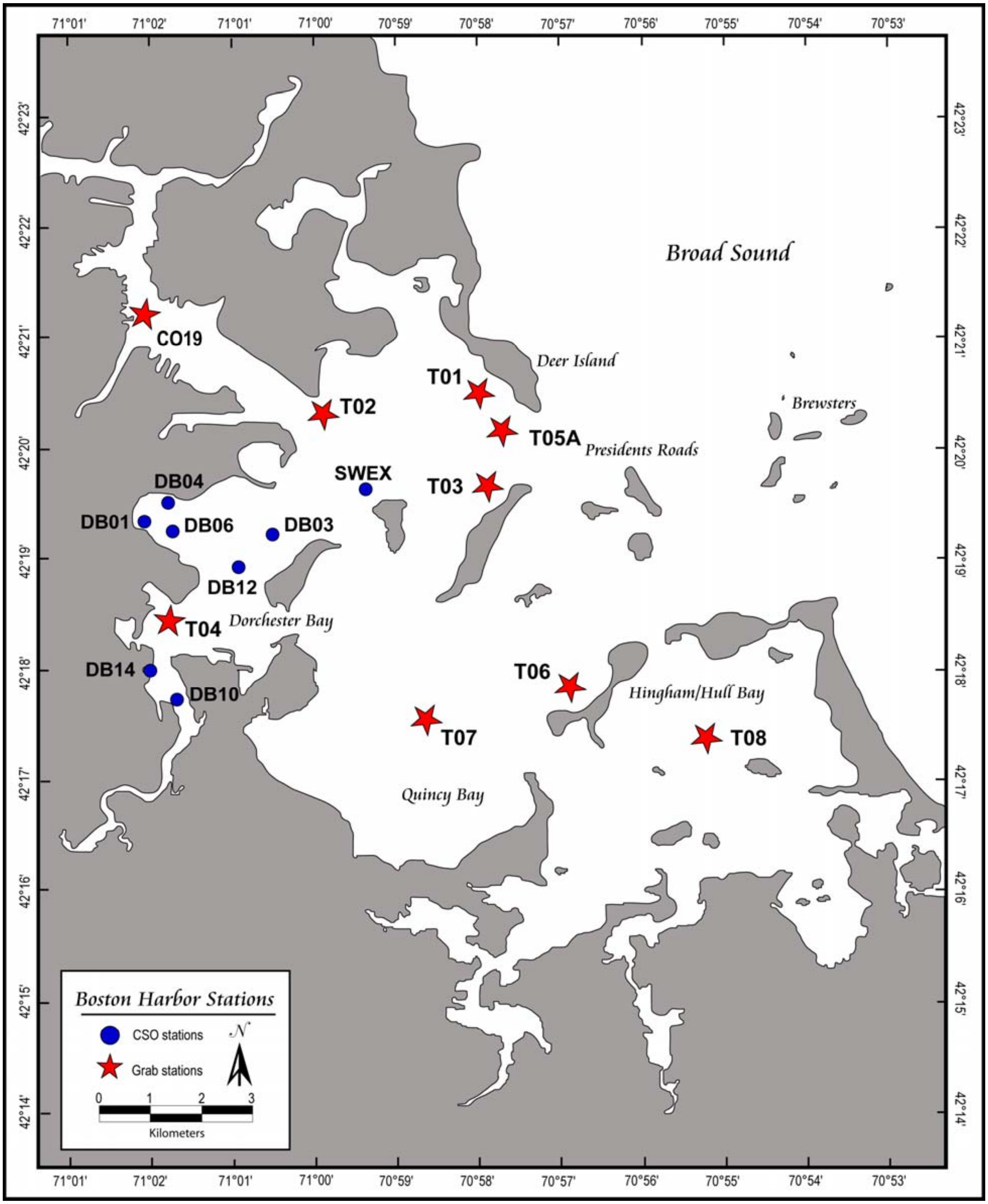


Figure 3. Locations of CSO/Harbor Sediment Contaminant Survey Stations.

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. Samples for sediment chemistry and benthic infauna will be collected at all 23 nearfield stations during the period of this contract (Table 3; Figure 4). In 2004, all 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).

Farfield benthic surveys, conducted in August each year (Task 6.2), contribute reference and early-warning data on soft-bottom habitats in Massachusetts and Cape Cod Bays. In 2004, the eight farfield stations were divided into two groups, each group to be sampled every other year, so that all stations are sampled every two years (Tables 3 and 4, Figure 5). Stations FF04 and FF05 are within the Stellwagen Bank National Marine Sanctuary.

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. Furthermore, these surveys provide rapid comparison of benthic conditions to the Contingency Plan threshold (Appendix A) for depth of sediment redox potential discontinuity (RPD) as sediment profile imagery (digital since 2002) allows a faster evaluation of the benthos to be made than can be accomplished through traditional faunal analyses. 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 6). 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.

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 effort in outfall monitoring, 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 HOM5 (based on Table 1-1 in Maciolek *et al*. 2005). 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.

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 2006
[2] Stations to be sampled for benthic infauna in 2007

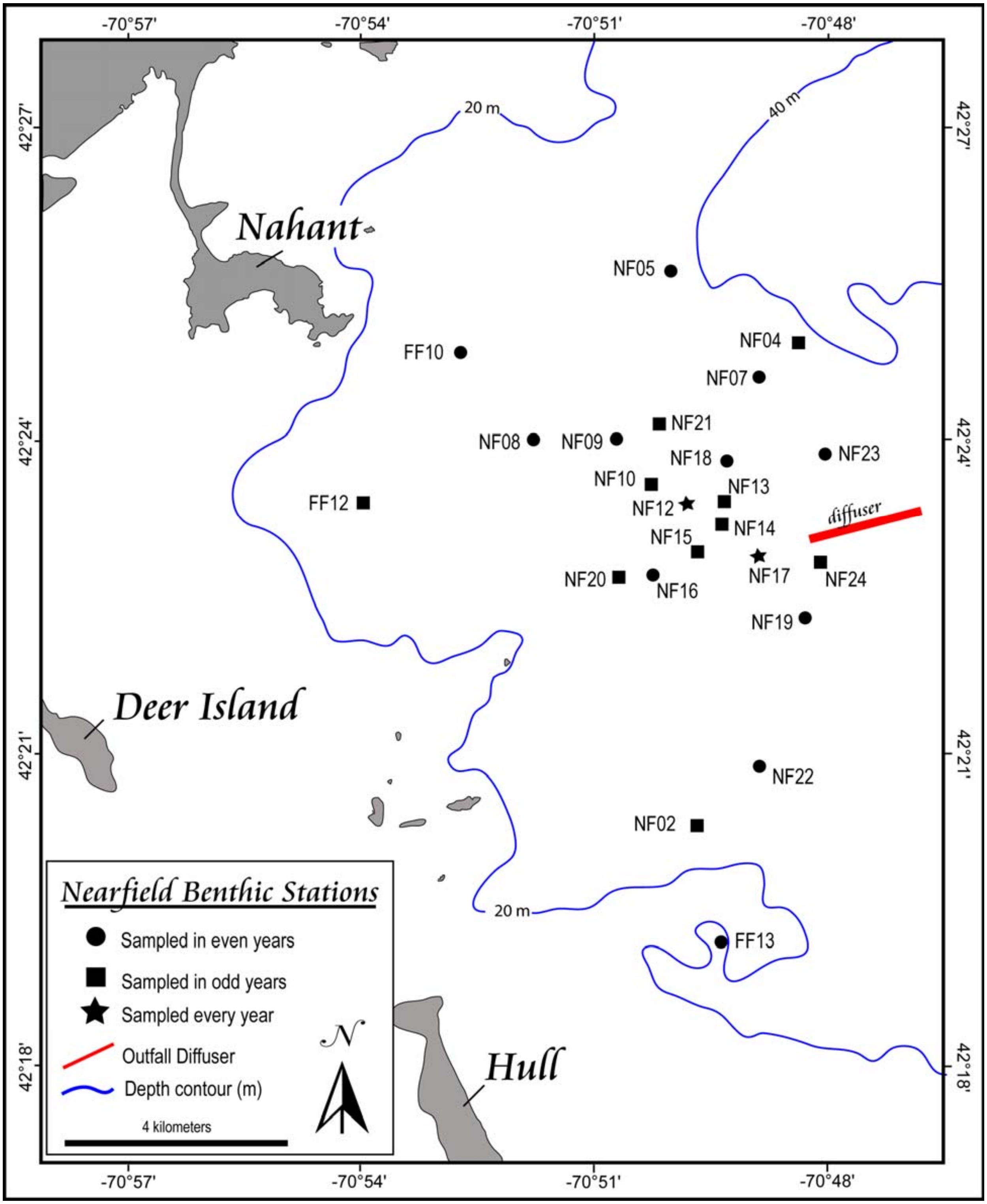


Figure 4. Locations of Nearfield Benthic Monitoring Stations.

Table 4. Sampling Design for Nearfield and Farfield Benthic Collections in 2006 and 2007.

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	2006, 2007	3	2	2
2006 replicated nearfield (2 stations)	FF10, FF13	2006	3	0	2
2006 unreplicated nearfield (9 stations)	NF05, NF07, NF08, NF09, NF16, NF18, NF19, NF22, NF23	2006	1	0	1
2006 farfield (4 stations)	FF04, FF05, FF07, FF09	2006	3	0	2
2007 replicated nearfield (2 stations)	FF12, NF24	2007	3	0	2
2007 unreplicated nearfield (8 stations)	NF02, NF04, NF10, NF13, NF14, NF15, NF20, NF21	2007	1	0	1
2007 farfield (4 stations)	FF01A, FF06, FF11, FF14	2007	3	0	2

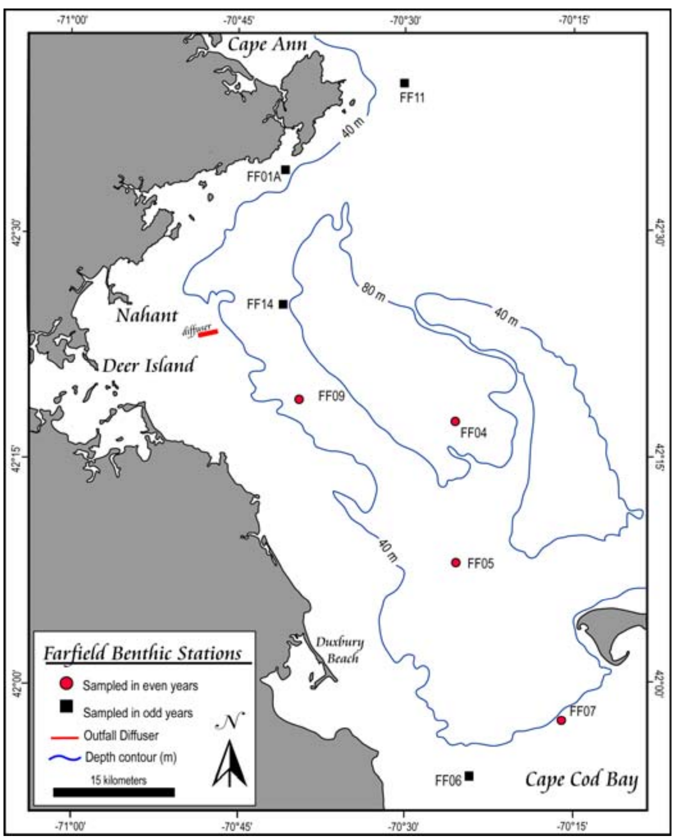


Figure 5. Locations of Farfield Benthic Monitoring Stations

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

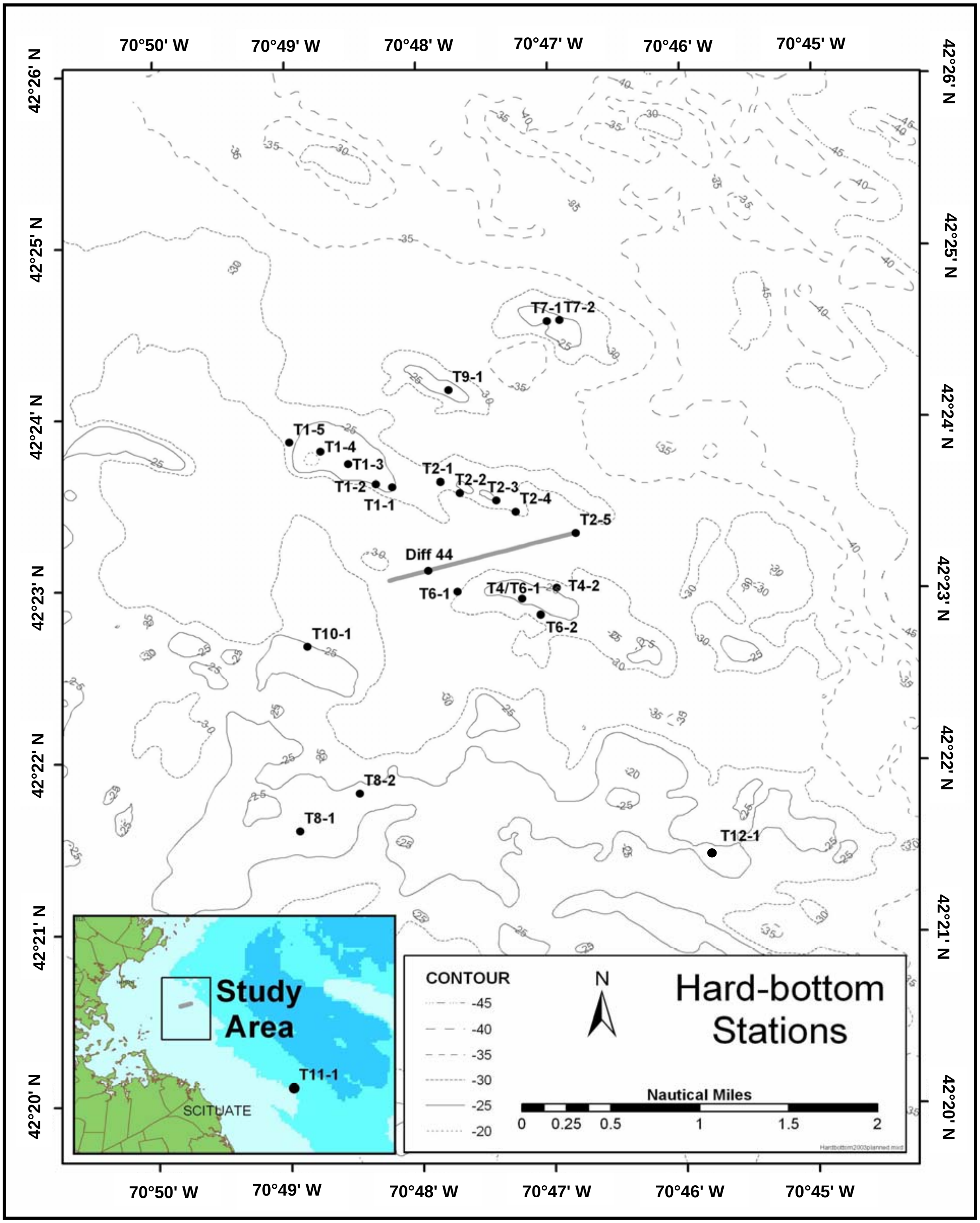


Figure 6. Locations of Hard-bottom Benthic Monitoring Stations

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	<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

A6.3 Schedule of Activities and Deliverables

Benthic (Sea-Floor) Monitoring activities under this contract will span the period from the date of project initiation (January 12, 2006) until September 2008 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 9). Schedules for these activities and deliverables for 2006–2008 are outlined in Tables 7 and 8.

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 2006	Nearfield Hard-bottom Survey (Task 6.4)	May 2006		July 2006
August 2006	Harbor Traditional and Outfall Soft-Bottom Survey[1] (Tasks 5.1, 6.1, 6.2)	July 2006[1]	August 2006 (Task 6.1 only)	September 2006[1]
August 2006	CSO/Harbor Sediment Contaminant Survey[1] (Task 5.3)	July 2006[1]		September 2006[1]
August 2006	Harbor Reconnaissance (SPI) Survey[2] (Task 5.2)	July 2006[2]		September 2006[2]
August 2006	Nearfield Sediment Profile Image Survey[2] (Task 6.3)	July 2006[2]	September 2006	September 2006[2]
June 2007	Nearfield Hard-bottom Survey (Task 6.4)	May 2007		July 2007
August 2007	Harbor Traditional and Outfall Soft-Bottom Survey[1] (Tasks 5.1, 6.1, 6.2)	July 2007[1]	August 2007 (Task 6.1 only)	September 2007[1]
August 2007	Harbor Reconnaissance (SPI) Survey[2] (Task 5.2)	July 2007	September 2007[2]	September 2007[2]
August 2007	Nearfield Sediment Profile Image Survey[2] (Task 6.3)	July 2007	September 2007[2]	September 2007[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 each year will be prepared to include the Harbor Traditional and both Outfall Soft-Bottom Surveys. For 2006, these reports will also include the CSO Harbor Sediment Contaminant Survey.

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

Table 8. Overview of Data Submissions and Synthesis Reports.

Survey Date (2006)	Deliverable	Due Dates* Data/Report
June 2006	Nearfield Hard-bottom Data Submission (Task 7.6.1 analysis reported under Task 4)	15 December 2006
	Nearfield Hard-bottom Data Report Review (Task 7.6.2)	31 January 2007
August 2006	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 2006
	Nearfield Faunal Data Submission (Task 7.3.2 analysis reported under Task 4)	15 November 2006
	Nearfield Faunal Data Report Review (Task 7.3.3)	31 December 2006
	Farfield Faunal Data Submission (Task 7.4.2 analysis reported under Task 4)	15 January 2007
	Harbor Faunal Sorting Completion Letter Report (Task 7.2.1)	15 January 2007
	Farfield Faunal Data Report Review (Task 7.4.3)	28 February 2007
	Harbor Faunal Data Submission (Task 7.2.2 analysis reported under Task 4)	15 March 2007
	Harbor Faunal Data Report Review (Task 7.2.3)	30 April 2007
	Nearfield Sediment Profile Imaging Data Submission (Task 7.5.3 analysis reported under Task 4)	30 October 2007
	Nearfield Sediment Profile Imaging Data Report Review (Task 7.5.4)	15 December 2007
	Harbor Sediment Profile Imaging Data Submission (Task 7.5.1 analysis reported under Task 4)	15 January 2007
	Harbor Sediment Profile Imaging Data Report Review (Task 7.5.2)	28 February 2007
2006 Annual	Outfall Benthic Synthesis Report - Outline (Task 9.1)	April 2007
	Outfall Benthic Synthesis Report - Draft (Task 9.1)	May 2007
	Reference Collection Status Report (Task 7.1)	June 2007
	Harbor Benthic Synthesis Report - Outline (Task 9.2)	June 2007
	CSO Sediment/Harbor Contaminant Report – Outline (Task 9.3)	June 2007
	Outfall Benthic Synthesis Report - Final (Task 9.1)	July 2007
	CSO Sediment/Harbor Contaminant Report – Draft (Task 9.3)	July 2007
	Harbor Benthic Synthesis Report - Draft (Task 9.2)	July 2007
	Harbor Benthic Synthesis Report - Final (Task 9.2)	September 2007
	CSO Sediment/Harbor Contaminant Report – Final (Task 9.3)	September 2007

Table 8. (continued)

Survey Date (2007)	Deliverable	Due Dates* Data/Report
June 2007	Nearfield Hard-bottom Data Submission (Task 7.6.1 analysis reported under Task 4)	15 December 2007
	Nearfield Hard-bottom Data Report Review (Task 7.6.2)	31 January 2008
August 2007	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 2007
	Nearfield Faunal Data Submission (Task 7.3.2 analysis reported under Task 4)	15 November 2007
	Nearfield Faunal Data Report Review (Task 7.3.3)	31 December 2007
	Farfield Faunal Data Submission (Task 7.4.2 analysis reported under Task 4)	15 January 2008
	Harbor Faunal Sorting Completion Letter Report (Task 7.2.1)	15 January 2008
	Farfield Faunal Data Report Review (Task 7.4.3)	28 February 2008
	Harbor Faunal Data Submission (Task 7.2.2 analysis reported under Task 4)	15 March 2008
	Harbor Faunal Data Report Review (Task 7.2.3)	30 April 2008
	Nearfield Sediment Profile Imaging Data Submission (Task 7.5.3 analysis reported under Task 4)	30 October 2008
	Nearfield Sediment Profile Imaging Data Report Review (Task 7.5.4)	15 December 2008
	Harbor Sediment Profile Imaging Data Submission (Task 7.5.1 analysis reported under Task 4)	15 January 2008
	Harbor Sediment Profile Imaging Data Report Review (Task 7.5.2)	28 February 2008
2007 Annual	Outfall Benthic Synthesis Report - Outline (Task 9.1)	April 2008
	Outfall Benthic Synthesis Report - Draft (Task 9.1)	May 2008
	Reference Collection Status Report (Task 7.1)	June 2008
	Harbor Benthic Synthesis Report - Outline (Task 9.2)	June 2008
	Harbor Benthic Synthesis Report - Draft (Task 9.2)	July 2008
	Harbor Benthic Synthesis Report - Final (Task 9.2)	September 2008

* 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 CWQAPP 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 listed in Blake and Hilbig 1995 (HOM2), Kropp and Boyle 2001 (HOM3), and Williams *et al.* 2005 (HOM4). Hard-bottom survey sites will be the same as those listed in Williams, *et al*. 2005.

Quality objectives are given below. Details of how these criteria are met for each component of the Benthic (Sea-Floor) 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 are 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 at least a depth of 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 are labeled accurately. Procedures for sample handling are detailed in Section B3.

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

All sediment samples scheduled to be analyzed for TOC, organic contaminants, and metals during HOM5 will be analyzed by the MWRA Department of Laboratory Services (DLS). The data quality objectives (DQOs) for the DLS are provided in Prasse *et al.* (2004). 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 will be provided in an update to Prasse *et al.* (2004) to be prepared by the MWRA.

A7.1.3 *Sediment Profile Imagery*

The data quality objectives 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) that images obtained are clear and of high quality.

A7.1.4 *Hard-bottom ROV Survey*

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

A7.2 Laboratory Activities

A7.2.1 *Infaunal Analysis*

The data quality objectives for the analysis of benthic infauna are that (1) all samples are processed, (2) all animals are removed from the sediment for identification and enumeration, (3) all infaunal animals are 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 evaluation as discussed in Section B5.

A7.2.2 *Sediment Profile Image Analysis*

The quality control objectives for SPI analysis are that (1) at least 3 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 quality control procedures discussed in Section B5.

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

The data quality objectives 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 the QAPP. Prior to starting work, personnel will be given instructions specific to the project, covering the following areas:

- Organization and lines of communication and authority

- Overview of the QAPP
- QAPP requirement
- QA/QC requirements
- Documentation requirements
- Health and safety requirements

Instructions will be provided and documented by the ENSR Project Manager, ENSR Field Team Leader, 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 activities. 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 HOM5, 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 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 field notebook 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 subcontracting laboratories to ENSR will be as described in their statement of work (SOW). Faunal data submitted to ENSR by Ruff Systematics and Ocean's Taxonomic Services may be submitted electronically or by hard-copy alone. Cove Corporation, Hecker Environmental and Diaz & Daughters will provide at least one hardcopy of the data tables and one copy of an electronic data deliverable (EDD). These will be in the form of a loading application for infaunal and hard-bottom data and in the form of an Excel spreadsheet for SPI data.

Data deliverables will be provided to MWRA by ENSR on the schedule described in this QAPP (Section A6.3). The laboratory will provide data documentation and one copy of an electronic data deliverable (EDD). 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 (Sea-Floor) 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 on page 1 of this document. Revision 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 follow the draft guidelines (Appendix C) established by U.S. Environmental Protection Agency for use on the *OSV Bold* and 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 both the Nearfield faunal sampling and Sediment Profiling Image survey, 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, addressing MWRA's comments, will be due two weeks after receipt of the comments. If MWRA does not submit comments within the two-week period, the draft survey report will be considered final.

A9.4.5 *Reference Collection Status Report*

Once per year (June 2007 and June 2008), a reference collection status report will be prepared after MWRA accepts all infaunal data submissions and ENSR has reviewed all resultant reports from the prior year's sampling. The report, in letter format, will include:

- A hierarchical taxonomic list of all taxa comprising the collection, including the MWRA station ID from which the specimen came
- The current species code for all taxa from the EM&MS database
- The staff with custody of parts of the collection
- Any new taxa identified in the previous year's samples
- 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 (Sea-Floor) Monitoring program (except Task 7.1, which requires a Status Report), the sample analysis data will be prepared and delivered to MWRA. For the benthic infauna and hard-bottom survey 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, then 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:

- Documentation of in-house checks (for example, sample scatter plots and listing any checking programs run)
- Cover letter describing any problems during loading
- Notes on all missing data and all data qualified as "suspect/invalid"
- List of problems encountered and corrective action taken
- Explanation of any outstanding issues resulting from the checks
- 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)
- Summary statistics
- 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 Reports*

Benthic synthesis reports will be prepared from data collected during the Benthic (Sea-floor) Monitoring program under three tasks. The Outfall Benthic Report (Task 9.1) and Harbor Benthic Report (Task 9.2) are annual reports. The CSO Sediment/Harbor Contaminant Report (Task 9.3) will be prepared only for data collected in 2006. All project data used in the synthesis reports will be derived from the MWRA EM&MS database. MWRA will provide to ENSR data generated by MWRA's DLS (all sediment chemistry, physicochemical, and microbiological parameters) along with the data generated by ENSR. Analyses of infaunal, sediment chemistry, SPI, and hard-bottom data are described below.

A9.4.8.1 Infaunal Data Analyses

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

The detailed analysis of the faunal data from the outfall area will focus on (1) assessing the patterns of community structure in Massachusetts Bay, and (2) determining the nature of any changes in community structure through time, and (3) evaluating whether these changes could be attributed to discharges from the MWRA outfall. Nearfield data analyses will include stations FF10, FF12, and FF13 as well as stations with an NF prefix.

Analysis of the soft-bottom benthic data for both the harbor and outfall areas will be directed by Dr. Nancy J. Maciolek. A general analysis plan is presented below; additional analyses will be prepared if deemed appropriate for the particular database being analyzed.

A9.4.8.1.1 Preliminary Data Treatment

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

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

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

A9.4.8.1.2 Diversity Analyses

Magurran (1988) classified diversity indices into three categories: (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*). For HOM5 synthesis reports, all of these categories will be explored. The PRIMER package of statistical routines will be used to calculate the diversity indices, including Shannon's H' (base 2), Pielou's evenness value J', Fisher's *alpha* (Clarke and Gorley 2001), and to generate species accumulation curves. Shannon's H' will be calculated using base $\log_2$ because that base provides results closest to Shannon's original intent. Pielou's (1966) J', which is the observed H' divided by H_{max}, is a measure of the evenness component of diversity.

One measure of species richness that will be presented is simply the number of valid species per sample. The rarefaction (ES_n) method (Sanders, 1968) as modified by Hurlbert (1971) is more sensitive to rare species than is Shannon's index, and is another indication of diversity. Rarefaction curves will be generated for each replicate sample, with the number of points set at 25, from 2 to the maximal number of specimens in the sample.

The Shannon index, which is based on information theory, has been popular with marine ecologists for many years, but this index assumes that individuals are randomly sampled from an infinitely large population and that all species are present in the sample (Pielou 1966, 1975; Magurran 1988). However, neither assumption correctly describes the environmental samples collected in most marine benthic programs, including this one.

Fisher *et al*. (1943) developed a diversity index, *alpha*, based on the assumption that the distribution of individuals among species follows a log-series distribution. May (1975) demonstrated that the Sanders-Hurlbert rarefaction curves are often identical to log-series *alpha* curves. In addition, Taylor's (1978) studies of the properties of this index found that it was the best index for discriminating among subtly different sites. Hubble (2001) considers *alpha* the fundamental biodiversity parameter and promoted the use of this index for studies of diversity in all environments. For the harbor and outfall monitoring program, long-term trends in Fisher's *alpha* have proven to be the most informative.

A9.4.8.1.3 Similarity Analysis & Ordination

The multivariate programs used in the analysis are included in COMPAH96, which was originally written by Dr. Donald Boesch and is now available from Dr. Eugene Gallagher at UMass/Boston (http://www.es.umb.edu/edgwebp.htm). Patterns in benthic communities will be analyzed by cluster analysis using the similarity algorithm CNESS (chord-normalized expected species shared), which was developed by Gallagher (Trueblood *et al*., 1994; Snelgrove *et al.,* 2001) and is related to Grassle and Smith's (1976) NESS (normalized expected species shared). CNESS and NESS include several indices that can be made more or less sensitive to rare species in the community. CNESS is calculated from the expected species shared (ESS) between two random draws of *m* individuals from two samples, and has a maximum value of /2 (1.41). The value of *m* to be used in these analyses will be determined through use of a statistical computer program specifically written by Gallagher (*findcnm*) for this purpose. Other similarity measures such as the Bray-Curtis measure, which is influenced by dominant species, will also be applied to the HOM5 data. If used, Bray-Curtis may be calculated using PRIMER. Both station and species cluster groups will be generated using unweighted pair group mean average sorting (UPGMA).

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

For HOM5, a full community analysis will be developed using classification analysis to explore the data for (1) evidence of impact of the outfall in Massachusetts Bay, and (2) evidence of recovery in Boston Harbor after pollution abatement. Cluster and PCA-H analyses will be conducted on the current year's datasets and, in a limited manner, on the baseline datasets. Additional statistical tests will be applied to address specific questions pertinent to the outfall and to the harbor.

A9.4.8.2 Statistical Analyses for Sedimentary and Chemistry Data

The sediment data will be analyzed using a variety of statistical and graphical methods. The specific analyses, including statistical tests, will be developed through team discussions, including with MWRA, and documented along with the report outline. 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). The testing will be used to test for differences, harbor-wide (all grab and CSO stations) and by station, in TOC and *C. perfringens* by monitoring year. 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.

The relationship between all measured sedimentary variables (contaminant data, grain size, TOC, log-transformed *C. perfringens)*, collected at all harbor CSO stations and outfall stations NF12 and NF17, will be determined using correlation analyses, *e.g.*, pair-wise comparisons. These analyses will also be used to determine the relationship between grain size, TOC, and log-transformed *C. perfringens* data on the remaining nearfield grab stations as well as harbor stations sampled by grab in 2007. 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, and time periods corresponding to various level of pollution abatement in Boston Harbor (*e.g*., Taylor 2005). These data analyses will be employed to detect outfall effects if present. Additional evaluations using box plots, ternary plots, and range plots may be performed to assess temporal and spatial trends over time.

A9.4.8.3 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). Correlation and principle 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. All statistical tests will be conducted using SAS's JMP program for Macintosh.

A9.4.8.4 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 MWRA 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. To facilitate these comparisons, sediment drape categories will be converted to numerical codes as follows: clean to very light (0); light (1); moderately light (2); moderate (3); moderately heavy (4); and heavy (5). In addition, the five levels of percent cover (1-5%, 6-10%, 11-50%, 51-90%, >90%) of coralline algae and relative abundance categories (rare, few, common, abundant, very abundant) of filamentous red algae will be assigned corresponding abundance values (1, 2, 5, 15, 20).

Data from the still photographs will be normalized to account for differences in the number of still photographs collected at each station and data from the video will be normalized to account for differences in the amount of time spent on the bottom. The structure of the benthic communities inhabiting the hard-bottom stations will be examined using hierarchical classification analysis with the percent similarity coefficient and unweighted pair-group clustering. The percent similarity coefficient is used because it relies on the relative proportion that each species contributes to the faunal composition, and consequently is least sensitive to differences in sampling effort among locations. Additional statistical treatments of the data may be implemented during HOM5.

A9.4.8.5 Preparation of Synthesis Reports

Biological, chemical, and physical data collected under the Benthic (Sea-Floor) Monitoring program will be used to prepare synthesis reports (Tasks 9.1, 9.2, and 9.3). Dr. Nancy J. Maciolek will be the task manager and editor for all synthesis reports and lead author for the outfall and harbor synthesis reports. Mr. Greg Durell will be the lead author for the CSO/harbor sediment contaminant report for 2006. Each report will be reviewed by scientists who are knowledgeable in the subject matter of the report. Such review will ensure that interpretations made in the reports are scientifically and technically valid and meet the MWRA's needs. To ensure readability and accuracy in use of scientific language, symbols, and format, each report will be reviewed by a technical editor and ENSR's QA Officer. Thirty days prior to the due date of the draft report, an outline will be delivered to the MWRA. The due dates for the draft and final annual synthesis reports are listed in Section A6.3. The specific approach to each report is presented below.

A9.4.8.5.1 Outfall Benthic Report (Task 9.1)

The report 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. In particular, this report will address the several questions posed in the monitoring plan (MWRA 1997b, 2001, 2004) regarding

- Sediment contamination and tracers
  - *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?*
- Benthic communities
  - *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?*

There were nine baseline (pre-operational) surveys in the nearfield and farfield of Massachusetts Bay (1992–2000). This extensive database provides a guide to understanding year-to-year patterns in benthic infauna, status of pre-discharge contaminant levels, and some aspects of sediment transport patterns across the nearfield that may affect benthic communities. A series of key indicators (threshold parameters) were established, with caution and warning levels, to indicate where changes from baseline might be occurring due to the new outfall (MWRA 1997a, 2001). During HOM5, MWRA will evaluate the benthic data with respect to monitoring thresholds described in the Contingency and Outfall Monitoring Plans (MWRA 1997a, b; MWRA 2001) and the three MWRA benthic threshold Standard Operating Procedures (Appendix A) and return the data to ENSR for inclusion in the outfall synthesis report.

The specific objective of addressing the monitoring questions will be accomplished by

- Evaluation of the most recent year's data collected at the nearfield and farfield stations in the context of the baseline
- Evaluation of data against all relevant monitoring thresholds, devoting special attention to understanding the background of any thresholds that appear to have been exceeded
- Analysis of long-term trends in soft-bottom benthic community structure, species diversity, species richness, and species composition at individual stations and between sedimentary environments (*i.e.*, assessment of soft-bottom nearfield and farfield communities from the standpoint of the current year's status and comparison with baseline)

- Evaluation of the current and long-term hard-bottom results in terms of effects of the outfall discharge on attached organisms and sedimentation rates
- Mapping and interpretation of the distribution and possible changes in the sedimentary environment near the outfall following analysis of sediment profile images (RPD, etc.) and sediment parameters collected with traditional methods (TOC, grain size, and *Clostridium* spores). Climatological events such as winter storms and hurricanes will be taken into account when interpreting any changes in the sedimentary environment
- Determination of trends in the distribution and potential accumulation of organic and metal contaminants in nearfield and farfield sediments
- Integration of results, where possible, with data collected as part of the Water Column monitoring, and Benthic Flux results with special emphasis on seasonal trends in near- bottom chlorophyll and dissolved oxygen and sediment respiration as possible integrators of benthic processes

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

A9.4.8.5.2 Harbor Benthic Report (Task 9.2)

The analysis and interpretation of the harbor benthic data is similar to that proposed for the outfall benthic report except that there is a different objective: instead of tracking potential impacts from a new outfall, the harbor benthic analysis will focus on changes that might be due to improvement in the benthic environment, including the relocation of the outfall to Massachusetts Bay.

For 2006 and 2007, benthic and SPI samples, as well as the complementary sedimentary parameters grain size, TOC, and *Clostridium*, will be collected in August. In 2006, as part of the CSO survey (see below) samples for metals and organics analysis will also be collected at all stations.

The harbor benthic synthesis will be prepared annually. 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
- Document the distribution of *Ampelisca* spp. in Boston Harbor
- Map benthic processes in Boston Harbor as determined from analysis of SPI images
- Integrate results where possible with other on-going studies such as benthic flux studies, harbor water quality data being collected separately by MWRA, and outfall monitoring results (Task 9.1)

A9.4.8.5.3 Contaminated Sediments Report (Task 9.3)

One CSO synthesis report, using data obtained in 2006, will be prepared during HOM5. The purpose of the CSO Sediment Contaminant Report is (1) to explain the extent to which sediment contamination in Dorchester Bay is due to CSO discharges, and how contaminant levels in that area have changed since

1990; and (2) to help in evaluating the extent to which long-term changes may be occurring in contaminant concentrations in Boston Harbor sediments.

Previous data developed in CSO sediment surveys performed in 1990, 1994, 1998, and 2002 (Durell *et al*. 1991; Durell 1995; Lefkovitz *et al*. 1999, 2006) and the 1997 harbor contaminant study (Blake *et al*. 1998) will be carefully compared with the 2006 results. Results from earlier reports will be updated to evaluate long-term trends at stations where time-series of data are available. Many of the statistical tests (*e.g*., Pearson's and Kendall's correlation coefficients), described for sediment analysis as part of Task 9.1 (see above) will also be applied to the CSO data.

A9.5 Project files

The project files will be the central repository for all documents, except for those relating to sediment chemisty, relevant to sampling and analysis activities as described in this QAPP; 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 electronic data deliverables (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 HOM5 will be retained with all the project records for at least six years after the termination of the project.

Section B – DATA GENERATION AND ACQUISITION

B1 Sampling Process Design (Experimental Design)

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 benthic surveys within a subtask.

The parameters to be measured during the various Benthic (Sea-Floor) Monitoring tasks can be characterized as macrobiological and sedimentological (habitat properties). Macrobiological parameters, based primarily on the species-level identifications, include community measures such as abundance (or percent cover), numbers of species, and diversity. Some sediment habitat properties are measured during the SPI studies (Table 10) and include information about sediment geophysical properties, including sediment grain size, and the general nature of the infaunal community.

Samples for laboratory measurements of sedimentological properties, such as grain size and levels of contaminants as well as an evaluation of levels of *Clostridium* spores, will be collected but not analyzed under Benthic Monitoring Services (Agreement II). These 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 CWQAPP (Libby *et al*., 2006) 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 Deputy Project Manager Kenneth Keay; a copy will be provided to the chief scientist prior to the survey.

Planned field samples and analytical methods are summarized in Tables 7 and 11, respectively. The numbers of field samples and the shipboard processing and storage requirements for all samples collected for the Benthic (Sea-Floor) Monitoring tasks are listed in Tables 12 (harbor benthic surveys) and 13 (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; ENSR provides sample containers for biology.

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

Table 9. Number of Samples to be Collected on Each Survey, and in Total, by Task.

	Task 5 Harbor Surveys						Task 6 Outfall Surveys							
	5.1 (Grabs)		5.2 (SPI)		5.3 (CSO)		6.1 (NF Grabs)		6.2 (FF Grabs)		6.3 (NF SPI)		6.4 (NF Hard)	
	Survey	*Total*	*Survey*	*Total*	*Survey*	*Total*	*Survey*	*Total*	*Survey*	*Total*	*Survey*	*Total*	*Survey*	*Total*
Infauna (2006, 2007)	27, 27	54	—	—	—	—	21, 20	41	12,12	24	—	—	—	—
Sediment Chemistry (2006, 2007)	—	—	—	—					—	—	—	—	—	—
Organics					51, 0	51	4, 4	8						
Metals					51, 0	51	4, 4	8						
Ancillary Parameters (2006, 2007)	—	—	—	—					—	—	—	—	—	—
Total Organic Carbon (TOC)					51, 0	51	17, 16	33						
Grain Size					51 ,0	51	17, 16	33						
C. perfringens					51, 0	51	17, 16	33						
Sediment Profile Images (SPI) (2006, 2007)	—	—	183, 183	366	—	—	—	—	—	—	—	—	—	—
Hard-bottom Slides Video (min)	—	—	—	—	—	—	—	—	—	—	—	—	828, 828 460, 460	1656 920

Table 10. 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	—	V	Identify as amphipod or polychaete
Density	Number	V	Estimate number (none, few, some, many)
Surface Features			
Pelletal Layer	—	V	Note if present
Bacterial Mats	—	V	If present, note color
Infauna			
Visible Infauna	Number	V	Count, identify
Burrow Structures	—	V	Count
Feeding (Oxic) Voids	Number	V	Count
Successional Stage	—	V	Identify
Organism Sediment Index	—	CA	Derived from RPD, Successional Stage, Voids (Rhoads and Germano 1986)

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

Table 11. Benthic Survey Sample Analyses.

Parameter	Laboratory	Unit of Measurement	Method	Reference
Infaunal Analysis	Cove Corporation; ENSR Marine and Coastal Center	Count/species (# per grab)	ID and Enumeration	Section B4
Organic Analyses				
Polycyclic Aromatic Hydrocarbons (PAH)	MWRA's DLS*	µg/kg dry wt.	GC/MS	Prasse *et al.* 2006 (in prep)
Polychlorinated Biphenyls (PCB's)	MWRA's DLS	µg/kg dry wt.	GC/MS	Prasse *et al.* 2006 (in prep)
Pesticides	MWRA's DLS	µg/kg dry wt.	GC/MS	Prasse *et al.* 2006 (in prep)
Metals Analyses				
Major Metals (Al, Fe)	MWRA's DLS	% dry wt.	ICP/FAA	Prasse *et al.* 2006 (in prep)
Trace Metals (Ag, Cd, Pb) (Cr, Cu, Ni) (Hg) (Pb) (Zn)	MWRA's DLS	mg/kg dry wt.	ICP/GFA/FAA ICP/GFA/GFA CVAA ICP/GFA/FAA ICP/FAA	Prasse *et al.* 2006 (in prep)
Ancillary Physicochemical and Microbiological Parameters				
Total Organic Carbon (TOC)	MWRA's DLS	%C by dry weight	DC-190	Prasse *et al.* 2006 (in prep)
Sediment Grain Size**	MWRA's DLS	-----	-----	DLS will update Prasse *et al*. 2006 (in prep)
Microbiology:** *Clostridium perfringens*	MWRA's DLS	-----	-----	DLS will update Prasse *et al*. 2006 (in prep)
Sediment Profile Images	Diaz and Daughters	Various (see Table 10)	Various	See Section B4
Hard-bottom	Hecker Environmental	Various	Various	See Section B4

* Department of Laboratory Services

** Sediment grain size and *C. perfringens* analytical laboratories and procedures are not yet determined.

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

Activity	**Task 5.1 Harbor Infaunal Survey**	**Task 5.2 Harbor Reconnaissance Survey (SPI)**	**Task 5.3 CSO Contaminant Sediment Survey**
Stations	9; T01–T08 and C019 (Table 2)	61; T01–T08 and C019; R02–R53 (Table 2)	17; Table 1 and Lefkovitz *et al.*, 2006 (2006 only)
Weather/sea state/ bottom depth	Record general conditions; record bottom depth to nearest 0.5 m	As for Task 5.1	As for Task 5.1
Marine mammals	Note incidental observations	As for Task 5.1	As for Task 5.1
Sampling: Gear	0.04-m^2 Ted Young-modified Van Veen grab sampler	Sediment profile camera	(0.1 or 0.04-m^2) Kynar-coated Ted Young-modified Van Veen grab sampler
Sampling: Measurements	Record penetration depth to nearest 0.5 cm and sediment volume to nearest 0.5 L	Record prism penetration (0.5 cm)	As for Task 5.1
Sampling: Sediment texture	Describe qualitatively	Not Applicable (NA)	As for Task 5.1
Sampling: aRPD depth	Record aRPD to nearest 0.5 cm	Visual estimate	As for Task 5.1
Faunal Samples: Number	3 each station	3 images at each station	NA
Faunal Samples: Processing	Rinse over 300-m-mesh sieve; fix in 10% buffered formalin	Check counter	NA
Faunal Samples: Storage	Clean, labeled plastic jars; ambient temperature	NA	NA
Chemistry/Microbiology Samples (All): Number	2007 only; 1 each station (*C. perfringens*, TOC, GS); for 2006 see Task 5.3	NA	2006 only; 3 each station (Chemistry, Metals, *C. perfringens*, TOC, GS)
Chemistry Samples (Organics): Processing	NA	NA	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize, and collect ~125 mL subsample
Chemistry Samples (Organics): Storage[1]	NA	NA	Clean, labeled glass jar with Teflon-lined cap; freeze (–20° C); holding time is 1 year to extract (if samples frozen) and 40-d from extraction to analysis
Chemistry Samples (Metals): Processing	NA	NA	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize, and collect ~75 mL subsample
Chemistry Samples (Metals): Storage [1]	NA	NA	Clean and labeled I-Chem® container; freeze (–20° C); holding time is 6 months to preparation; Hg holding time is 28 days
Chemistry Samples (Ancillary): Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~ 50 mL subsample for TOC and ~ 125–200 mL for grain size	NA	As for Task 5.1

Activity	**Task 5.1 Harbor Infaunal Survey**	**Task 5.2 Harbor Reconnaissance Survey (SPI)**	**Task 5.3 CSO Contaminant Sediment Survey**
Chemistry Samples (Ancillary): Storage[1]	Clean, labeled glass jar (freeze TOC, grain size, refrigerate); holding times: TOC – 28 days; grain size – 30 days	NA	As for Task 5.1
Microbiology Samples: Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~75 mL subsample	NA	As for Task 5.1
Microbiology Samples: Storage[1]	Sterile specimen cup; refrigerate at 1–4°C[1].	NA	As for Task 5.1

[1] Sediment samples collected in 2006 and 2007 will be shipped to DLS for testing. Grain size and microbiology samples will then be sent by DLS to the laboratories (to be determined) chosen to perform those analyses.

Table 13. Field Samples, Processing, and Storage for 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	In 2006: 13 (Table 4) In 2007: 12 (Table 4)	In 2006: 4 (Table 4) In 2007: 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: RPD depth	Record visual estimate (0.5 cm)	As for Task 6.1	Estimate from images (see Section B2.2.3)	NA
Faunal Samples: Number	In 2006: 3 each at stations NF12, NF17, FF10, FF13, 1 each at NF05, NF07, NF08, NF09, NF16, NF18, NF19, NF22, NF23 (Table 3) In 2007: 3 each at stations NF12, NF17, FF12, NF24; 1 each at NF02, NF04, NF10, NF13, NF14, NF15, NF20, NF21 (Table 3)	In 2006: 3 each at stations FF04, FF05, FF07, FF09 (Table 3) In 2007: 3 each at stations FF01A, FF06, FF11, FF14 (Table 3)	3 each station	20 min videotape, 36 still photos per waypoint
Faunal Samples: 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)	NA
Faunal Samples: Storage	Clean, labeled plastic jar; ambident temperature	As for Task 6.1	NA	NA
Chemistry/ microbiology Samples: Number 2006	In 2006: 2 each at NF12, NF17 for Organics, Metals, *C. perfringens*, TOC, and GS; 2 each at FF10, FF13 and 1 each at remaining 9 stations for *C. perfringens*, TOC, and GS only. (Table 3)	In 2006: 2 each at stations FF04, FF05, FF07, FF09 for *C. perfringens*, TOC and GS only. (Table 3)	NA	NA

Table 13. (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 2007	In 2007: 2 each at NF12, NF17 for Organics, Metals, Microbiology, TOC, and GS; 2 each at FF12, NF24 and 1 each at NF02, NF04, NF10, NF13, NF14, NF15, NF20, NF21 for Microbiology, TOC, and GS only. (Table 3)	In 2007: 2 each at FF01A, FF06, FF11, FF14 for Microbiology, TOC, and GS 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 glass jar with Teflon-lined cap; freeze (20° C); holding time is 1 year to extract (if samples are frozen) and 40-days from extraction to analysis	As for Task 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 and labeled Spex container; freeze (20° C); holding time is 6 months to preparation; Hg holding time is 28 days	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 ~ 125 mL for grain size (if samples are coarse, subsample ~ 200 mL for grain size)	As for Task 6.1	NA	NA
Chemistry Samples (Ancillary): Storage[1]	Clean, labeled glass jar (TOC and grain size); freeze (TOC) refrigerate grain size; holding time for TOC is 28 days; 30 days for grain size	As for Task 6.1	NA	NA
Microbiology Samples: Processing	Use Kynar-coated scoop to collect upper 0–2 cm from grab, homogenize and collect ~75 mL subsample	As for Task 6.1	NA	NA
Microbiology Samples: Storage[1]	Sterile specimen cup; refrigerate at 1–4° C[2]	As for Task 6.1	NA	NA

[1] Sediment samples collected in 2006 and 2007 will be shipped to DLS for testing. Grain size and microbiology samples will then be sent by DLS to the laboratories (to be determined) chosen to perform those analyses.

[2] *Clostridium 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 7, 12, and 13.

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 apparent redox potential discontinuity (RPD) will be visually estimated. The apparent RPD 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 sediment surface has no measurable RPD layer and is considered to be anoxic. If the surface is oxidized, a clear, plastic ruler, marked in millimeters, will be pushed into the sediment and pulled out toward the investigator. This action creates a vertical profile that can be examined and allows the apparent RPD to be measured to the nearest millimeter. Alternatively, the same ruler will be used to gently scrape off the surface layers, in millimeter fractions, until the gray-to-black anoxic sediment layer is exposed. The distance from the surface to the uppermost portion of the gray-to-black subsurface sediments is the depth of the aRPD. Both methods will be used on the MWRA biological sampling cruises to estimate apparent RPD depths. Any sediment adhering to the surface of the ruler will be rinsed back into the grab for processing with the remainder of the sample. The volume of the grab will be estimated by comparing the measured penetration depth with a prepared table of penetration depths versus grab volumes (Table 14). 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 the laboratory and proper disposal. Before the grab is retrieved, the vessel must be positioned so that the engine exhaust will not contaminate the sample when it has been brought on deck.

Table 14. 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
>13 (over penetration) 0.10 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 75 mL of sample for metals analysis will be placed into an acid-cleaned, plastic, 125 mL (4-oz) I-Chem® jar (Prasse et al. 2004) jar. Approximately 50- and 125-mL subsamples for TOC and grain size will be placed into separate 125 mL (4-oz) and 250 mL (8-oz) wide-mouth glass jars, respectively. If the sediment is coarse, then approximately 200 mL of wet sediment will be subsampled for grain size analysis. A subsample to be used for *Clostridium perfringens* analysis will be placed into a sterile specimen cup (½ to ¾ full), labeled, and refrigerated or frozen until analysis. These samples will be labeled, refrigerated at 1–4°C, and delivered to DLS within 24 hours of survey completion.

No sediment holding times 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 camera enclosed in a pressure-resistant housing, a 45E prism, and a mirror that reflects an image of the sediment through the camera lens. A strobe mounted inside the prism is used to illuminate the sediment. Prior to every field deployment, all essential items are gathered and tested for proper operation. The camera/prism system is mounted in a cradle that is secured to a larger frame which ensures that the prism penetrates the sediment at a 90° angle. A winch is used to lower the entire assembly at a steady rate to the seafloor. When the system is on the seabed, the penetration rate of the camera/prism assembly into the sediment is controlled by a hydraulic piston. The camera can be triggered from the surface or on contact with the seabed. To permit proper penetration of the sediment by the prism, there is a brief time delay between contact with the seafloor and the first image capture. The delay ranges from 1 second in soft mud to 15 seconds in hard sand. After the required number of replicates, the camera assembly is returned to the ship.

The video signal from the digital camera will be sent to the surface via cable so that prism penetration can be monitored and an initial impression of benthic habitat type can be formed. The initial evaluation will be done on the boat in real-time or between stations by an experienced senior scientist (Dr. Robert Diaz or Dr. Randy Cutter). The video signal will be recorded for later detailed evaluation and 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 digital images provide high-resolution image 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 color RPD
- 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. For HOM5, 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 was used successfully for 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 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 DVD and EHG videotapes (VHS format) 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 11 and 12 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. 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 organisms will be picked from the samples and sorted into major taxonomic groups. All acceptable infaunal samples will be processed. 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.

The sediment chemistry samples collected during the Harbor benthic (Task 5.1), CSO/harbor contaminant (Task 5.3), and outfall benthic (Tasks 6.1 and 6.2) surveys must be kept cold or frozen. 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, 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 frozen samples will be placed on dry ice with protective layers of foam or bubble wrap to ensure that they remain intact and frozen during shipment.

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 Sample Custody

B3.2.1 *Sample Tracking*

Sample custody will be tracked through sample labels (Figure 7), station logs (Figure 8), and custody forms (Figure 9).

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 monitoring program 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 15 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. Every sample will have a unique *Container-ID*. 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.

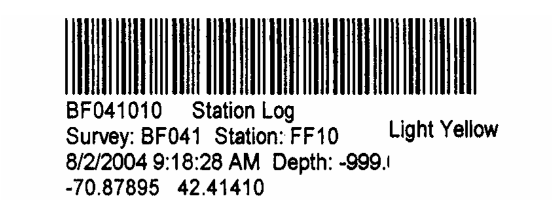


Figure 7. Example of an Infaunal Sample Label.

STATION LOG

For Benthic Sediment Grab Samples

Project Name: MWRA Harbor and Outfall Monitoring – Contract OP-44B

SURVEY: **BC061** STATION ID: **NF24** TIME ON STATION:__________________ STATION DEPTH (M):__________________DATE:____________________		Weather:____________________________ Recorded By:_________________________
Comments	Sample ID Label	Field Measurements
		Grab Size: 0.04-m^2 0.1-m^2
		Grab Penetration (cm):
		Sediment Texture:
		Redox Depth (cm):
		Analyses: (circle all applicable) Organics Metals TC GR CL EN/FE FA
		Comment:
	Sieved By:	
		Grab Size: 0.04-m^2 0.1-m^2
		Grab Penetration (cm):
		Sediment Texture:
		Redox Depth (cm):
		Analyses: (circle all applicable) Organics Metals TC GR CL EN/FE FA
		Comment:
	Sieved By:	
		Grab Size: 0.04-m^2 0.1-m^2
		Grab Penetration (cm):
		Sediment Texture:
		Redox Depth (cm):
		Analyses: (circle all applicable) Organics Metals TC GR CL EN/FE FA
		Comment:
	Sieved By:	
		Grab Size: 0.04-m^2 0.1-m^2
		Grab Penetration (cm):
		Sediment Texture:
		Redox Depth (cm):
		Analyses: (circle all applicable) Organics Metals TC GR CL EN/FE FA
		Comment:
	Sieved By:	

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

Figure 8. 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

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

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

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 9. Example of a Chain-of-Custody Form.

The NavSam© software produces two labels (Figure 7) for each bottle, one for the bottle and the second to be affixed to the Station Log (Figure 8). 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 8) at each station. The log includes header fields for entering pertinent information about each station, such as arrival time, bottom depth, and weather observations. In addition, the log sheets contain spaces for specific grab data, such as penetration depth, apparent RPD and general descriptions. These sheets will remain in the survey logbook and will be maintained in the project files. During field collection, COC forms (Figure 9) 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 15. 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. Chain of custody (COC) forms generated by the NavSam© system (Figure 9) will accompany the samples. One complete copy of the infauna COC forms will be included in each shipping container and return original COC to ENSR, see below. After the samples are sorted, Cove will return the appropriate specimens to ENSR for identification using its own custody transfer forms (see Appendix B).

Sediment chemistry samples will be 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, and unusual events or deviations from the project QAPP will be documented in detail on the COC and the task manger and project manager notified. Copies of completed custody forms will be faxed back to the task manager, Isabelle Williams, within 24 hrs. of receipt. For biology samples, an e-mail confirming receipt of all samples will be sent to ENSR within 24 hours of receipt; the signed custody forms 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.

B3.2.3 *Sample Archival Policies*

The types of materials that may be archived under this Benthic Monitoring Services (Agreement II) include sample residues, 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 regarded those specimens.

B4 Analytical Methods

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

B4.1 Macrofaunal Analysis

At Cove Corporation, samples will be rinsed with fresh water over 300-Φm-mesh screens to remove any broken-up mud casts and transferred to 70S80% ethanol for sorting and storage (Cove 1999, Appendix E). 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, using a dissecting microscope, to major taxonomic categories such as polychaetes, arthropods, and mollusks.

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. 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, Molluscs, Miscellaneous Phyla
- Mr. Russ Winchell (Ocean's Taxonomic Services)—Oligochaetes
- Ms. Paula Winchell (ENSR)—Miscellaneous Phyla

Dr. James A. Blake (ENSR) will provide general oversight of the taxonomy performed for the Benthic (Sea-Floor) Monitoring studies. MWRA has established a project-specific reference collection. The reference collection is a valuable resource that will be used by project taxonomists to ensure comparability of the taxonomic identifications performed under HOM5 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 2008.

B4.2 Sediment Profile Image Analysis

B4.2.1 *General Approach*

Dr. Robert Diaz of Diaz and Daughters will perform the SPI analysis. After field collection, analysis will continue with a reanalysis of the videotapes previously examined in the field. A visual analysis including the same parameters as estimated from the video SPI will be conducted. These data will be combined with the video data and the final rapid "quick look" analysis will be completed within 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 visually by examining the images and recording all observed features into a preformatted, standardized spreadsheet file. The videotapes also are analyzed visually, with all observed features also recorded into a preformatted, standardized spreadsheet. 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 procedures for each image are standardized by executing a series of macro commands. Data generated from each image analyzed are saved sequentially to an ASCII file for additional analysis and reduction via Excel.

B4.2.2 *Specific Analyses*

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

Prism penetration provides a geotechnical estimate of sediment compaction, with the profile camera prism acting as a dead weight penetrometer. The farther the prism enters into the sediment the softer the sediments, and likely the higher the water content. Penetration is measured simply as the distance the sediment moves up the 25-cm length of the faceplate. If the weight of the camera frame is not changed during field image collection then the prism penetration provides a means for assessing the relative sediment compaction between stations or different habitat types.
Surface relief is measured as the difference between the maximum and minimum distance the prism penetrates. This parameter provides an estimate of small-scale bed roughness, on the order of the prism

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

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

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

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

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

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

Subsurface features include a variety of features such as burrows, water filled voids, SAV rhizomes , infaunal organisms, gas voids, shell debris, detrital layers, and sediment lenses of different grain size.

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

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

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 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.

Accuracy and Precision
For HOM5, 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 H 10^{-5} degrees (Libby *et al.*, 2006).

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) for all benthic surveys, 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 postion 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 project's time interval requirement for obtaining positions during sampling 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 CWQAPP (Libby *et al.*, 2006).

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, Total Organic Carbon (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 and
- Securing the grab on deck.

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

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

In certain locations, however, slight over-penetration may be 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 HOM5 Benthic Monitoring Services (Agreement II) 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 Grab Sampling above) and by ensuring that samples are well homogenized and subsampled and preserved following methods detailed in Section B3.

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 HOM5 Benthic Monitoring Services (Agreement II) for each survey.

B5.1.3 *Sediment Profile Imagery*

The data quality objectives for the field collection of the SPI will be met by following several procedures. Proper assembly and operation of the 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 differential global positioning system (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 data quality objectives 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.

<u>Accuracy, Precision, and Representativeness</u>
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.

<u>Comparability</u>
The field methods used will be similar to those followed previously. The hard-bottom surveys will follow the same transects as those listed in Williams *et al.* 2005 for HOM4. All transects will be occupied so that the nature of the epifauna and sedimentary environment in the hard-bottom area can be compared to the previous surveys.

<u>Completeness</u>
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 Quality Control (QC) analysis. Samples will be divided into batches of approximately 10 samples. All samples will be pre-sorted by a junior technician and then 100% re-sorted by an experienced technician. Approximately 10% of the samples from each batch will then be randomly chosen for an independent QC check. If more than 5% of the total organisms in the QC sample have been missed, all remaining samples from that batch will be re-sorted.

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

Completeness
All samples collected are scheduled for analysis. 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.

Comparability
Methods of analysis will be comparable to those used in previous benthic investigations in Boston Harbor and Massachusetts Bay. Comparability of the identifications will be ensured through the use of standard taxonomic references and by comparison of specimens to 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*

Accuracy
Control of the computer image analysis includes system preparation, actual image analysis, and data reduction. A set of standard instructions is followed in setting up the image processor. 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 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).

DVD and video images will be viewed 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. Video footage will be examined by Drs. Barbara Hecker and Pamela Neubert.

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 2006 and 2007 will be analyzed by the MWRA Department of Laboratory Services (DLS). The data quality objectives (DQOs) for the DLS are provided in Prasse *et al.* (2004).

B5.2.5 *Physicochemical and Microbiological Parameters*

Sediment samples collected in 2006 and 2007 will be analyzed for TOC by DLS; the DQOs for TOC testing are provided in Prasse *et al.* (2004).

In 2006 and 2007, sediment grain size and *Clostridium perfringens* analyses will be performed by laboratories to be determined by the MWRA. DQOs for grain size and *Clostridium* analyses will be provided in an update to Prasse *et al.* (2004) to be prepared by the MWRA.

No field-collected quality control 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.

Under HOM5, 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 the sampled collected during HOM5, see Prasse *et. al.* (2004) 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 film 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.* 2006).

B7.2 Laboratory Equipment

Under HOM5, 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 HOM5, see Prasse *et. al.* (2004, 2006 in prep. and updates as issued by DLS.

B8 Inspection/Acceptance of Supplies and Consumables

For HOM5, 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 9). 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 10 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 floppy-disk backups of all electronic data generated each day. Each floppy-disk label will include a survey ID, date, name of person creating the backup files, and a disk number. When the equipment is returned to Battelle, a second complete backup labeled "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.

ENSR, Battelle, and all other laboratories (excepting 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.

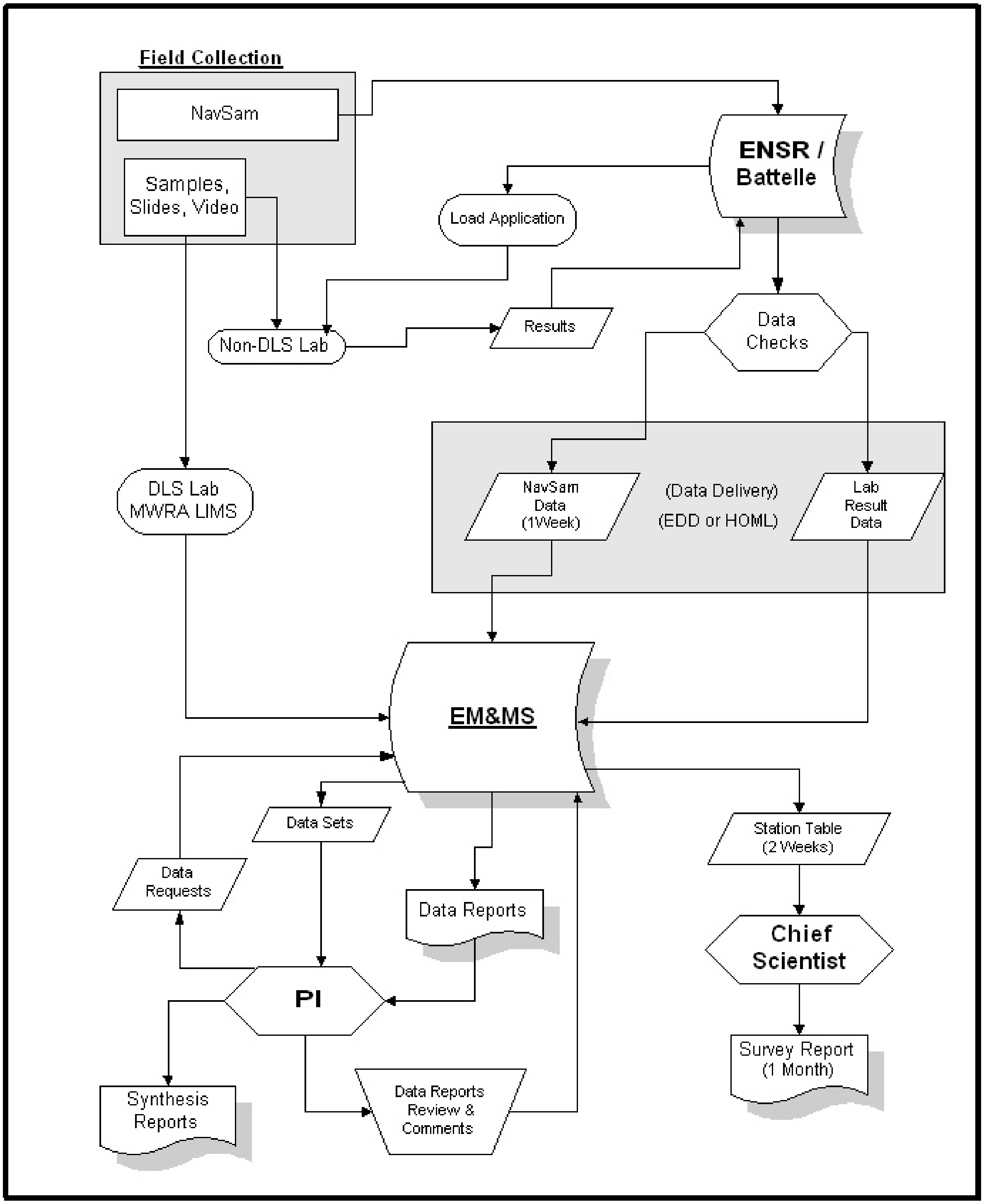


Figure 10. Overview of the Data Management Strategy for Benthic Monitoring

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. Data reduction procedures and formulae are defined in laboratory Standard Operating Procedures (SOP)s. For HOM5, 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 for 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 Benthic Monitoring Services (Agreement II). Details regarding DLS's data reduction procedures are provided in Prasse *et al.*, (2004) and Prasse *et al.*, (2006), in prep.

B10.2.3 *SPI Analysis*

After visual and computer image analyses are completed, a standard set of parameters (Table 8) 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 acquired under the Benthic Monitoring Services (Agreement II) 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. The loading application includes the collection data to increase data quality and data flow efficiency. 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 HOM5 contract but these formats are subject to change and have already changed once since the contract was generated. 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 are in place so duplication cannot occur.

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

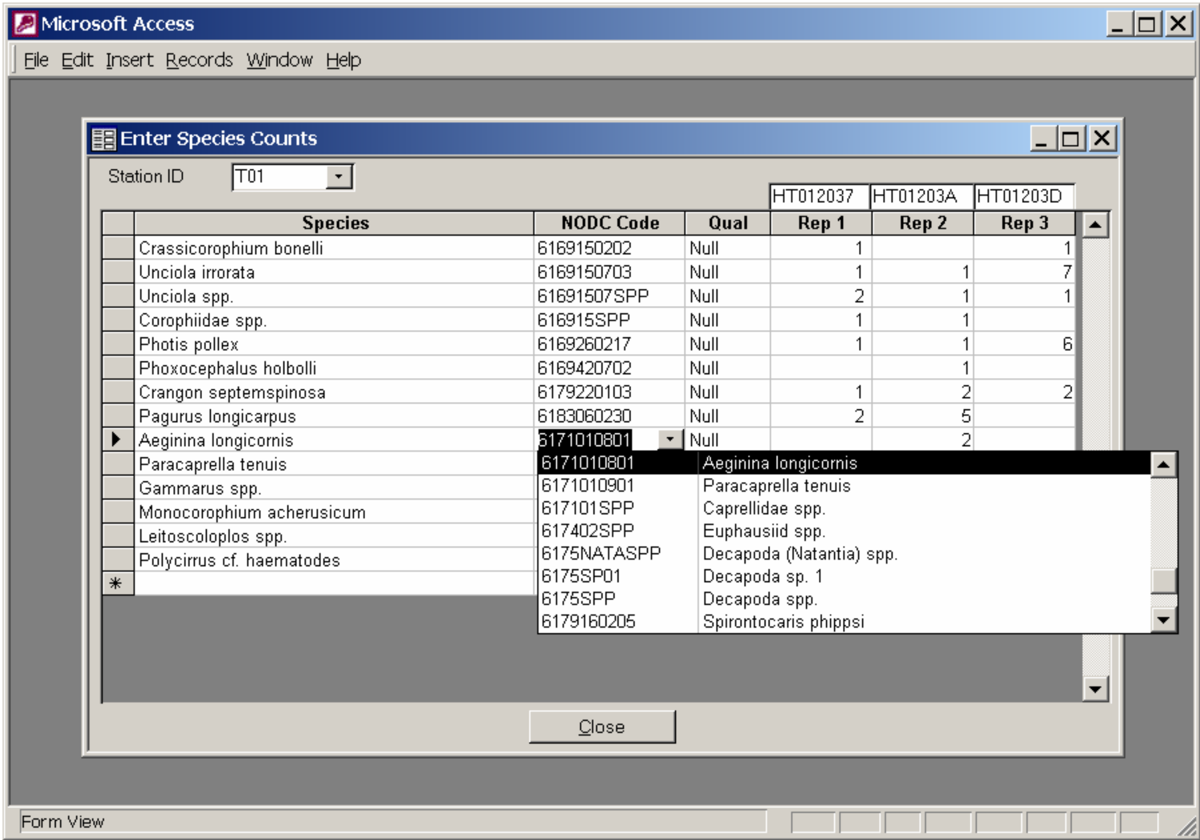
Users of the benthic infaunal loading application will not see a form populated with all the species names, but must choose the proper species code from a pull-down list (Figure 11). Selection of the proper code automatically enters the correct species name in the species field. The codes in the list 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.* 2004, 2006 in prep) 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.



Microsoft Access

File Edit Insert Records Window Help

Enter Species Counts

Station ID: T01

Species	NODC Code	Qual	Rep 1 (HT012037)	Rep 2 (HT01203A)	Rep 3 (HT01203D)
Crassicorophium bonelli	6169150202	Null	1		1
Unciola irrorata	6169150703	Null	1	1	7
Unciola spp.	61691507SPP	Null	2	1	1
Corophiidae spp.	616915SPP	Null	1	1	
Photis pollex	6169260217	Null	1	1	6
Phoxocephalus holbolli	6169420702	Null		1	
Crangon septemspinosa	6179220103	Null	1	2	2
Pagurus longicarpus	6183060230	Null	2	5	
Aeginina longicornis	6171010801	Null		2	
Paracaprella tenuis					
Gammarus spp.					
Monocorophium acherusicum					
Leitoscoloplos spp.					
Polycirrus cf. haematodes					

6171010801	Aeginina longicornis
6171010901	Paracaprella tenuis
617101SPP	Caprellidae spp.
617402SPP	Euphausiid spp.
6175NATASPP	Decapoda (Natantia) spp.
6175SP01	Decapoda sp. 1
6175SPP	Decapoda spp.
6179160205	Spirontocaris phippsi

Close

Form View

Figure 11. 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 by the SPI analytical laboratory to ENSR for data review and transmittal on to Battelle. 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 many available functions, including quality control 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 quality control 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 and summary statistics.

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 can be used in the SPI loading application as well as other qualifiers that may pertain to the infaunal and hard-bottom 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 (LOC_DRUMLIN_CODE, PRIMARY_SUBS_CODE**,** PARAM_CODE SECONDARY_SUBS_CODE, and SED_DRAPE_CODE) are too numerous to list, as are the SPEC_CODEs found in the infaunal abundance data. These codes can be found in the Oracle table maintained by MWRA. The database tables CODE_LIST and SPECIES_CODES have been populated with most of the codes used for these data. Additional codes are added by the MWRA database manager when requested by Battelle data management.

Additional database codes used for the benthic monitoring task are included in Table 20. A comprehensive list of parameters and database codes for sediment chemical and physicochemical analytes can be found by inquiry to the MWRA 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 Sediment (Field RPD only) and SPI Analysis.

Parameter	Param_code	Meth_ Code	Unit_ code	Gear_code
Number of inactive water filled spaces in sediment resulting from abandonment of feeding voids	ANOXIC_VOID_NUM	KP93		HMMSPCAM
Redox potential discontinuity at the bottom of the bioturbation layer – where sediment is sulfidic	ARPD	WILL02	cm	RULER
Average penetration	AVG_PEN	KP93	cm	HMMSPCAM
Average depth of redox potential discontinuity	AVG_RPD	KP93	cm	HMMSPCAM
Number of burrows	BURR_NO	KP93		HMMSPCAM
Number of gas filled spaces in sediment resulting from methanogenesis	GAS_VOID_NUM	KP93		HMMSPCAM
Sediment grain size	GRN_SZ	KP93		HMMSPCAM
Organism-Sediment Index	OSI	KP93		HMMSPCAM
Number of active, water-filled spaces in sediment resulting from sub-surface feeding activity of infauna	OXIC_VOID_NUM	KP93		HMMSPCAM
Maximum penetration depth of camera	PEN_MAX	KP93	cm	HMMSPCAM
Minimum penetration depth of camera	PEN_MIN	KP93	cm	HMMSPCAM
Maximum depth of redox potential discontinuity	RPD_MAX	KP93	cm	HMMSPCAM
Surface relief across the 15 cm width of the face plate. Calculated as (PEN_MAX – PEN_MIN)	SR	KP93	cm	HMMSPCAM
Infaunal worms counted	SUB_FAUNA_WORMS	KP93		HMMSPCAM
Infaunal successional stage	SUCC_STG	KP93		HMMSPCAM
Features on the sediment surface	SURFACE_FEATURES	KP93		HMMSPCAM
Amphipod tube	TUBE_AMPH	KP93		HMMSPCAM
Polychaete tube	TUBE_POLY	KP93		HMMSPCAM

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

Data submissions from the laboratory will consist of final electronic spreadsheets (SPI) or final loading applications as discussed above. The submissions will be logged in upon receipt and a copy of the login will be maintained on file under the login id. Data will be loaded into a temporary table 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 from the laboratories will receive a quality assurance 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 quality control 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 quality control checks (for example, stations more than specified distance from target) will also be submitted to MWRA with the data export.

B10.5 Data Report Quality Control Checks

Prior to data submission to MWRA, Battelle will perform the SPI range checks defined in Table 21. The benthic area senior scientists, Drs. James Blake and Nancy Maciolek, will review the results of the checks prior to submission of the SPI dataset. Infaunal quality control checks that include plots of various parameters against previously accepted data (Table 21) will be run by MWRA subsequent to dataset submission. Drs. James A. Blake and Nancy Maciolek will review the results of the infaunal checks as part of the infaunal data report review. Table 21 presents a list of QC checks that will be performed on benthic data.

Table 20. Descriptions of Other Database Codes used in HOM5 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	HMMSPCAM	Hulcher Model Minnie Sediment Profile Camera
GEAR_CODE	VV01	0.1-m2 Young-Modified Van Veen Grab
GEAR_CODE	VV04	0.04-m2 Young-modified Van Veen Grab
INSTR_CODE	MICR	Microscope
INSTR_CODE	RULER	Measurement by ruler
MATRIX_CODE	SED	Sediment
METH_CODE	ENUM	Enumeration
METH_CODE	KP93	Kelly and Kropp 1993 Soft-bottom QA Plan
METH_CODE	WILL02	Williams *et al.* 2002 Benthic QA Plan
SAMP_VOL_UNIT_CODE	L	Liter
UNIT_CODE	0.04m2	Units associated with a VanVeen 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	e	Results not reported, value given is NULL. Explanation in COMMENTS field
VAL_QUAL	p	Lab sample bottles mislabeled - caution data us
VAL_QUAL	q	Possibly suspect/invalid and not fit for use. Investigation pending.
VAL_QUAL	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

Table 21. 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.		

Section 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 HOM5 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 22 and 23.

C1.1.2 *Field Sampling Technical System Audit*

The Project QA Officer and/or ENSR Field Team 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 24) 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 25) 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 project 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 22. 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 specimen cups)___________		
☐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 23. Field Safety and Equipment Checklist for HOM5

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 24. 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 25. 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. QA assignments for individual laboratories are indicated in Table 1.

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 while work is in progress, the subcontractor QA Officer or his/her designee will conduct an inspection to evaluate the laboratory data-production process. All data must be reviewed by the subcontractor QA Officer prior to submission to the 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 1-9 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 Field Team Leader 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 Field Team Leader. The Field Team Leader 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 Data Quality Objectives (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 Laboratory 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.

Section 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 the Benthic Monitoring Services (Agreement II) program.

D1.3 Data Management

The review process will include verification of manually entered data, quality control 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 ENSR 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.

At Battelle, a second-level review of electronic submissions will be performed when the data are analyzed selectively using methods such as scatter plots, univariate and multivariate analyses, and range checks to identify suspect values. Routine system back-ups are performed daily.

For HOM5, a third-level 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.

Finally, a fourth review by ENSR will take place after MWRA exports the data as a data report to verify that all data has 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 HOM5 benthic monitoring and as listed in Section A9.4.

- Documentation of in-house checks (for example, sample scatter plots and listing any checking programs run)
- Cover letter describing any problems during loading

- Notes on all missing data and all data qualified as "suspect/invalid"
- List of problems encountered and corrective action taken
- Explanation of any outstanding issues resulting from the checks
- 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)
- Summary statistics
- 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 data quality objectives 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 HOM5 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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