QUALITY ASSURANCE PROJECT PLAN

for

MWRA EFFLUENT OUTFALL MONITORING PROGRAM: BASELINE WATER QUALITY MONITORING OF MASSACHUSETTS BAY

1992

by

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Submitted to:
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March 23, 1992

Amended June 10, 1993

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MWRA Effluent Outfall Monitoring Program:
Baseline Water Quality Monitoring of Massachusetts Bay

2.0 PROJECT REQUESTED BY

Massachusetts Water Resources Authority
Environmental Quality Department

3.0 DATE OF REQUEST

February 18, 1992

4.0 DATE OF PROJECT INITIATION

February 20, 1992

5.0 PROJECT MANAGEMENT

MWRA Department Director/Project Manager/Task Manager

Dr. Michael Connor, Director of Environmental Quality Department
Ms. Wendy Smith, Project Manager for MESTA Contract
Dr. Michael Mickelson, Task Manager for Outfall Monitoring

Battelle Program Manager/Task Leaders

Dr. Damian Shea, Outfall Monitoring Program Manager
Dr. John Kelly, Task Leader
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6.0 BATTELLE QUALITY ASSURANCE OFFICER

Ms. Debra McGrath

7.0 PROJECT DESCRIPTION

7.1 BACKGROUND

The Massachusetts Water Resources Authority (MWRA) is implementing a long-term monitoring plan (MWRA, 1991) for the future MWRA effluent outfall that will be located in Massachusetts Bay (see Figure 1). The purpose of the monitoring is to verify compliance with the discharge permit and to assess the potential environmental impact of effluent discharge into Massachusetts Bay. To help establish the present conditions with respect to water properties, nutrients, and other important parameters of eutrophication, Battelle will be conducting twenty-two water-quality surveys throughout Massachusetts Bay during 1992. A detailed description of the monitoring and its rationale are given in the Outfall Monitoring Plan (MWRA, 1991). The work described in this Quality Assurance Project Plan (QAPjP) addresses the baseline activities described in the Outfall Monitoring Plan under water column sampling.

This QAPjP describes the technical activities to be performed at sea and in the laboratory, data quality requirements and assessments, project management (organization and responsibilities of Battelle staff and subcontractors), and a schedule of activities and deliverables. This QAPjP conforms to the format used by the Environmental Protection Agency, Office of Water, and it provides the information necessary to implement the monitoring described in the Outfall Monitoring Plan (MWRA, 1991). The plan described in this QAPjP may require minor modifications throughout the year (e.g., changes in schedule, staff, or equipment); therefore, separate survey plans will be developed for each survey to list the important operational details required to conduct each survey.

7.2 OBJECTIVES AND SCOPE OF WORK

The objectives of this project are discussed in detail in the MWRA Effluent Outfall Monitoring Plan (MWRA, 1991) and are summarized below.

Physical Oceanography

- Obtain high-resolution measurements of water properties throughout Massachusetts Bay
- Use vertical-profile data on water properties at selected sites in Massachusetts and Cape Cod Bays for analysis of large-scale spatial (10s of km) and temporal (seasonal) variability in water properties and to provide supporting data to help interpret biological and chemical data
- Use high-resolution, near-synoptic, water-property measurements along transects within the nearfield area for analysis of smaller-scale spatial (km) and temporal (semi-monthly) variability in water properties, and develop a three-dimensional picture of water properties near the future outfall

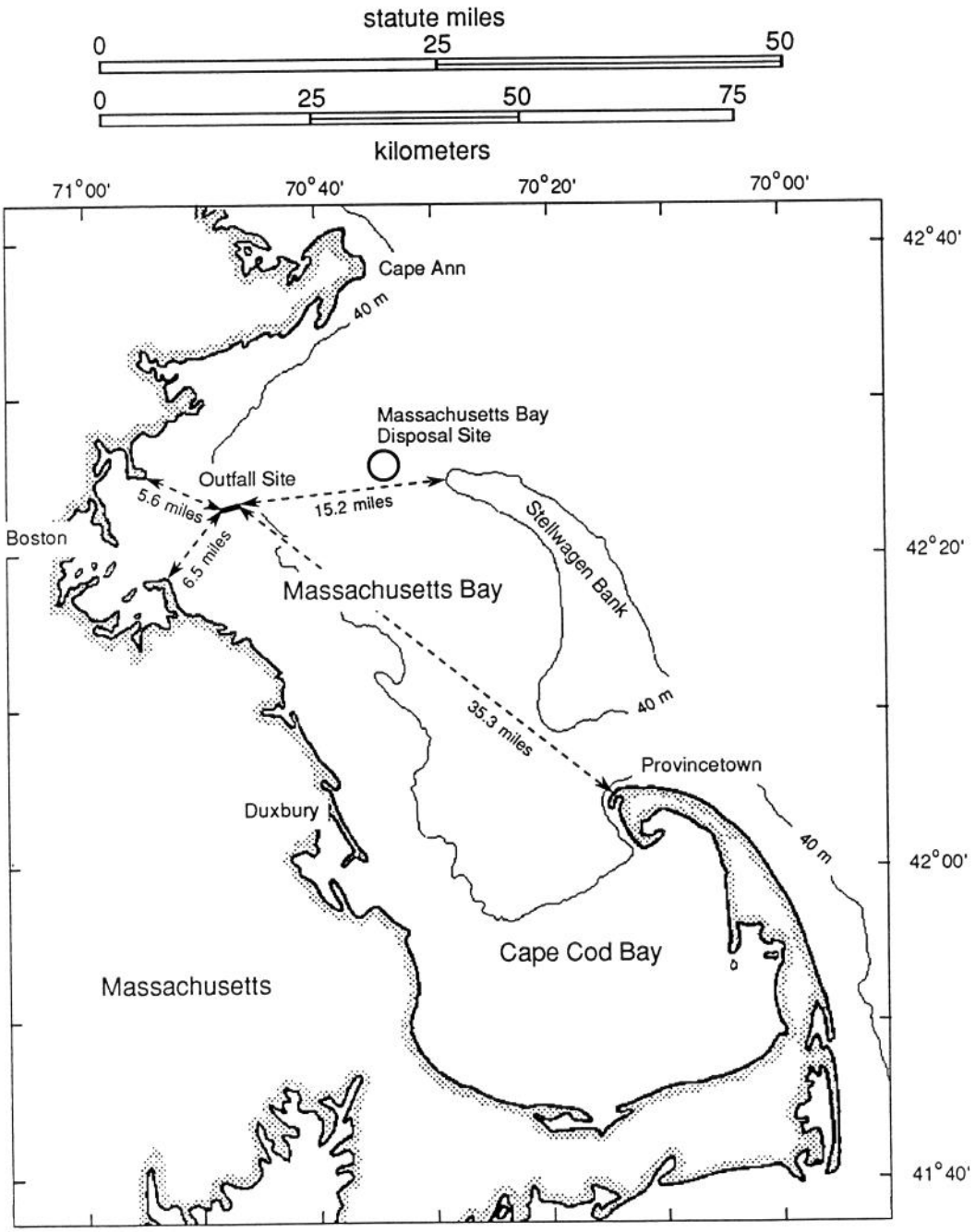

Figure 1. Massachusetts and Cape Cod Bays

Nutrients

- Obtain nutrient measurements in water that is representative of Massachusetts and Cape Cod Bays
- Use vertical-profile data on nutrients at selected sites in Massachusetts and Cape Cod Bays for analysis of large-scale spatial (10s of km) and temporal (seasonal) variability in nutrient concentrations and to provide supporting data to help to interpret biological data
- Use vertical-profile data on nutrients along transects of closely-spaced stations within the nearfield area for analysis of smaller-scale spatial (km) and temporal (semi-monthly) variability in nutrient concentrations, and develop a three-dimensional picture of the nutrient field near the future outfall

Plankton

- Obtain high-quality identification and enumeration of phytoplankton and zooplankton in water that is representative of Massachusetts and Cape Cod Bays
- Use vertical-profile data on plankton at selected sites in Massachusetts and Cape Cod Bays for analysis of large-scale spatial (10s of km) and temporal (seasonal) variability in plankton distribution

Water Column Respiration and Production

- Obtain a reasonable estimate of the rates of water-column respiration and production in water that is representative of Massachusetts and Cape Cod Bays

General

- Evaluate the utility of various measurements to detect change or to help to explain observed change
- Provide data to help to modify the monitoring program to allow a more efficient means of attaining monitoring objectives
- Use the data appropriately to describe the water-quality conditions (over space and time) in Massachusetts and Cape Cod Bays

To meet these objectives, Battelle will conduct six 4-day farfield surveys in Massachusetts and Cape Cod Bays and sixteen 2-day nearfield surveys in the vicinity of the future outfall during 1992. Six of the nearfield surveys will be coupled with the six farfield surveys and constitute one "cruise"; thus there will be a total of sixteen cruises in 1992. *In situ* measurements will be taken and samples will be collected for laboratory analyses to obtain the following types of data.

- Dissolved inorganic nutrients: nitrate, nitrite, ammonium, phosphate, and silicate
- Chlorophyll *a* and phaeopigments in extracts of filtered water

- *In situ* fluorometric measurements of chlorophyll, optical-beam transmittance (turbidity), light irradiance, salinity, temperature, and dissolved oxygen
- Total suspended solids and dissolved oxygen in discrete water samples
- Organic nutrients: dissolved carbon, nitrogen, and phosphorus; particulate carbon and nitrogen
- Phytoplankton and zooplankton identification and enumeration
- Rates of water-column respiration and production.

All data will be processed, reviewed for quality and technical reasonableness, synthesized, interpreted, and then reported to the MWRA. This scope of work is divided into the following tasks.

Task 1 - Development of the Quality Assurance Project Plan
Task 2 - Nearfield Nutrient/Hydrography Surveys
Task 3 - Biology/Productivity and Combined Nearfield-Farfield Nutrient/Hydrography Surveys
Task 4 - Plankton Taxonomy
Task 5 - Nutrient Analysis and Respiration/Productivity Measurements
Task 6 - Data Management
Task 7 - Data Synthesis, Interpretation, and Reporting

The relevant work to be performed under each of these tasks is described in the next section.

7.3 TECHNICAL APPROACH

This section presents the technical approach to be used for the field surveys, the processing and analysis of samples, and the reporting of all data. Sections 7.3.2 and 7.3.3 describe the field surveys; sections 7.3.4 and 7.3.5 describe the laboratory analyses, and Sections 7.3.6 and 7.3.7 describe data management, synthesis, and reporting. Details on sampling procedures, data reduction and analysis techniques, and reporting are given in later sections of this report.

7.3.1 Task 1 - Development of the Quality Assurance Project Plan

The first task under this project was the development of this Quality Assurance Project Plan (QAPjP). This QAPjP conforms to the format used by the Environmental Protection Agency, Office of Water, and it provides the information necessary to implement the monitoring described in the MWRA Effluent Outfall Monitoring Plan (MWRA, 1991). The development of this QAPjP was aided by discussions with MWRA staff and members of the MWRA Outfall Monitoring Task Force.

7.3.2 Task 2 - Nearfield Nutrient/Hydrography Surveys

Under this task, Battelle will conduct ten nearfield nutrient/hydrography surveys. These will be 2-day cruises to sample the twenty-one nearfield stations (all stations starting with "N", Figure 2). The objective for the first day is to perform high-resolution vertical profile sampling at each station to characterize selected physical, chemical, and biological properties and to obtain discrete samples for nutrients and phytoplankton. The objective for the second day is to perform high-resolution horizontal tow sampling at and between stations along transects to enable a three-dimensional description of selected physical, chemical, and biological measures of the nearfield region of the proposed MWRA outfall. Ten of the sixteen nearfield surveys will be conducted under this task. The remaining six nearfield surveys will be combined with the farfield surveys under Task 3.

Similar *in situ* measurements will be made each day (Table 1). Additionally on the first day, water samples from five selected depths at all twenty-one stations will be collected for nutrient analyses and surface samples from six stations (Table 1) will be collected for phytoplankton analysis. Depths for nutrient samples will be determined from hydrographic data gathered on the downcast and sampling conducted on the upcast. Depths will include a near bottom sample, a sample of the mid-depth chlorophyll maximum (if present), a sample above and below the mid-depth chlorophyll maximum, and a near surface sample. Near bottom samples will be collected routinely within 5 m of the bottom. During periods of possible low dissolved oxygen (DO), or when the down-cast profile indicates low DO in the bottom water, samples will be collected as close to the bottom as possible (without damaging the *in situ* sensor package). The surface water samples for phytoplankton will be collected, preserved, and archived for possible taxonomy; only samples from one station will be analyzed (see Section 7.3.4).

The primary method for sample collection on the first day of nearfield surveys will be a Rosette sampler with Go-Flo (or Nisken) bottles and with a CTD system, irradiance sensor, and other sensors (Table 1). This Rosette sampler will also be used on the farfield and biology/productivity surveys (Section 7.3.3). The principal sampling equipment to provide high-resolution horizontal towed sampling will be the Battelle Ocean Sampling System (BOSS) — a towfish housing instruments for *in situ* measurements and a pumping system for continuous delivery of seawater to the ship (Table 1). A smaller system, the Mini-BOSS (Table 1), will be used as a backup on all surveys and may be used as a substitute for the BOSS on smaller vessels.

Besides the regular sampling at each station, collection of additional water samples to be analyzed for chlorophyll, total suspended solids, and dissolved oxygen will be performed to provide comparative data and calibration for *in situ* measurements. Numbers and timing of such sampling will be determined on the basis of the first cruise (combined nearfield-farfield) results, in consultation with MWRA, and specified in survey plans for later cruises. Water samples will be analyzed under Task 5.

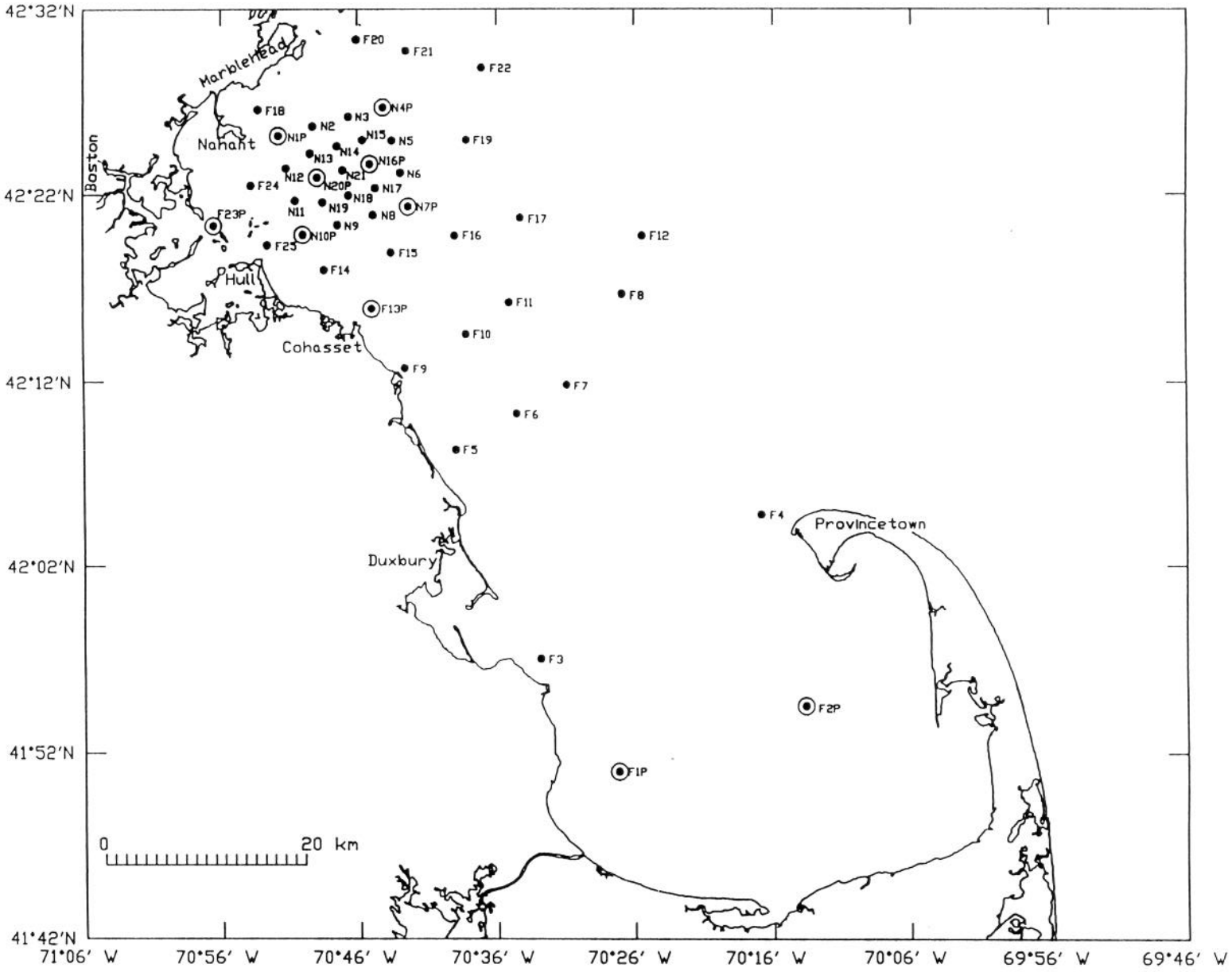

Figure 2. **Water Quality Sampling Stations in Massachusetts and Cape Cod Bays. Station Codes - F: Farfield, N: Nearfield, P: Productivity**

Table 1. Measurements at the Nearfield Nutrient/Hydrography Stations

Parameter	Method or Instrument	Frequency of Sampling per Station	Sampling Approach	
			Day 1	Day 2
Chlorophyll	Chelsea Aquatracka III *in situ* fluorometer	Continuous *in situ* recording	Vertical profiles with Rosette	Towing with BOSS
Chlorophyll	Turner Model 10 fluorometer	Continuous onboard recording	Mini-BOSS pump on Rosette	Same
Turbidity	Sea Tech 25-cm Optical Beam Transmissometer	Continuous *in situ* recording	Vertical profiles with Rosette	Same
Irradiance	Biospherical QSP-200AL Irradiance Sensor[a]	Same	Same	Same
Conductivity[b]	SeaBird SBE-9 or Ocean Sensors OS100	Same	Same	Same
Temperature[b]	SeaBird SBE-9 or Ocean Sensors OS100	Same	Same	Same
Depth[b] (Pressure)	SeaBird SBE-9 or Ocean Sensors OS100	Same	Same	Same
Dissolved[b] Oxygen	SeaBird SBE-13 or Royce Dissolved Oxygen Sensor on OS100 CTD	Same	Same	Same
Dissolved Inorganic Nutrients	Water samples filtered and frozen	5 depths	Samples from Go-Flos on Rosette	Not sampled
Phytoplankton	Whole water sample	One	Surface sample at stations N1P, N4P, N7P, N10P, N16P, N20P	Not sampled

[a]The Biospherical Sensor will not be available for the first few cruises. A LICOR Irradiance Sensor, meter, and deck cell will be used instead; it will be lowered by hand and readings manually recorded.

[b]The SeaBird CTD system will be used on the Rosette sampler and the BOSS; the Ocean Sensors OS100 will be used on the Mini-BOSS (the routine backup system and the primary system on smaller vessels).

7.3.3 Task 3 - Biology/Productivity and Combined Nearfield-Farfield Nutrient/Hydrography Surveys

The objectives are to characterize the water quality at stations in the Massachusetts/Cape Cod Bays region and at a selected subset of stations to provide detailed information on nutrient forms and particle concentrations, the species composition of plankton community, and the metabolism of the water column. Under this task, Battelle will conduct six 3- to 4-day surveys, sampling at twenty-five farfield stations and six nearfield stations in Massachusetts and Cape Cod Bays. At twenty-one farfield stations (labeled "F" but lacking a terminal "P", Figure 2) the parameters measured will be the same as for the nearfield survey day 1 (Table 1), minus only the surface samples for phytoplankton. Nutrient samples will be analyzed under Task 5.

At ten stations (F1P, F2P, F13P, F23P, N1P, N4P, N7P, N10P, N16P, N20P; Figure 2) sampling will be conducted to include all measures made at the twenty-one nutrient/hydrography farfield stations, plus additional discrete sampling for biological/productivity measurements listed in Table 2. Further, one special station (F25) will be sampled for dissolved and particulate organic nutrients as listed in Table 2; these measures are to provide total nutrient measurements at a main point of water outflow from Boston Harbor. The additional samples collected at the biology/productivity stations and Station F25 will be analyzed under Tasks 4 and 5.

Routinely, only one discrete sample for each parameter, station, and depth will be collected. However, to provide for estimates of within-station sampling error for statistical purposes, an additional 5 to 10% of the total samples (Table 2 parameters plus nutrients) to be analyzed will be collected from duplicate bottles. Duplicates will be collected on every other combined nearfield-farfield cruise, starting with the second cruise (March). For Table 2 parameters, including dissolved oxygen but excluding the metabolism incubations, a random selection of a station from Massachusetts Bay and from Cape Cod Bay will be made. For selected stations, the surface and mid-depth chlorophyll maximum will be sampled from duplicate bottles tripped at the same depth and a separate net tow made for zooplankton. For nutrients, more than one station in Massachusetts and Cape Cod Bays will be selected and duplicate bottle casts taken and sampled from all depths chosen for vertical profiling.

The equipment for sampling the above stations for the Farfield and Biology/Productivity Surveys will be a General Oceanics Model 1015 rosette system with 5- and 10-L GO-FLO bottles. Sampling by bottles is both to provide undamaged phytoplankton cells and to obtain discrete samples for the planned measurements. For the farfield surveys, a SeaBird SBE-9 CTD system with SeaBird SBE-13 dissolved oxygen sensor will be mounted on the rosette system to take measurements of conductivity, temperature, depth, and dissolved oxygen (Table 1). The Ocean Sensors OS100 (Table 1) will be used as a backup CTD system.

Table 2. Measurements at the Biological/Productivity Stations

Parameter	Frequency of Sampling per Station
Chlorophyll *a* and phaeopigments	Two depths: surface and mid-depth chlorophyll maximum[a]
Total suspended solids	Same
Particulate Organic Nutrients Carbon and Nitrogen	Same
Dissolved Organic Nutrients Carbon, Nitrogen, Phosphorus	Same
Metabolism Production and Respiration	Same
Phytoplankton	Five depths[a]
Net zooplankton	One vertical-oblique tow

[a]Samples will be from the same GO-FLO bottles used to collect dissolved inorganic nutrient samples at those depths. Only two depths will be analyzed for phytoplankton (see text).

For turbidity, light, and chlorophyll respectively, a Sea Tech transmissometer, Biospherical sensor, and Chelsea fluorometer (Table 1) will be mounted on the rosette. The same instruments (except the Biospherical sensor) will be mounted on the Mini-BOSS, whenever the Mini-BOSS is used.

To reduce ship mobilization effort, six of the sixteen 2-day nearfield surveys (as described in Section 7.3.2) will be conducted at the completion of the farfield surveys under this task as part of the combined cruise activity.

7.3.4 Task 4 - Plankton Taxonomy

Under this task, Battelle's subcontractor, the University of Massachusetts at Dartmouth (UMD), will help to collect samples for both phytoplankton and zooplankton and, in the laboratory, will perform taxonomic analyses to identify and enumerate the species present. Details of the laboratory analyses are provided in Section 12.2. The samples will be collected during the six combined nearfield-farfield surveys and the ten nearfield surveys.

Biology/Productivity Surveys

Phytoplankton taxonomy will be performed on water samples collected at two depths (surface and chlorophyll maximum) from the ten biology/productivity stations. Over six cruises, this amounts to 120 samples that will be analyzed. An additional twelve samples will be analyzed from duplicate samples taken to estimate sampling variability. Samples from the other three depths will be preserved and archived. Zooplankton taxonomy will be performed on samples from the vertical-oblique tows at all ten biology/productivity stations; over six cruises, this amounts to 60 zooplankton samples. An additional six samples, taken from duplicates to estimate sampling variability, also will be analyzed.

Nearfield Nutrient/Hydrography Surveys

Samples from Station N10P of the sixteen surveys will be analyzed for phytoplankton taxonomy under this task. This represents an additional ten samples that will be analyzed. The other collected samples will be preserved and archived.

7.3.5 Task 5 - Nutrient Analysis and Respiration/Productivity Measurements

Under this task, Battelle's subcontractor, the University of Rhode Island (URI), will help to collect water samples and will analyze the samples for dissolved inorganic nutrients (nitrate, nitrite, phosphate, silicate, and ammonium), dissolved and particulate organic carbon (DOC/POC), dissolved and particulate organic nitrogen (DON/PON), dissolved organic phosphorus (DOP), total suspended solids (TSS), and chlorophyll *a* and phaeopigments. Dissolved inorganic nutrient samples will be filtered and preserved with

chloroform on board. Filtered samples for dissolved organics will be either preserved appropriately or frozen on board. Filters with collected particulate matter for chlorophyll analysis will be frozen. Separate filters of collected particulate matter to be used for the analysis of POC, PON, and TSS will be air dried. Proper sample conditions will be maintained in transfer to the shore laboratory and further maintained until analysis. Detailed sample treatment and laboratory analytical procedures for all water chemistry are described in later sections. The above samples will be collected during the six combined nearfield-farfield surveys and during the ten nearfield surveys.

Samples will also be collected and incubated for measurement of dissolved oxygen (DO) to estimate rates of respiration and production. The light box incubations are further described below. There will be some additional samples collected for DO to calibrate the *in situ* DO probe. An autotitrator will be onboard during the February OSV *Anderson* survey to allow on-board titrations. On subsequent surveys, the vessel will be returning to port at the end of the day and DO samples will be transferred to shore for titration in the laboratory (either at Battelle or URI) by URI subcontractor staff. Fixed samples will be kept in the dark will be titrated within 24 hours.

Nutrients

Discrete water samples collected from up to five depths at each of the twenty-five farfield stations and twenty-one nearfield stations will be analyzed for dissolved inorganic nutrients. Over six combined nearfield-farfield cruises, a total of 1560 (from [25 + 6 + 21] stations and five depths) nutrient samples will be analyzed. Discrete samples from five depths at each of the twenty-one nearfield stations on ten surveys amounts to another 1050 nutrient samples that will be analyzed. Another 140 samples taken to assess sampling variability also will be analyzed.

Biology/Productivity Parameters

Discrete water samples collected from two depths (surface and chlorophyll maximum) at each of the ten biology/productivity stations will be analyzed for DOC/POC, DON/PON, DOP, TSS, and chlorophyll *a* and phaeopigments. Over six cruises, 120 analyses for each parameter will be performed. An additional 10%, or twelve samples, for estimating sampling variability will be analyzed. Samples collected at two depths and ten stations over the six cruises will also be used for measuring rates of water column respiration and productivity. The oxygen titrations used to estimate these rates will include, for each depth, a minimum of 2 initial bottles that also provide the *in situ* concentration, two light bottle replicates at approximately six different light levels, and 3 dark bottles. Overall, this amounts to 2040 sample titrations.

At one farfield station, additional samples will be collected from two depths at each of the six cruises (twelve samples), and will be analyzed for DOC/POC, DON/PON, and DOP.

7.3.6 Task 6 - Data Management

Work conducted under this task is to provide an efficient means of quickly disseminating monitoring information to MWRA scientists, Outfall Monitoring Task Force members, and the general public. An integrated plan for data management will be developed under this task to transforming raw data from *in situ* measurements and laboratory analyses into readily accessible information. This will include

- Establishing sample tracking procedures and documentation forms
- Developing new and/or modifying existing data reporting protocols
- Developing a data management plan for physical oceanographic data
- Loading data into the MWRA database and geographic information system
- Implementing data presentation software tools for use by MWRA

Specific details of the data management procedures, reporting protocols, electronic data format, etc. will be developed under this task and approved by the MWRA prior to implementation.

7.3.7 Task 7 - Data Synthesis, Interpretation, and Reporting

This task will be to draw together physical oceanographic information, biological data, and chemical concentrations. The physical oceanographic measurements will be synthesized with the other data to describe the ecological conditions measured at different cruises and how these conditions change as a function of season. All of the data from the chemical analyses will be examined and reported in the synthesis and integration effort. Biological data examined will include the counts of phytoplankton and zooplankton taxa, in addition to metabolic rates measured at biology/productivity stations.

The precise form and content of the synthesis reports will be determined in consultation with the MWRA. Three "quarterly" reports will be prepared. An outline for each report will be provided to the MWRA for comment prior to final preparation of the report; this will allow for modification in the reporting as necessary throughout the project. The primary emphasis of each quarterly synthesis report will be description of spatial and temporal patterns of oceanographic and ecological conditions during the season covered. Reports will cover three seasons: 1) the winter-spring period from February through April (five cruises); 2) the late spring-early summer period from May through August (6 cruises); and 3) the fall period from September to early November (4 cruises). Data from the final nearfield cruise of 1992 will be provided with the survey report (see Section 9.0), but will not be included in a synthesis report delivered in 1992. Synthesis reports will contain graphics, tables, statistics, and text necessary to illustrate and describe spatial and temporal trends in Massachusetts and Cape Cod Bays. The report will also include interpretation of the oceanographic and ecological relationships among nearfield and farfield stations. Data will be submitted to the MWRA for its own use in electronic format as well as included in appendices to synthesis reports.

8.0 PROJECT FISCAL INFORMATION

This project is being carried out under a task order contract between MWRA and Battelle Ocean Sciences, contract O038, task order 40, 41, 42, 43, 44, and 45.

9.0 SCHEDULE OF ACTIVITIES AND DELIVERABLES

The schedule of activities and deliverables for this program is tied to survey activities. Tentative survey dates are given below.

Nearfield Surveys

- March 23 - 26
- April 27 - 30
- May 18 - 21
- July 6 - 9
- July 27 - 30
- August 10 - 13
- September 8 - 11
- September 28 - October 1
- November 2 - 5
- November 30 - December 3

Combined Nearfield-Farfield Surveys

- February 22 - March 1
- March 9 - 17
- April 6 - 12
- June 22 - 29
- August 24 - 30
- October 13 - 19

The deliverables under this program will include this QAPjP and survey plans for each of the sixteen nearfield surveys and each of the six farfield surveys. Each survey plan will follow the new guidelines established by EPA for use of the OSV *Anderson* regardless of vessel used on the survey. The survey plan will be submitted to the MWRA at least 7 days prior to the survey. Survey reports also will be provided to MWRA within 2 weeks after each survey demobilization; the content of such reporting will include a summary of survey operations, problems encountered, and numbers/types of samples collected. A single survey report will be submitted for each of the combined nearfield-farfield surveys, for a total of sixteen survey reports.

Additionally, three quarterly reports will be submitted as deliverables to MWRA. Each will integrate and synthesize results of data obtained during approximately the previous 3 months. The format, content, and schedule of delivery of these reports will be developed fully as part of Task 7. Results from this monitoring program will be formally presented to the Outfall Monitoring Task Force by Battelle. Two presentations are expected, one mid-year presentation prior to revision of the MWRA Effluent Outfall Monitoring Plan, and one year-end presentation after the fall survey data have been synthesized.

Monthly progress reports will be submitted to MWRA by the fifteenth of each month, beginning 15 April 1992, summarizing technical activities performed and costs incurred for the previous month.

10.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

The project organization is shown in Figure 3. Ms. Wendy Smith is the MWRA Project Manager for the Marine Environmental Services Technical Assistance (MESTA) contract and will be informed of all matters pertaining to cost and schedule. Dr. Michael Mickelson is the MWRA Task Manager. Dr. Damian Shea is the Battelle Program Manager responsible for the overall performance of this program. Dr. Shea has been responsible for developing this QAPjP (Task 1); he has been assisted by Dr. John (Jack) Kelly, Mr. John (Chip) Ryther, and Dr. Carlton Hunt. Mr. Ryther is the Task Leader for Tasks 2 and 3. Mr. Ryther will be responsible for coordinating all survey operations and ensuring successful completion of each survey. It is expected that Mr. Ryther will be the chief scientist on most of the nearfield cruises, but that he may designate an alternate chief scientist from Battelle at his discretion. Mr. Ryther will also be responsible for writing the survey plans and reports. Mr. Kevin King or Mr. Jack Becthold will be the Battelle technician on each cruise. Mr. Carl Albro will be the senior engineer and will be responsible for all *in situ* instrument data processing. Dr. Scott McDowell will provide technical review of the hydrographic data. Dr. McDowell, in addition to Dr. Kelly and Dr. Shea, will review survey plans and reports.

Dr. Kelly is the Task Leader for Tasks 4 and 5; he will oversee subcontractors conducting the sampling and laboratory work related to plankton, nutrients, and respiration/production. Battelle's subcontractor, the University of Massachusetts at Dartmouth (UMD), will be performing work under Task 4. Dr. Jefferson Turner will be the subtask leader at UMD and he will either perform or oversee the taxonomic analysis. Mr. David Borkman, of UMD, will perform phytoplankton taxonomy and assist with sample collection. Battelle's subcontractor, the University of Rhode Island (URI), will be performing work under Task 5. Dr. Peter Doering will be the subtask leader at URI and he will oversee all analyses. Dr. Candace Oviatt, of URI, will provide technical oversight to URI subtasks. Ms. Laura Reed and Mr. Edwin Requintina, both of URI, will assist with sample collection and analysis. Mr. Eric Klos of URI will serve as an alternate to assist with field sampling.

The Task Leader for data management (Task 6) is Mr. Tom Gulbransen. He will be assisted by Mr. John Hennessy and Ms. Ellie Baptiste. The Task Leader for data synthesis, interpretation, and reporting (Task 7) is Dr. Kelly. He will be responsible for synthesizing subcontractor reports and writing the quarterly interpretive reports. Dr. Kelly will be assisted by Drs. Doering, Hunt, McDowell, Oviatt, Shea, and Turner. Ms. Debra McGrath will oversee the quality assurance (QA) of all technical activities conducted by Battelle.

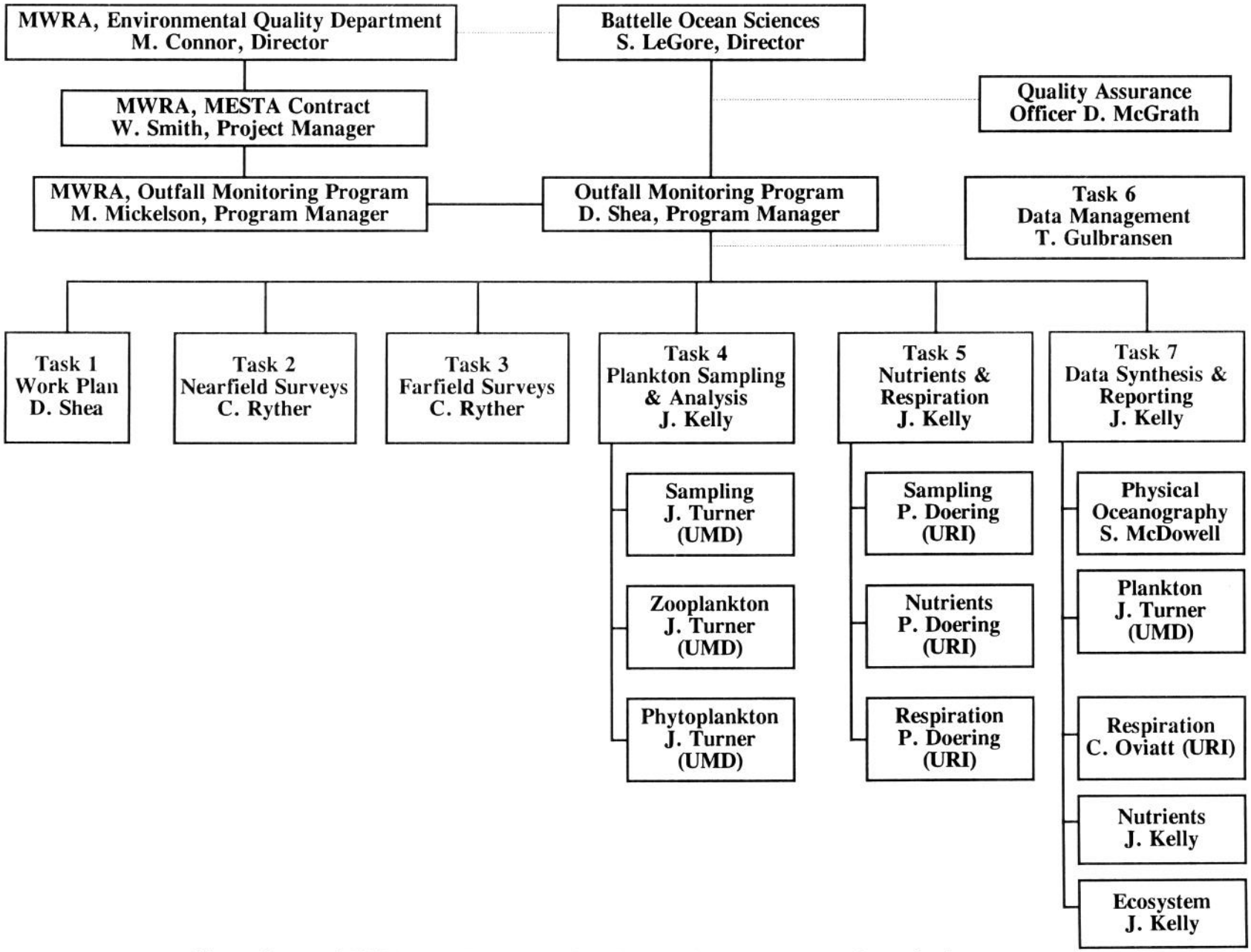

Figure 3. **MWRA Baseline Water-Quality Monitoring Program Organization**

11.0 DATA QUALITY REQUIREMENTS AND ASSESSMENTS

11.1 WATER PROPERTY DATA

Precision and Accuracy

All survey components will be thoroughly tested and calibration checks performed before survey operations begin. A number of parameters that are measured by wet chemical techniques will be compared to electronically-gathered data; these comparisons provide an additional check to ensure accuracy of reported numbers. In general, the sampling instruments will perform according to specifications below (cf. McDowell *et al.*, 1991); meeting these specifications will provide levels of precision in excess of that required for successful description of water properties for the monitoring program.

Other parameters will be measured continuously *in situ*. The SeaTech 25-cm transmissometer, used to measure optical-beam transmittance (turbidity) has an accuracy of $\pm 0.5\%$ and a linearity of $\pm 0.1\%$. The Turner Designs model 10 fluorometer, as configured for chlorophyll *a*, has a limit of detectability of 5 parts per trillion. The Chelsea Instruments fluorometer has a range of 0.1 μg/L to 100 μg/L and an accuracy of ± 0.01 μg/L. The Biospherical irradiance sensor has a 0 to 4 volt output range and a minimum sensitivity of 0.01% of full sunlight.

The measurement performance specifications for the SeaBird CTD (conductivity/temperature/depth) system are given in Table 3.

Table 3. Accuracy and Precision of SeaBird CTD System

Parameter	Units	Range	Accuracy	Resolution (Better Than)
Pressure	decibars	0-3000	0.60	0.12
Temperature	°C	−5 to +35	0.004	0.0003
Conductivity	mS/cm	0 to 70	0.001	0.00004
Salinity	PSU	0.5 to 45	0.0006	0.00002
Dissolved oxygen	mg/L	0 to 15	±0.1	0.01

The measurement performance specifications for the Ocean Sensors OS-100 CTD (conductivity/ temperature/depth) data-acquisition system are presented in Table 4.

Table 4. Accuracy and Precision of Ocean Sensors CTD System

Parameter	Units	Range	Accuracy	Resolution (Better Than)
Pressure	decibars	0-1000	0.3%	0.005%
Temperature	°C	−2 to 30	0.015	0.001
Conductivity	mS/cm	0.5 to 65	0.020	0.001
Salinity	PSU	0.5 to 45	0.030	0.001
Clock	s	1 s to 1 year	1 s	0.1
Dissolved oxygen	mg/L	0-10	±0.1	0.1

Completeness

As data are acquired electronically and monitored in real-time, no data loss is expected. With the sampling rates of the CTD and navigation systems, sufficient data will be acquired to map the water masses, and locate the depth of the pycnocline and chlorophyll *a* maximum in Massachusetts and Cape Cod Bays. The 4- to 5-kn survey speeds during towing operations at the outfall site will also allow a large area to be covered in the 1-day tow operation. Stations will not be occupied if CTD measures (at a minimum) cannot be obtained. If instrument malfunctions occur and operations are modified or suspended during any survey day, a decision on modification of activities for that survey will be made with consultation and agreement of MWRA, whenever possible.

Comparability

The instrumentation that is being used during the outfall monitoring surveys is similar to the instrumentation routinely used by EPA, National Oceanic and Atmospheric Administration (NOAA), and other research institutions working in Massachusetts Bay. Thus, the data should be consistent and comparable with previous studies. During the review and synthesis of the survey data, the results will be compared with the general ranges of water property data obtained from past studies. Recent surveys include Boston Harbor (McDowell *et al.,* 1991) and Massachusetts/Cape Cod Bays (Townsend *et al.*, 1991; other studies in Massachusetts Bays Program).

Representativeness

The *in situ* instruments described above provide data to delineate water masses by monitoring changes in water properties at a high degree of resolution. The vertical profiles and horizontal tows conducted under this project will provide more data than has been previously acquired in the future outfall region and will be used in part to determine what is representative and required to meet the monitoring objectives. During each vertical-profile upcast, the sensor package will be held stationary at each sampling depth for at least 1 min to allow time for sensor (e.g., DO probe) equilibration.

11.2 NAVIGATION DATA

Accuracy

All sampling will be conducted within several hundred meters of station, and the vessel will be repositioned if necessary for extended sampling if drift pushes the vessel further than 200 m from station. The Northstar GPS/Loran system has an absolute accuracy of 15-100 m, depending upon the implementation of Selective Availability (SA), which is adequate for the outfall monitoring surveys in Massachusetts Bay. Undifferentiated GPS will be used routinely (for an accuracy better than 100 m); differentiated GPS might be used later in the year. The latitude/longitude of the Loran system will be automatically calibrated by the GPS position. Positions will also be checked at two calibration points — the "B" buoy in Massachusetts Bay and at port for each cruise.

Precision

Loran time delays (TDs) will be recorded, as well as latitude/longitude positions. The Northstar system automatically applies additional secondary-phase factor (ASF) corrections to the Loran data and the unit displays TDs in hundredths of microseconds, providing accurate and repeatable positions.

Completeness

Navigation positions will be obtained at a rate of one sample per second and with the combined GPS/Loran system; no bad navigation data are expected.

Comparability

The Massachusetts Bay and Boston Harbor charts will be displayed on the navigation CRT monitor. Corrected latitude/longitude positions will be recorded, and these positions will be comparable to those obtained by other researchers that have used or are using undifferentiated GPS or corrected Loran.

Representativeness

The Loran TDs and corrected latitude/longitude positions are representative of the position obtained during this or other water-quality research programs within Massachusetts Bay.

11.3 WATER SAMPLES

Accuracy

The sampling objective is to obtain uncontaminated samples representative of their location. Procedures (cf. Lambert and Oviatt, 1986) follow standard methods, proven to maximize meeting this objective. Samples for dissolved inorganic nutrients, organic nutrients, TSS, phytoplankton, and chlorophyll will be collected from labeled GO-FLO hydrocast bottles taken from depths recorded in the navigational log. Samples for dissolved oxygen (DO) will be carefully siphoned into 300-mL BOD bottles with ground glass stoppers. Each sample will be clearly labeled with a unique sampling identifier (station, depth or hydrocast bottle number, and date) that will allow the sample to be traced from collection through analysis to reporting. All samples will be handled and stored according to the procedures given in Lambert and Oviatt, 1986.

Precision

Sampling precision will be monitored through the collection of duplicate hydrocast bottle samples at 5% to 10% of all sample events. If samples are collected by pump, duplicate samples for nutrients will be acquired within 0.5 min of each other while the *in situ* pump is held stationary at the same sample depth.

Completeness

At each station, five depths are scheduled for discrete sampling; these depths will be based on position relative to a subsurface chlorophyll maximum usually associated with the presence of a pycnocline separating surface and bottom water layers. At the discretion of the Chief Scientist and if no distinct vertical hydrographic structure is apparent from the real-time *in situ* sampling, the number of depths sampled may be reduced to a minimum of three in shallow waters (less than about 25 m) and four in deeper waters. In all cases, the objectives of the program will not be compromised if representative surface and mid-depth ("chlorophyll maximum" if present) samples for nutrient and biological studies, and measurements of bottom-water dissolved oxygen, are successfully collected. In the event of sample loss or equipment malfunction, the Chief Scientist will determine the need for appropriate corrective action (e.g., resampling).

Comparability

Collection of the water samples coincidently with water-property data will allow the conversion of relative turbidity units to milligrams per liter (mg/L) of total suspended solids. Collection of samples for both chlorophyll and dissolved oxygen coincidently with *in situ* electronically-captured data will allow comparison of the two methods. Nutrient concentrations (dissolved and particulate) will be compared to recent previous surveys of the study area. Concentration units for reporting will follow standard convention for most oceanographic studies: all nutrients (μM), chlorophyll (μg L^{-1}), TSS (mg L^{-1}), DO (mg L^{-1} or percent saturation).

Representativeness

Water samples will be collected, handled, and transported using procedures that ensure that the resulting data represent the sample material collected. Duplicate analyses of separate hydrocast bottles or from the Mini-BOSS sampling stream will be used to address sampling variability of the environment.

11.4 LABORATORY ANALYSIS

11.4.1 Nutrients, Chlorophyll, and Suspended Solids Data

Accuracy

Nutrient, chlorophyll, and total suspended solids (TSS) measurements will be performed by accepted oceanographic techniques and are fully described (with holding times, detection limits, etc.) in Lambert and Oviatt (1986). Accuracy is assessed by analyzing standard reference materials where these are available, by determining the percent recovery of known compounds, and through intercalibration exercises with other laboratories. Nutrient samples will be referenced against standard curves based on primary standards maintained by the subcontracting laboratory. For DOC, PC, PN, chlorophyll, and TSS, the reported value will represent the mean of duplicates, depending on instrumentation. Reporting will include results of duplicate analyses, standards, and blanks following Lambert and Oviatt (1986). All equipment for nutrient, chlorophyll, and TSS is maintained through regular maintenance and calibration.

Precision

The expected analytical error for duplicate nutrient analyses is as follows: ± 0.05 μM NH_4^+ and PO_4, ± 0.1 μM NO_3 + NO_2. Total nitrogen analyses (the basis for dissolved organic nitrogen) have an expected analytical error of ± 0.1 μM at 10 μM N and ± 0.3 μM at 60 μM N. For a duplicate analysis of total P (the basis for dissolved organic P), the expected error is ± 0.04 μM of the mean at 1.0 μM P. The error for duplicate DOC analyses is expected to be less than ± 5 % of the mean. For both particulate N and P, the expected error for duplicate analyses is 10-12% of the mean. Chlorophyll methods yield an expected error of ± 5 % of the mean of duplicate samples. The precision of TSS analysis is expected to be ± 5 % or less.

Completeness

It is expected that 100% of the samples collected and intended for analysis will be analyzed, however a sample loss of less than 10% would not compromise the objectives of the program. Sufficient sample volumes will be taken to run more than a single analysis, providing a safeguard against any instrument malfunction during a given analysis.

Comparability

The laboratory methods are standard oceanographic methods and thus comparable to many other studies. Values will be compared against other recent survey results in the study area.

Representativeness

Laboratory methods use procedures that ensure that the resulting data represent the sample material collected. Checks by performance of duplicate analyses from a single sample bottle will help verify representativeness.

11.4.2 Plankton Data

Accuracy

Plankton identifications are performed by recognized taxonomic experts using accepted taxonomic references for classification. All samples will be retained as a voucher collection for future reference.

Precision

Counts of phytoplankton aliquots containing at least 400 cells will be made; this gives precision of 10%. Duplicate zooplankton splits will be performed to assess variance due to laboratory subsampling. Duplicate field replicates for 5-10% of the total number of samples will provide estimates of sampling error.

Completeness

It is expected that 100% of the samples intended for analysis will be completed. Sample collection, preservation, and handling procedures provide sample safety and proper treatment for biologic tissues. The objectives of the program will not be compromised if only 80% of planned zooplankton samples are analyzed. Many additional phytoplankton samples will be collected and archived. If some portion of the samples intended for analysis cannot be completed, then others from the archived collection would be analyzed.

Comparability

The methods follow procedures used in a recent Massachusetts DEP study in Buzzards Bay by the UMD subcontractor (Turner *et al.*, 1989) and are comparable to those used in other oceanographic studies in the region (see references cited in Turner *et al.*, 1989).

Representativeness

Plankton identifications include either splitting or counting subsets of sufficient individuals to characterize the sample with an accuracy in general of $\pm 10\%$ or better. Tows will be taken to ensure a representative sample of the station at the time of collection. At the discretion of the subtask leader and the Chief

Scientist, the tow technique and duration may be modified to provide an adequate sample. For example, net clogging by high concentrations of larger phytoplankton can compromise a zooplankton tow because the net does not "fish" during the entire tow. The flow meters on the net will be watched to see if this situation arises; if they are not turning at the conclusion of a vertical-oblique tow, the depth of tow, ship speed, and/or duration of tow may be modified.

11.4.3 Respiration/Production Data

Accuracy

Changes in dissolved oxygen provide a direct basis for determination of respiration and production. The dissolved oxygen measurements use a highly accurate potentiometric titration endpoint. Rates of metabolism will be determined in BOD bottles that individually have known contained volumes. Light settings will be set and checked after each incubation to ensure accuracy and constancy of light exposure.

Precision

The precision of the dissolved oxygen analysis is expected to be ± 0.1 % or less.

Completeness

Assuming no malfunction of the light box at sea and suitable seas for on-board titration, we expect all bottles incubated will be titrated and concentrations determined.

Comparability

Light-dark bottle measurements can be compared to recent and historical studies in Long Island Sound and Narragansett Bay, in addition to extensive studies of eutrophication in experimental mesocosm tanks at URI. Values can be converted from oxygen to carbon units by using established quotients available from recent comparisons in the literature.

Representativeness

Light and dark incubations will be performed in duplicate or triplicate bottles representative of the original collected sample and at light settings from low levels to bright sun near the water surface. As results from the initial cruise are available, the chosen light settings and experimental design will be evaluated. If necessary, modifications will be made and tested further prior to subsequent cruises.

12.0 SAMPLING AND ANALYTICAL PROCEDURES

12.1 ONBOARD SAMPLING

Specific details on sampling equipment, including *in situ* instrumentation and water sample collection procedures, are given below.

12.1.1 Primary Sampling Procedures for Surveys

The primary water-sampling/hydrographic-measurement system used during all surveys will consist of the following components:

- BOSS winch, 150-m 12-conductor Kevlar cable and sheave
- General Oceanics Model 1015 rosette system
- 5- and 10-L GO-FLO (or Nisken) bottles
- SeaBird SBE-9 CTD system
- SeaBird SBE-13 dissolved oxygen sensor
- SeaTech 25 cm transmissometer
- Chelsea Aquatracka III *in situ* fluorometer
- Biospherical QSP-200AL irradiance sensor
- Datasonics altimeter

Water Samples for Biology and Chemistry

Discrete water samples at all stations will be collected with a General Oceanics Model 1015 rosette system equipped with 5- and 10-L GO-FLO bottles. Samples for phytoplankton, dissolved inorganic nutrients, particulate and dissolved organic nutrients, chlorophyll, TSS, and DO samples also will be taken from these sample bottles. At depths where seventeen 300-mL BOD bottles are to be filled for metabolism measurements, the 10-L GO-FLO bottles will be necessary; otherwise less than 2 L of sample are needed. Bottles will be lowered through the water column in an open position. On the upcast of a vertical profile, a bottle will be electronically closed at specified depths using the rosette deck unit. (Refer to Item 1 in Appendix A for detailed rosette operation.) Bottled-water sampling events will be electronically flagged in the BOSS data file using an "event mark" so that a precise vessel position and the concurrent *in situ* water-column parameters (salinity, temperature, turbidity, dissolved oxygen, chlorophyll *a,* irradiance, and depth) are linked with a particular bottle sample.

Hydrographic Sampling

With the Seabird SBE-9 CTD system, conductivity, temperature, and pressure sensor data are digitized in the underwater unit at 32 scans per second, and data is transmitted to the deck unit via two electrical conductors in the profiling cable. The SBE has data interfaces for additional sensors; the DO sensor, transmissometer, *in situ* fluorometer, irradiance sensor, and altimeter will be interfaced directly to the SeaBird underwater unit.

Dissolved Oxygen

The SBE-13 dissolved oxygen sensor provides *in situ* measurement of oceanic oxygen concentrations. The SBE sensor is the "Beckman" polarographic type which produces an oxygen-dependent electrical current and incorporates a thermistor for determination of membrane temperature. The SBE-5 pump is used to service the conductivity and oxygen sensors and permits active pumping of water past the sensor membrane, thereby minimizing changes in response time between down and upcasts or when profiling is stopped to take a bottle sample. Details of the SBE-13 operating procedures are in Item 2 in Appendix A.

Turbidity

A 25-cm-pathlength SeaTech transmissometer will be interfaced to the CTD and mounted to the rosette system. The SeaTech unit has been designed to provide accurate *in situ* measurements of optical beam transmission, which is directly related to the concentration of suspended matter in the water at the point of measurement. The transmissometer can detect small changes in turbidity and is an effective tool for identifying different water masses. (Refer to Item 3 in Appendix A for detailed transmissometer information.)

Chelsea Aquatracka III Fluorometer

The Chelsea fluorometer will be interfaced directly to the CTD system and also mounted on the rosette. For the MWRA monitoring surveys, the Aquatracka III unit will provide *in situ* measurements of chlorophyll *a* concentrations. For backup chlorophyll *a* measurements, water will be pumped to the surface through a Teflon tube enclosed in the profiling cable to a Turner Model 10 fluorometer, configured with the filters for chlorophyll *a*. Post-survey data comparisons of the Chelsea and Turner fluorometers will be used to check the performance of the *in situ* sensor and to verify the lag time for the water flow through the cable. (Refer to Items 4 and 5 in Appendix A for detailed operation of the Chelsea and Turner fluorometers.)

Biospherical Irradiance Sensor

The Biospherical irradiance sensor will be mounted on a bracket off the rosette (and possibly the BOSS) and will be used to measure photosynthetically active radiation (PAR) underwater from most directions (3pi steradians). A reference irradiance sensor will also be used on deck to monitor changing radiation conditions above the surface of the water (e.g., due to atmospheric conditions). Refer to Item 6 in Appendix A for detailed Biospherical irradiance sensor operation.

Datasonics Altimeter

A Datasonics altimeter will be mounted on the rosette (and BOSS) facing downward to provide an accurate measurement of the system height off the bottom. This will allow vertical profiling to within 1-2 m of bottom and horizontal towing within 5 m of bottom without risk of bottom impact.

***In Situ* Seawater Pump**

A specialized seawater pump, developed at Battelle, has been mounted on the Rosette and BOSS towfish to deliver seawater to the onboard laboratory at the rate of 10 L/min through a Teflon® tube enclosed in the electromechanical profiling cable. The pump will run continuously during vertical profiling and horizontal towing operations, and water will be passed through a Turner Model 10 fluorometer, set up with filters for chlorophyll *a*. The pump system includes an all-Teflon laboratory manifold system for control of water flow and collection of water samples from the underwater unit. Water-sampling procedures using the BOSS seawater pump are provided in Item 9 in Appendix A.

Depth Measurements

For depth measurements during vertical and horizontal profiling operations, the JRC JFF-120 Dual-frequency color video echosounder will be utilized. The transducer for this system will be mounted on a swivelling boom near the stern of the ship. This will permit tracking of the Rosette and Mini-BOSS Systems to the bottom during vertical profiling operations on the farfield surveys. On the nearfield surveys, the echosounder will be used to provide a continuous bathymetric profile during the horizontal transects. For detailed operation of the JRC echosounder refer to Item 10 in Appendix A.

Navigation Equipment

Vessel positioning during the profiling operations will be accomplished using a Northstar model 800 integrated global positioning system (GPS)/Loran. The GPS/Loran system will automatically choose between GPS and Loran, based on best accuracy. Ordinarily, undifferentiated GPS will be used.

The GPS receiver has six dedicated channels and is capable of locking onto six different satellites at one time. This ensures strong signal reception and accurate and reliable positioning with 1-s updates. For operation of the Northstar GPS/Loran refer to Item 11 in Appendix A.

BOSS Navigation and Display Computer

Specialized software routines developed by Battelle will be used to display underwater sensor outputs such as salinity, temperature, dissolved oxygen, turbidity, depth, sensor height, and *in situ* chlorophyll *a,* and irradiance data in real-time on a color CRT monitor. In addition, the ship-mounted Turner fluorometer and video echosounder will also be interfaced to the BOSS computer and the data displayed in real time. Once the data are acquired, they will be automatically written to a data file and logged concurrently with position data from the navigation system. The color monitor will also display the digitized coastlines, navigation aids, sampling stations, and vessel track. A second monitor will be furnished to the vessel captain as a steering display.

Profiling Operations

During the surveys, vertical profiling with the rosette/Seabird CTD system will be performed through the stern hydraulic A-frame of the OSV *Anderson* and the alternative 50-ft research vessel. A continuous hydrographic profile (surface to bottom) will be obtained on the downcast and water samples at five depths obtained on the upcast.

Zooplankton Net Tows

Following water sample collection at the biology/productivity stations, a vertical zooplankton tow will be performed using a flow-metered net with 102-μm mesh. Tows will be over the entire water column in a vertical-oblique fashion, with just enough headway to keep the net stretched out. Nets are equipped with flowmeters and net clogging becomes apparent when a net is retrieved and the flowmeter is no longer turning. In the event of net clogging due to large amounts of chain-forming diatoms, tows may have to be restricted to the surface water or other portion of the water column.

12.1.2 Backup Sampling Procedures for Surveys

On the OSV *Anderson* surveys, the *Anderson*'s rosette will serve as the backup water-sampling system. On the remaining farfield surveys, bottles will be lowered on a hydro wire and triggered with messengers if problems are experienced with the rosette system.

On the February *Anderson* survey (and possibly other surveys), the Biospherical sensor will not be available and a Licor underwater quantum sensor, used regularly by URI in other ongoing studies, will be used for underwater PAR measurements. Underwater and deck reference sensors will be connected to an analog deck unit. The system includes a cable reel with 75 m of cable, which will be marked at 5 m intervals. The sensor will be lowered off the point of the ship facing the sun, with care that the sensor is not shadowed by the ship. Measurements will be recorded manually at regular depth intervals. On subsequent surveys, the Licor system will be used as a backup PAR measurement device. (Refer to

Item 7 in Appendix A for detailed Licor irradiance sensor operation.)

A more portable Battelle Ocean Sampling System (Mini-BOSS) may be used on nearfield surveys conducted on smaller vessels and will also be used as a backup CTD system on all other surveys. The Mini-BOSS system components are described below.

- Mini-BOSS winch and handling system with 60-m cable
- Mini-BOSS towfish
- Ocean Sensors CTD
- Royce dissolved-oxygen sensor
- *In situ* seawater pump

In cases where the Mini-BOSS is used, the towfish and cable will be configured to accept the SeaTech transmissometer, Chelsea Instruments fluorometer, and Datasonics altimeter described above.

The Mini-BOSS winch and articulated boom-handling system will be mounted at port side of the vessel during the surveys. This system will be used as the backup CTD system, but vertical profiles will be limited to 60 m. During vertical profiling operations, the Mini-BOSS system is tethered at the tail to improve sensor flushing. During vertical and horizontal profiling with the Mini-BOSS, water samples can be obtained using the *in situ* pump and Teflon tube for nutrient, chlorophyll *a,* and TSS analyses. All phytoplankton samples will be collected using a bottle or bucket (surface only).

All Mini-BOSS components are housed in a custom-designed towfish that allows high towing speeds, open flow past the sensors and pump inlet, and sensor protection from submerged obstructions or bottom impact. Sensors are mounted in the towfish on a removable tray, permitting easy installation and field servicing.

Ocean Sensors CTD System

An Ocean Sensors OS100 high-resolution conductivity/temperature/depth (CTD) profiling system is the central component of the Mini-BOSS sensor suite. The major parameters measured are seawater electrical conductivity, temperature, and pressure. These parameters are used in the computation of salinity, sensor depth, temperature, and seawater density.

Royce Dissolved Oxygen Sensor

The OS100 CTD is configured with a Royce dissolved-oxygen sensor which is designed with a rugged casing of corrosion-resistant epoxy with stainless steel fittings. The sensor also includes an automatic temperature compensator for accurate measurement of dissolved oxygen regardless of water temperature. Detailed operation of the OS100 and Royce DO sensor is presented in Item 8 in Appendix A.

12.1.3 Onboard Sample Processing

Nutrients, Chlorophyll, and Suspended Solids

Samples for dissolved nutrients, chlorophyll, and total suspended solids will be filtered onboard with a 2syringe-filter system. A sample of about 60 to 75 mL for dissolved inorganic nutrients will be filtered through a 47-mm-dia 0.4-μm Nuclepore membrane filter directly into 125-mL polyethylene bottles and preserved with chloroform. For DOC, about 60-75 mL of similarly filtered sample will be placed directly into precleaned amber-glass bottles, and samples frozen. A single 20 mL of sample for DON and DOP analysis will be filtered through the precombusted glass-fiber filter into a precleaned, capped test tube. These samples will be fixed with buffered potassium persulfate solution and digested at 100°C in the field (Lambert and Oviatt, 1986).

Material retained on a precombusted glass-fiber filter from 10 mL of sample will be analyzed for chlorophyll *a*. Filters will be carefully folded, placed in aluminum foil, and frozen. For combined particulate carbon and nitrogen analysis, about 50 mL of sample will be passed through a precombusted glass-fiber filter; the filter then will be carefully folded and air dried. For TSS, about 1 L of water will be filtered through preweighed 0.4-μm Nuclepore filters. The filter will be placed in labeled petri dishes and air dried. All samples frozen on the ship will remain frozen until analysis. All filtered sample volumes will be recorded in a laboratory notebook.

Respiration/Production

Eighteen 300-mL BOD bottles will be filled from each sampling depth of the biological/productivity stations. Duplicate bottles will be placed in the onboard light box at each of six fixed light levels that approximately cover the irradiance levels to be found in the euphotic zone. For standardization, the light levels will be fixed across cruises. Three additional BOD dark bottles will be placed in the incubation box, which will have flowing water to maintain temperatures near the ambient surface water in the Bay. Three other BOD bottles will be fixed (Lambert and Oviatt, 1986) immediately and represent both *in situ* DO concentrations, as well as initial values for the incubations. After about six hours (actual time will be recorded), the remaining fifteen bottles from a given sampling location will be fixed. It is intended that all titrations will be performed on board as seas permit.

Phytoplankton

Samples of 1 L will be taken directly from the GO-FLO sampling bottles and preserved immediately using Lugol's solution. All phytoplankton samples will be stored at ambient temperature.

Zooplankton

Sample nets will be washed into a jar to obtain all material, which will be preserved immediately with a 5-10% formalin:sea water solution. All zooplankton samples will be stored at ambient temperature.

12.2 SAMPLE PROCESSING AND ANALYSIS

Dissolved Inorganic Nutrients

Methods will follow those described by Lambert and Oviatt (1986). Briefly, dissolved inorganic nutrient concentrations will be determined on samples that have been passed through a 0.4-μm Nuclepore membrane filter. The concentrations of ammonia, nitrate, nitrite, silicate, and phosphate will be measured colorimetrically on a Technicon II Autoanalyzer. This instrument simply automates standard manual techniques for the analysis of nutrients. The analysis of ammonia is based on the technique of Solorzano (1969) in which absorbance of an indophenol blue complex is measured at 630 nm. Nitrite will be measured by the method of Bendschneider and Robinson (1952). Nitrate and nitrite will be measured by reducing all nitrate in the sample to nitrite and analyzing for nitrite as above. The concentration of nitrate will be obtained by difference. The reduction will be accomplished with a cadmium column (Morris and Riley, 1963). The analysis of phosphate will be based on the molybdate blue procedure of Murphy and Riley (1962). The colorimetric analysis of silicate will be based on that of Brewer and Riley (1966).

Chlorophyll *a*

Methods will be as described by Lambert and Oviatt (1986). The concentrations of chlorophyll *a* and phaeophytin will be determined fluorometrically using a Turner fluorometer by the method of Yentsch and Menzel (1963) as modified by Lorenzen (1966).

Particulate Carbon and Nitrogen

Methods will follow those described by Lambert and Oviatt (1986). Particulate matter collected on a glass-fiber filter will be ignited at high temperature (1050°) in a Carlo Erba Model 1106 CHN elemental analyzer. The combustion releases total carbon and nitrogen in the sample in gaseous form. These products will be quantified by the analyzer using a gas chromatography column and a thermal conductivity detector.

Dissolved Organic Nitrogen and Phosphorus

The concentrations of dissolved organic nitrogen or phosphorus will be determined by the difference between total dissolved and total dissolved inorganic. The procedures by which the concentrations of dissolved inorganic nitrogen and phosphorus are obtained have already been described. To determine the concentration of total dissolved nitrogen and phosphorus we use the method of Valderama (1981). This wet-chemistry technique utilizes persulphate to oxidize organic nitrogen and phosphorus to nitrate and phosphate. The concentrations of the latter are then determined colorimetrically on a Technicon Autoanalyzer as for dissolved inorganic nutrients as described above. One advantage of this method over others is that nitrogen and phosphorus concentrations are determined on the same sample. This is useful when concentrations of the two are to be compared.

Dissolved Organic Carbon

Dissolved organic carbon will also be determined by persulphate digestion (Lambert and Oviatt, 1986) using an O.I. Model 700 TOC Analyzer. Some doubt concerning the accuracy of this method exists, and recent work suggests that the higher concentrations obtained by high temperature combustion more nearly reflect true levels of DOC in nature (Sugimura and Suzuki, 1988). We have intercalibrated our analysis with an Ionics high temperature combustion instrument. Results for both fresh and salt water agreed to within 6%. In addition a recent comparison of methods revealed no difference between concentrations obtained by wet oxidation with persulphate and high temperature combustion (J.I. Hedges, pers. comm.).

Total Suspended Solids

Methods will be as described in Lambert and Oviatt (1986). Briefly, the weight of material suspended in sea water is determined by filtering an appropriate volume (up to 1 liter) through a pre-weighed 0.4-μm Nuclepore membrane filter. The filter is rinsed with deionized water to remove salt, dried to constant weight at 60°C and reweighed. All weighings are performed on a Cahn electrobalance with removal of static charges on filters and sample prior to weighing.

Phytoplankton Production and Respiration

Metabolism measures will be as described in Lambert and Oviatt (1986). Phytoplankton production and respiration will be measured by the light-dark bottle oxygen technique (Strickland and Parsons, 1972). Until recently the use of this method in oligotrophic waters was limited by the precision of the Winkler titration for measuring the concentration of dissolved oxygen. Because of its greater sensitivity, the $^{14}CO_2$ method (Steemann Nielsen, 1952) became the method of choice for measuring primary production. Just what sort of production the $^{14}CO_2$ method measures has been a matter of debate and after an extensive comparison of methods, Bender *et al.* (1987) concluded that ^{14}C production estimates ranged from 60 to 100% of gross primary production and were not precisely fixed with respect to other measures of planktonic community metabolism. Recent advances in establishing the endpoint of the Winkler titration for dissolved oxygen have sufficiently increased the sensitivity of the light-dark bottle oxygen technique so that it can be reliably used in oligotrophic waters (Oudot *et al.*, 1988). We will use the potentiometric endpoint determination described by Oudot *et al.* (1988) which yields a precision of 0.1%.

The measurement of planktonic community metabolism by the light-dark bottle oxygen technique is appropriate for several reasons. Owing to the above mentioned advances, accurate measurement of net primary production and dark respiration can be achieved. The concentration of dissolved oxygen in the outfall receiving waters is a matter of concern. Direct measurement of oxygen metabolism in these waters will enhance the project's ability to interpret changes in oxygen concentration. Finally should it be desirable to express metabolism in terms of carbon, oxygen values can be easily converted using established quotients (Bender *et al.*, 1987; Oviatt *et al.*, 1986).

Owing to a restricted time at sea, and the desire for comparability between stations and between cruises, light and dark bottles will be incubated in a photosynthetron using a modification of the methodology of Lewis and Smith (1983). BOD bottles (300 ml) filled with water from a given depth will be incubated in the photosynthetron at 6 light levels ranging from 0 (dark bottles) to about 2000μE/m^2/sec for 6 hours. A photosynthesis vs. irradiance curve can be constructed from these data. Such curves form the basis for many productivity models and allow calculation of parameters indicative of physiological state of the phytoplankton population (Platt *et al.*, 1980; Platt *et al.*, 1988; Keller, 1988).

Phytoplankton

Methods are described by Turner *et al.* (1989). Cells will be concentrated by gravimetric sedimentation in graduated cylinders until aliquots of 10 mL are obtained. These aliquots will be examined in a Sedgwick-Rafter cell at 400x with phase contrast light microscopy. Aliquots of at least 400 cells will be counted. Individuals cells will be identified to lowest possible taxon.

Zooplankton

Methods are described by Turner *et al.* (1989). Field samples will be drained, concentrated, transferred to 70% ethanol, and split with a Folsom plankton splitter to obtain subsamples of 500-1,000 animals. These will be sorted with a Wild M-5 dissecting microscope and animals identified to lowest possible taxon.

13.0 SAMPLE CUSTODY

13.1 FIELD CUSTODY

13.1.1 Electronic Data

Field custody of electronic data will follow the procedures given in Battelle SOP 7-024 and will be the responsibility of Mr. John H. Ryther, Jr.

13.1.2 Water Samples

Subcontractors will assume custody of samples immediately upon sample collection. Field documentation will consist of laboratory notebooks, field-log sheets, and chain-of-custody (COC) forms containing the project name, station code, sample-type designation, alphanumeric sample codes, and other pertinent information on the sample (see Figures 4 and 5). During field collection, COC forms will be completed in duplicate 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 duplicate label that also contains the same alphanumeric code as the corresponding label on the sample container, ensuring the tracking of sample location and status. The original COC form will be kept by the subcontractor along with the samples during transport and storage. The duplicate log form will be retained by the Battelle Chief Scientist and placed in project files at Battelle.

13.2 LABORATORY CUSTODY

13.2.1 Electronic Data

Laboratory custody of electronic data will be the responsibility of Mr. Carl Albro.

13.2.2 Water Samples

Laboratory custody of all samples will be the responsibility of Battelle's subcontractors. Upon receipt of samples at the subcontractor's laboratory, the subcontractor will examine the samples received, verify that the information recorded on the COC forms is accurate, and log the samples into the laboratory by signing the COC form in the Received By area and entering the date and time of receipt. Any inconsistencies between those samples listed as being released and those actually received, or any damage to containers, labels, etc. will be noted in laboratory's sample log book. Unique laboratory sample identification numbers will be used to track the samples through the laboratory. All archived samples will remain in the custody of the subcontracting laboratory for a period of one year after sample collection, at which time the MWRA will be contacted about their disposition.

PROJECT NUMBER

PROJECT NAME MWRA Monitoring Cruise #2

STATION_____ Bottom Depth_____

Time on station_____

Sampling method Rosette/BOSS

Time Rosette/BOSS in water_____

Time Rosette/BOSS out water_____

Hydrographic profile_____

Time	Event	Code	Bottle Depth	Bottle #
				1
				2
				3
				4
				5
				6
				7
				8
				9
				10

No. of water samples collected_____

Irradiance profile_____ time in_____ time out_____

Zooplankton tow_____ time in_____ time out_____

Phytoplankton_____ # Depths sampled_____

Nutrients_____ # Depths sampled_____

Biological/Productivity Parameters_____ # Depths sampled_____

Comments:

_____ _____

Recorded by Date

Figure 4. Example of Typical Field-Log Sheet.

CHAIN OF CUSTODY/ SAMPLE ID FORM

WQC00104

Title: MWRA Water Quality Monitoring Prog.
Matrix Type: Sea Water
Analytical Protocol: Diss. Inorganic Nutrients
Analytical Lab:

Battelle Ocean Sciences
Date: _____
Recorder: _____
Cruise: Net Mesh: _____ um
Preservative: _____

Sample Label	Sample Number Date	Station #	Depth	Time	Comments
	_____ Collected By: _____ / ___ / ___ /92				
	_____ Collected By: _____ / ___ / ___ /92				
	_____ Collected By: _____ / ___ / ___ /92				
	_____ Collected By: _____ / ___ / ___ /92				
	_____ Collected By: _____ / ___ / ___ /92				

Relinquished By/Date/Time/Company	Transporter/Airbill #	Received By/Date/Time/Company

PLEASE RETURN THIS COMPLETED CHAIN OF CUSTODY FORM TO

Figure 5. Example of Typical Chain-of-Custody Form.

14.0 CALIBRATION PROCEDURES AND PREVENTIVE MAINTENANCE

Logs of maintenance performed, calibrations, and any repairs made to instruments will be stored in the instrument files kept by Battelle and their subcontractors.

14.1 WATER QUALITY SENSORS

The SeaBird SBE-9 CTD and Ocean Sensors OS100 systems have been factory-calibrated within the last 6 months for conductivity, temperature, pressure, and dissolved oxygen. A brief comparison check between the SBE-9 and OS 100 CTD system will also be performed at Battelle's electronic shop before survey operations are initiated. Refer to Items 12 and 13 in Appendix A for detailed calibration procedures for the SeaBird and Ocean Sensors CTD and associated water quality equipment.

An electronic calibration check of the SeaTech transmissometer will be performed by recording the output voltages with the transmissometer immersed in filtered distilled water. This check is conducted to verify that the instrument is functioning within the operating range specified by the manufacturer. If a significant instrument problem is discovered, a spare transmissometer will be tested and used on the survey.

A six point chlorophyll *a* calibration will be performed with the Chelsea Instruments Aquatracka III and Turner Model 10 fluorometer using 10^{-6} g/mL chlorophyll *a* solution. Post survey analysis of the chlorophyll *a* data from discrete water samples will also be used to create a calibration curve for the fluorometer.

Upon retrieval of the rosette system and Mini-BOSS towfish, the CTD sensors, and transmissometer will be rinsed with distilled water. In addition, at the end of each survey day a protective cup with distilled water will be secured over the CTD sensors to keep the sensors moist and reduce equilibration time. The chain tension of the pump motor will be examined at regular intervals and the pump shut off prior to retrieving the rosette system and Mini-BOSS towfish.

The Biospherical and Licor irradiance instruments will be factory calibrated annually.

14.2 NAVIGATION EQUIPMENT

The GPS receiver (integrated in the Northstar 800 GPS/Loran system) will provide a corrected latitude/longitude position that will be used to automatically calibrate the Loran latitude/longitude when GPS data are not being received. Positions will also be checked at certain fixed calibration points; the absolute positions of these calibration points will be obtained from published charts and light lists. The time and position of the calibration sites will be entered in the field logbook. Following the survey, all navigation calibration information will be assessed to determine whether it is necessary to apply a calibration adjustment to the Loran positions.

The Northstar 800 GPS/Loran system automatically undergoes a thorough self-test when turned on. Cable connections and antenna mounts and brackets will be inspected and secured at regular intervals. Refer to Item 14 in Appendix A for detailed navigation calibration procedures.

14.3 LABORATORY INSTRUMENTS

Preventive maintenance of all subcontractor laboratory equipment will follow manufacturers recommendations. Calibration procedures for all laboratory analyses performed by URI are given in Lambert and Oviatt (1986).

15.0 DOCUMENTATION, DATA REDUCTION, AND REPORTING

15.1 DOCUMENTATION

All data will be collected on computer diskette, in bound laboratory notebooks, or on established forms. All notes will be written in ink. Corrections to hand-entered data will be initialed, dated, and justified. Completed forms, laboratory notebooks, or other forms of hand-entered data will be signed and dated by the individual entering the data. It will be the responsibility of the laboratory managers to ensure that all data entries and hand calculations are verified. In addition to these documentation procedures, sample logs associated with field and laboratory custody and tracking will be maintained in project files.

The BOSS data-acquisition software assigns a unique data filename to each horizontal transect or vertical profile made during the survey. The time, date, and position of the vessel at the start and end of each data file will be determined and stored on computer hard disk; a summary of the transects and stations made during each survey day will be printed on board the vessel and stored in the survey logbook. These printouts will be initialed and dated.

15.2 DATA REDUCTION AND REPORTING

15.2.1 Hydrographic and Navigation Data

The hydrographic data generated during the survey will consist of rapidly sampled, high-resolution measurements of conductivity, temperature, depth, dissolved oxygen, and turbidity, chlorophyll *a,* and irradiance. All data will be electronically logged with time and concurrent GPS/Loran vessel-position data. The PC-based data-acquisition system stores the data on hard disk to facilitate efficient data archiving and postcruise data processing and editing, as well as to prevent manual transcription errors.

Following the survey, all vertical and horizontal profile data from the BOSS will be processed, edited, and checked for quality. During the procedure, the data will be plotted in high-resolution, graphic form for visual inspection of data quality by an oceanographer.

Similarly, the GPS/Loran navigation data acquired by the CTD systems will be plotted graphically and inspected for data quality. If necessary, temporal averaging will be performed on the raw Loran data to provide smooth, realistic vessel tracks. Position data from the GPS component of the navigation system will also be used to aid in the absolute calibration of the Loran data.

The format for final data submission will be developed as part of Task 6 - Data Management.

15.2.2 Data from Subcontractor Laboratory Analyses

All data generated by Battelle subcontractors will be either electronically transferred from the instrument to a PC-based spreadsheet or manually read from the instrument display (or optical field of a microscope) and entered into laboratory notebooks. Data in laboratory notebooks will be manually entered into a PC-based spreadsheet. All data reduction will be performed electronically either by the instrument software or in a spreadsheet. The format for final data submission will be developed as part of Task 6 - Data Management.

16.0 DATA VALIDATION

All data reported for this project will be subject to check for errors in transcription, calculation, or computer input by the technical staff of the appropriate laboratory. Validation procedures for data generated at Battelle and its subcontractor laboratories will include

- Data hand-entered into a database or spreadsheet will be either verified 100% for accuracy or will be entered in duplicate and compared to highlight differences.
- Calculations performed manually will be checked for accuracy by a second staff member.
- Calculations performed by software will be checked by the technical staff member at a frequency sufficient to ensure the accuracy of the calculations. All data reduction algorithms will be verified by the subcontractor prior to final data submission.
- Electronically generated data will be reviewed in graphical form by the technical supervisor to ensure that the data are complete, accurate, and technically reasonable. The removal of all outliers, either manually or by computer algorithm, will be reviewed in graphical form by the technical supervisor.
- Analytical results and supporting data will be reviewed by the analytical supervisor to ensure that the data are complete, accurate, and technically correct.

Battelle task leaders will be responsible for validation of all data generated by Battelle. Subcontractor subtask leaders will be responsible for performing similar data-validation procedures to ensure that the data provided to Battelle are accurate, complete, and scientifically reasonable. Battelle task leaders will review all subcontractor data for technical reasonableness as an additional data validation procedure.

A primary component of data validation is compliance with the quality control criteria and protocols specified in Section 11.0, Data Quality Requirements and Assessments. Validation of the subcontractor analytical results will include analysis of standards, matrix spikes, and method blanks as well as the application of standard operating procedures (cf. Lambert and Oviatt, 1986) to minimize laboratory systematic or operator error. All analytical data generated at URI will be validated through the analysis of primary standards (accuracy), replicate analysis (precision), and procedural blanks (laboratory contamination or interferences).

17.0 PERFORMANCE AND SYSTEMS AUDITS

This project will be monitored by an independent Quality Assurance Unit (QAU) at Battelle that will oversee the quality of the data generated during the project. All tabular and graphic data reported in deliverables and associated raw data generated by Battelle will be audited by QAU personnel. Raw data will be reviewed for completeness and proper documentation. For laboratory data, statistical random audits will be conducted of reported values to ensure that they are accurate, traceable, and within the quality-control specifications of this QAPjP. For electronically acquired data (e.g., BOSS data files), the QAU will verify that computer software used to process the data have been validated.

All deliverables generated during the course of this project will be submitted to an internal review prior to delivery to MWRA. This three-part process consists of technical, editorial, and QA reviews.

Audits of the subcontractor laboratory data-collection programs will be the responsibility of the subcontractor subtask leader. During the time work is in progress, an audit will be conducted to evaluate the entire laboratory data-production process.

Performance reviews, procedures used to quantitatively determine the accuracy of the total measurement system or its components, will be the responsibility of technical personnel. Performance reviews will include assessment of quality control samples, such as blanks, spikes, SRMs, and replicates, which are discussed in detail in Section 11.0.

18.0 CORRECTIVE ACTION

Identification of problems regarding technical performance are the responsibility of all staff members working on this project. Responsibility for identifying deviations from schedule lies with the Battelle Program Manager. Technical problems relating to sample collection in the field (schedule, modifications to the sampling plan, and so on) will be resolved through discussion with the Battelle survey chief, Mr. John Ryther, the Program Manager, Dr. Damian Shea, and the MWRA Task Manager, Dr. Michael Mickelson. Problems relating to the overall successful completion of the program will be reported to the MWRA Task Manager in a timely manner for discussion and resolution between the Battelle and MWRA Managers.

Corrective action at the laboratory level will be resolved by the laboratory staff and the subcontractor subtask leaders. Responsibility for identification of deviation in cost and schedule lie with the respective subtask leaders. Any issues that affect the cost, schedule, or performance of the task will be reported to the Battelle Task Leader or Program Manager. They will be responsible for evaluating the overall impact to the project and discussing corrective actions with the MWRA Task Manager.

19.0 REPORTS

The deliverables under this project will include both a survey plan for each of the sixteen nearfield surveys and each of the six farfield surveys. Each survey plan will follow the new guidelines established by EPA for use of the OSV *Anderson*. Three copies of the final survey plan will be submitted to the MWRA at least 7 days prior to the survey. There will be no draft survey plan.

Survey reports will be submitted to MWRA within 2 weeks after each survey demobilization. A single survey report will be submitted for each of the combined nearfield-farfield surveys.

A monthly progress report will be submitted to MWRA by the fifteenth of each month that summarizes all technical activities and financial information from the previous month.

Three separate quarterly reports will be prepared that summarize the water-property, chemical, and biological data available for the preceding quarter. The format, content, and scheduling of these quarterly reports will be developed as part of Task 7. Three copies of the draft quarterly report will be submitted to MWRA for review. All requested edits and revisions will be discussed with MWRA, and revisions will be made insofar as they are within the scope of the project. Five copies of the edited final quarterly report will be submitted to MWRA within 30 days of receiving comments on the draft report.

A mid-year and end-of-year formal presentation of the monitoring results will be prepared and presented to the MWRA Outfall Monitoring Task Force. The format and content of this presentation will be developed as part of Task 7.

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Appendix A. Additional Operational Information

Item 1. Rosette Operation

Before the vertical profile is taken and before cocking the bottles on the deck, be sure that the bevel of the ramp/shaft in the center/top of the rosette is facing position number twelve. If necessary, use a small screwdriver to turn the ramp/shaft counter-clockwise until it is in the correct position. The "SAMPLES TAKEN" knob on the deck unit should also be rotated to the twelve position. Once a sample depth has been reached on the upcast, a bottle is tripped by pressing the red "TRIGGER" button on the deck unit. The green "READY" light will go out and the amber "SAMPLE" light on. Once the water sample has been taken, the "SAMPLES TAKEN" indicator knob on the deck unit will move in the counter-clockwise direction to the next numbered position. The "SAMPLE" light will go out and the "READY" light on. Always wait for the "READY" light to come on before taking the next sample. The rosette will not be completely loaded with bottles. The survey field log will indicate which positions are used and which are empty. Any empty positions between bottles must be tripped before sampling the next used bottle position. The following water sampling/hydrographic profiling procedures will be used:

1. Before the start of each cast, each of the bottles will be opened and attached to the rosette system.

2. With the vessel on station and the stern of the boat toward the sun during the downcast, the CTD/rosette system will be lowered into the water until completely submerged.

3. The BOSS program will be set to the hydrographic profiling mode and a file will be opened for each cast.

4. After the CTD/rosette has been submerged for approximately 2 minutes to allow all of the sensors to equilibrate, the system will be lowered at a descent rate of about 0.5m/s to within 5 meters of the bottom.

6. During the downcast the BOSS program will record the hydrographic data and display these data on a computer screen. The Chief Scientist will then use the real-time display of *in situ* fluorometry data to determine the five water-collection depths based on positions relative to a subsurface chlorophyll maximum.

7. During the upcast, the CTD/rosette will be maintained at each of the five selected depths for approximately 1 minute. Water will be collected by closing one or more of the bottles, depending on the amount of water needed. When the rosette deck unit indicates that the bottle has closed, an event will be electronically flagged in the BOSS data file using a unique "event mark" so that a precise vessel position and concurrent in-situ water column parameters will be linked to a particular water sample.

8. After collecting the surface water sample, the operator will close the cast file, and the CTD/rosette will be recovered.

Item 2. Seabird DO Operation

Before each cast remove the temporary Tygon™ tube connecting the intake of the conductivity sensor and the discharge of the SBE-5 pump. This tube will be replaced at the end of the cast once the instrument package is secured on deck. The tube is used to flush out the conductivity cell and the dissolved oxygen manifold with de-ionized water after each use. When re-attached between the SBE-5 pump discharge and the conductivity sensor intake a small amount of de-ionized water is left in the loop to insure that the dissolved oxygen membrane remains moist. At the start of each cast, allow the instrument package to equilibrate at the surface for at least two minutes. This allows the DO sensor to polarize and come to a stable reading.

Item 3. SeaTech Transmissometer Operation

Once per survey determine that the transmissometer is operational with the instrument package secured on deck, a reading of less than .5/m beam attenuation should be observed using the BOSS program display assuming the light path is unobstructed. Obstructing the light path should increase beam attenuation to a value greater than 25/m. After each cast, the optics of the transmissometer should be rinsed with de-ionized water.

Item 4. Chelsea Fluorometer Operation

The Chelsea fluorometer output, displayed with the BOSS program, will approach 0.0 ug/l when the instrument is on deck. Placing your hand at a 45 degree angle to both the light source and the detector should increase the data displayed to greater than 50 ug/l. After each cast, the optics of the Chelsea fluorometer should be rinsed with de-ionized water.

Item 5. Turner Fluorometer Operation

Unlike the Chelsea fluorometer, data from the Turner fluorometer are not combined with the data stream from the CTD system. The Turner fluorometer is directly interfaced to the analog to digital converter of the BOSS system. One channel of the A to D is used to log the fluorescence signal. A second channel is used to log the

range setting of the Turner. The range selection switch on the front panel of the Turner should always be set at "auto" when acquiring data with the BOSS system. The flow cell of the Turner should be flushed with de-ionized water at the end of each day, and blank suppression should be checked at this time as described in the Turner manual. Be sure that fresh desiccant packs have been placed in the sample compartment before each survey. Be sure that the hose connected to the intake and to the exhaust of the flow cell is completely opaque for at least four feet. Black tape can be wrapped around the hose to accomplish this.

Item 6. Biospherical Irradiance Operation

Data from two sensors are required for this operation; one deck mounted sensor, and one *in situ* sensor. The QSP200L Biospherical irradiance sensor is interfaced to the BOSS system via the CTD and is used to measure PAR underwater. The QSR240 is used to measure surface solar irradiance and is interfaced to the BOSS system via the systems analog to digital converter. On a clear day at local noon the surface solar irradiance as measured by the QSR240 should be 2000-3000 microeinsteins/(sec*m^2). The same measurement, on deck, using the underwater sensor, QSP200L, should be 3500-4000 microeinsteins/(sec*m^2). The difference in the readings is caused by the "immersion effect" calibration factor used for the wet sensor and by the different geometry of the two sensor housings. Both instruments should read zero when their protective caps are installed.

Item 7. Licor Irradiance Operation

The Licor Spherical Quantum underwater irradiance sensor is interfaced to a meter. The deck reference irradiance sensor is interfaced to a second meter. With both sensors in air, the readings from each meter are recorded manually. The underwater unit is lowered by hand and values are recorded from each meter at 1-m intervals for the first 10 m and thereafter at 5-m intervals until the 1% light level is achieved. During the lowering, the wire angle is estimated, recorded, and used for correcting depth.

Item 8. OS100/Royce DO Operation

No on-deck calibration is required for the Royce DO sensor. The membrane for the Royce dissolved oxygen sensor is kept moist between casts by securing a plastic bag containing a water- saturated sponge around the sensor head. The instrument package should be allowed to equilibrate at the surface for at least two minutes. This allows the dissolved oxygen sensor to polarize before starting the profile. Upon retrieval, the sensor head should be rinsed with de-ionized water and the plastic bag with sponge replaced.

Item 9. BOSS Seawater Pump Operation

Lag time, the time required for a slug of water to travel from the *in situ* pump to the collection point, will be determined each day before the first cast. The flow rate will be continuously monitored and displayed using the BOSS program. A "Countdown" value equal to the lag time will be entered into the BOSS program setup.

The following procedure will be used for sampling with seawater pump:

1. The Chief Scientist will determine the five water collection depths from the hydrographic data displayed during the downcast.

2. After reaching each depth, hit the F4 key to start the first countdown on the BOSS program. Once the countdown reaches zero, the tube should be completely flushed with water from the sampling depth.

3. Hit F9 at the end of the first countdown to start the actual water sample countdown. A unique "event mark" will be flagged in the BOSS data file for this sample.

4. Before the end of the second countdown, about 20 seconds, start rinsing Bottle(s).

5. At the end of the second countdown, take water sample.

6. Hit the F10 key as the sample is taken. A second unique "event mark" will be flagged in the BOSS data file indicating when the sample was taken.

7. Move on to the next sample depth.

Item 10. JRC Echosounder Operation

Depth is digitized and continuously logged by the BOSS program. Other than observing the bottom depth to determine how deep to send the instrument package, there is no interaction between the BOSS operator and the echosounder once the instrument is initially setup. Press the Power/Dim key to turn the unit on. Press the MODE key to insure that the unit is in the STD mode. Pressing the MODE key again will return the unit to the initial operations display. Press the SF (special function) key to check the transducer frequency. It should be 200 Khz. While in the SF display, ensure that the scan rate is 1/1 for a fast update rate and the highest resolution image. Press the key next to the Initial Settings selection and check that the draft, the distance from the face of the transducer to the water surface, is correct. Press SF key to return to the initial operations display. The top three control knobs behind the panel to the right of the display can be adjusted, if necessary. The gain control can be used to increase or decrease sensitivity. The normal setting is 3-5. The STC control can be adjusted to improve clarity by suppressing interference noise near

the surface. The normal STC setting is 3-6. If noise interference still appears on the screen, the noise suppression volume control can be used (N.SUPP.). This control is normally set at 0.

Item 11. Northstar 800 Loran/GPS Operation

Once the 12Vdc power supply for the GPS/Loran has been switched on there is typically no other setup interaction necessary between BOSS operator and the navigation system. The Loran C will go through its automatic hardware test routine, which can be observed on the front panel display. The GPS will also do an automatic self-test. Once the GPS has acquired at least one satellite, the green LED on the front panel will start flashing. When the GPS has acquired enough satellites to give a correct position, the green LED will remain lighted constantly. The Loran-C will display a latitude-longitude (Lat-Long) position once either of the two systems has acquired. If the position displayed is from the GPS, there will be a "G" displayed before the Latitude. GPS selection can be toggled between "only", "never", and "auto" by using the command 61 entry. Typical operation is in "auto". Loran C time delays can be displayed by pushing the "position" key on the display panel. Signal-to-noise ratios can be checked by using the command 99 entry. Lat-Long position, TD's, SNR's, and jitter are all automatically recorded with the BOSS program. Position calibration will be performed twice per day as outlined in Item 14.

Item 12. Seabird CTD Calibration

The Seabird SBE-3 temperature sensor is calibrated from -1 degree C to +31 degrees C at 6 or more data points. The SBE-4 Conductivity sensor is calibrated from approximately 2 to 6 S/m, and the SBE-13 Dissolved Oxygen sensor is calibrated from 0 ml/l to air saturation. All instruments are calibrated annually by the Northwest Regional Calibration Center (operating under contract to NOAA). The gain of the pressure sensor is very stable and doesn't need annual calibration. The offset of the pressure sensor is adjusted at the start of each survey to give a reading of zero on-deck. This offset is entered into the equipment setup file. Calibration and drift history records are maintained by both Seabird Electronics and Battelle Ocean Sciences. In addition, Battelle makes annual checks of the following:

1. SBE-9 Underwater unit Crystal Osc. Frequency

2. SBE-9 Underwater unit A/D channel accuracy

3. SBE-9 Underwater unit CTD freq. channel accuracy

Item 13. OS-100 CTD Calibration

The Ocean Sensors OS-100 CTD is factory calibrated annually. Temperature is calibrated from -2 to 35 degrees C at 8 data points. Conductivity is calibrated from .5 to 65 mS/cm at 8 data points. The gain of the pressure sensor is very stable and doesn't need annual calibration. The offset of the pressure sensor is adjusted at the start of each survey to give a reading of zero on-deck. This offset is entered into the equipment setup file. Calibration records are maintained at both Ocean Sensors and Battelle Ocean Sciences. Battelle also does an annual OS-100 A/D channel accuracy check.

Item 14. Loran/GPS Calibration

Navigation Calibration procedures are as follows:

1. An absolute position is obtained from published charts with a position accuracy approaching 2 seconds (approx. 40m).

2. The BOSS program is set to Calibration-Navigation mode.

3. Position data is observed by the BOSS program for a period of time, averaged, and then compared to the absolute position entered by the BOSS operator.

4. If the position offset is determined to be greater than the "jitter" error as seen by the system, a correction offset can be entered by the BOSS operator.

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