QUALITY ASSURANCE PROJECT PLAN

for

FRIENDS OF CASCO BAY

ENVIRONMENTAL MONITORING PROGRAM

Revision 5
RFA No. 17014

July 10, 2017

QUALITY ASSURANCE PROJECT PLAN

for

THE FRIENDS OF CASCO BAY
ENVIRONMENTAL MONITORING PROGRAM

prepared by
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prepared for

CASCO BAY ESTUARY PARTNERSHIP

and

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION 1

REVISION 5
July 10, 2017

APPROVALS:

Mike Doan, FOCB Research Associate & Citizen Stewards Coordinator	7/14/2017 Date
Curtis C Bohlen, Casco Bay Estuary Partnership Executive Director	7/25/17 Date
Angela D. Brewer, Department of Environmental Protection Section Leader	7/17/17 Date
Dr. Nora Conlon Ph.D, USEPA Quality Assurance Team Leader	7/27/2017 Date
Matthew Liebman, USEPA Region 1 Project Officer	7/27/2017 Date

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We would also like to acknowledge Art Clark and Steve Dimattei from USEPA Region 1 for their technical advice and guidance in the development of our original QAPP and subsequent revisions.

A.2. Table of Contents

A.3. Distribution List

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Official copies of the plan and any subsequent revisions will be sent to Curtis C. Bohlen, Angela D. Brewer, Diane Switzer, Dr. Nora Conlon, and Matthew Liebman. Notification of any revisions will be sent to all members of the Water Quality Advisory Committee as listed in Appendix I. Copies of the revised plan will be available to Committee members and other interested parties upon request.

A.4. Project / Task Organization

The Friends of Casco Bay Environmental Monitoring Program is coordinated by the staff of Friends of Casco Bay located in South Portland, Maine. The organizational structure of the program is shown in Figure 1.

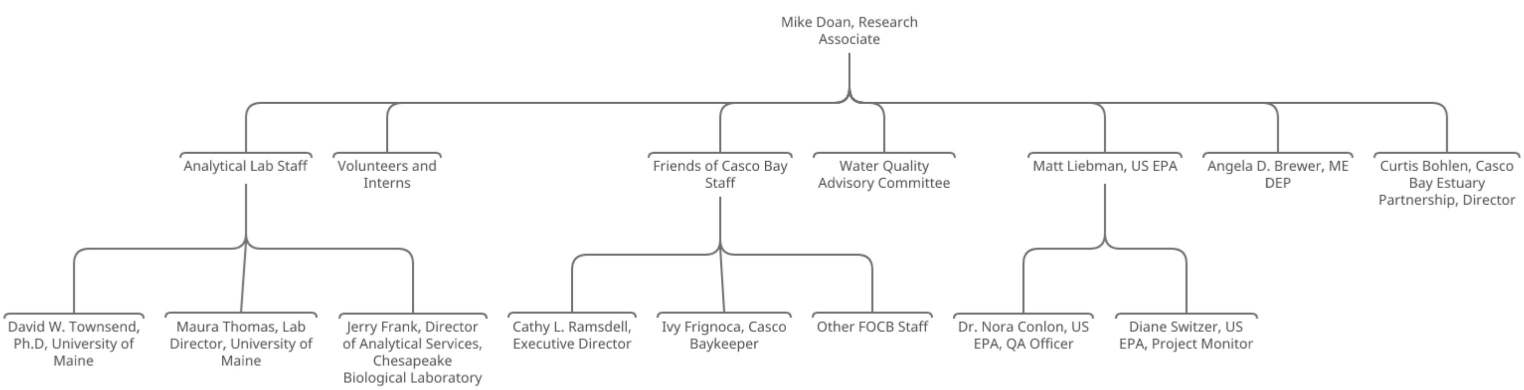
Mike Doan, FOCB's Research Associate, is the Program Coordinator for all monitoring efforts covered under this QAPP. These monitoring efforts include both volunteer (Citizen Stewards) and staff monitoring programs. Responsibilities of the Program Coordinator will include working with the committees, conducting volunteer training and QA sessions, conducting sampling from the BayKeeper boat, reviewing collected data, and overseeing the selection and maintenance of equipment for the monitoring program. The Program Coordinator will also network with other water quality monitoring programs and work to raise awareness of water quality issues within the community.

Other FOCB staff and Interns will participate in the program as necessary.

The Water Quality Advisory Committee is composed of representatives of academic institutions, state and federal agencies, independent scientists and water quality experts. This committee will provide technical advice on volunteer training, QA/QC, data analysis, and additional testing protocols on an on-call basis.

All status reports and final reports will be submitted to the Director of the Casco Bay Estuary Partnership as noted in contracts and work plans.

Figure 1: Environmental Monitoring Program Organization



A.5. Project Identification / Background

A. Objective and Scope Statement

Casco Bay became part of the U. S. Environmental Protection Agency's National Estuary Program in April, 1990. Casco Bay was nominated because of public concern about environmental degradation in the Bay. Casco Bay provides a major link between open ocean, fresh water, and the land. It has over 700 islands and exposed ledges and over 500 miles of coast. The Bay is extremely productive and provides essential food, cover, migratory corridors, and breeding and nursery areas for a wide variety of animals. Its rocky ledges, deep waters, mudflats, and wetlands provide habitats for birds, seals, whales, harbor porpoises, and many other species which contribute to a rich fishery. Portland is the second largest fishing port in New England. Casco Bay is an excellent area for both sail and power boating, for sea kayaking and wind surfing, and for bird watching, recreational fishing, and hunting.

Over the years, Casco Bay has been adversely impacted by human activities. Although many sources of pollution are now treated, questions remain about the ecological integrity of the Bay and about whether enough effort is being undertaken to protect that integrity. With the help of local governments and the public, the Casco Bay Estuary Partnership (CBEP) has developed the **"Casco Bay Plan 2016-2021"** a comprehensive strategy to address key issues impacting the environmental health of Casco Bay. Friends of Casco Bay (FOCB) intend to work closely with CBEP in the implementation of the plan and to ultimately assist in the protection of the Bay.

As a part of this effort, the Casco Bay Estuary Partnership has assisted in funding the Friends of Casco Bay Environmental Monitoring Program. This program has been organized and implemented by Friends of Casco Bay (FOCB) with technical and facilities support from Southern Maine Community College (SMCC). The planning and design of the program is done in conjunction with a Water Quality Advisory Committee (WQAC) made up of representatives of academic institutions, state and federal agencies, and independent scientists and water quality experts (Appendix 1). Volunteers form a large network of "bay watchers" who, by taking samples and making observations, can provide an ongoing assessment of water quality.

Friends of Casco Bay has organized a program that involves sampling around the Bay, in coastal waters. The parameters measured are five standard field data items: dissolved oxygen, pH, temperature, specific gravity (to determine salinity), and water clarity (limit of visibility). Nitrogen, both as Total and Dissolved Inorganic, is also regularly assessed. Sampling of river mouth stations has been coordinated with existing river and stream groups. The Maine Department of Environmental Protection (DEP) continues to work with the existing river, lake, and tidal water groups, and is the repository of data from all groups. The ultimate goal of the Casco Bay Estuary Partnership, the DEP, and Friends of Casco Bay is to have a coordinated and comprehensive citizen monitoring program for the Bay and watershed. Through this program, accurate data of known quality can be collected at a scope and frequency attainable only with volunteers.

During the first four years of the project, from 1993 to 1996, a dense network of sampling stations was established across Casco Bay. Samples were taken at Citizens Monitoring stations biweekly April through October. Stations monitored from the BayKeeper boat were sampled biweekly March through November (as allowed by weather conditions) and monthly December through February. The four years' worth of data demonstrated that conditions across the Bay were generally healthy, were relatively homogenous geographically, and changed fairly smoothly throughout the monitoring season.

On the basis of the previous data and after consultation with the Water Quality Advisory Committee, in February, 1997 the sampling frequency was changed to monthly for all stations. Monthly sampling allowed us to keep a close watch on what's going on in the Bay while making efficient use of our resources, especially staff and volunteer time.

In the spring of 2001 through 2005, FOCB staff began a series of internal program meetings to discuss data results and the future of the Citizen Stewards Monitoring Program. These meetings also coincided with two peer reviewed analytical reports *Friends of Casco Bay and Casco Bay Estuary Project ~ Six – Year Water Quality Data Analysis; 1993 – 1998 and Friends of Casco Bay ~ Twelve – Year Water Quality Data Analysis: 1993 – 2004,* both authored by P. Scott Libby from Battelle - Applied Coastal and Environmental Services. Based on recommendations from these peer reviewed reports, FOCB implemented the following recommendations:

- Collect samples early in the morning to document worst case water quality
- Increase sampling during months of concern – July – September
- Add nutrients and biomass measurements to quantify loading and ambient conditions – suite of nitrogen parameters and chlorophyll concentration

Beginning April 2005 FOCB staff and volunteers implemented the above recommendations with the addition of all volunteer sites to be monitored synoptically at 07:00 hrs and again at 15:00 hrs (± 30 min). In addition volunteers collected Dissolved Inorganic Nutrients from 2005 – 2010 during all sampling events. This effort was discontinued in 2010 due to funding but continues on the staff level during all profile trips. Total Nitrogen was added to staff monitoring efforts in 2008.

Friends of Casco Bay Staff have been monitoring the water column by profile sampling from surface to the bottom at ten stations around the Bay since 1991. In 2016, the program shifted to sampling at only three of the historical ten sites. These three sites are considered "sentinel sites," a subset of the original ten sites that have been sampled consistently whenever weather or boat issues have been an impediment to sampling at all ten sites.

In 2016, Unattended Sonde Data Collection will progress from being a pilot project to a full monitoring program. We will begin with one station, at the Chebeague Island Ferry pier on Cousins Island in Cumberland, Maine. Our plan is to use existing infrastructure for sonde deployment rather than maintain a buoy system. Two additional sites are planned for future years, one in Portland Harbor and one in eastern Casco Bay in order to represent the various regions of Casco Bay. Deployment will be identical to our 2015 pilot project with the exception of the addition of a pCO_2 sensor. This sensor will take hourly measurements and will be deployed next to the data sonde. Collecting pCO2 data replaces the total alkalinity sampling done in 2015. With measurements of pH collected by the sonde, coupled with the pCO2 measurements, dissolved inorganic carbon, total alkalinity, and calcium carbonate saturation state can be calculated. This information will provide a solid basis for understanding the carbonate chemistry conditions in the Bay, and will provide insight into coastal ocean acidification.

B. Data Usage

The data collected in the Environmental Monitoring Program can aid environmental managers in:

- Establishing baseline water quality conditions.
- Determining long-term water quality trends.
- Documenting some effects of water quality improvement programs, e.g. CSO abatement, overboard discharge elimination, implementation of storm water and Boatyards & Marinas Best Management Practices.
- Screening for sources of pollution by identifying current problems.
- Making decisions on shoreland planning and zoning.

The data gathered by the program is supplied to the Department of Environmental Protection and the Casco Bay Estuary Partnership annually. Data are given in digital form to help with assessment and management of water quality on a regulatory level, through the Department of Environmental Protection and included in the Casco Bay Estuary Partnership State of the Bay reporting.

A.6. PROJECT/TASK DESCRIPTION

A. TASKS

Since its inception, the Friends of Casco Bays Environmental Monitoring Program has been collecting data under the guidance of its first QAPP approved March 3, 1993 and subsequent revisions (Revision 1, approved May 1, 1997; Revision 2, approved July 12, 2001; Revision 3, approved September 15, 2006; Revision 4, approved March 28, 2011). Tasks outlined in this revision generally correlate with previously approved QAPP’s and are designed to maintain the program. A schedule of tasks and products (Table 1) will be revised as necessary and submitted for approval as outlined in annual Scope of Work contracts between Friends of Casco Bay and the Casco Bay Estuary Partnership. This document is valid for five years from the date of approval.

B. DESCRIPTION

The Friends of Casco Bay Environmental Monitoring Program consists of three distinct programs; the Citizen Stewards Water Quality Monitoring Program, Sentinel Site Profile Monitoring Program and a Continuous Monitoring Station. Appendix 2 has a map of these stations, and a complete list with coordinates can be found in Table 3.

Our **Citizen Stewards Water Quality Monitoring Program** maintains approximately 80-100 citizen volunteers to monitor water quality at (40) select shore based surface sites. Volunteers monitor water quality for basic oceanographic parameters: dissolved oxygen, temperature, salinity, pH, and water clarity by means of a specially modified field kit known as the *"Casco Bay Tidal Water Monitoring Kit"* from LaMotte Company and approved by EPA Quality Assurance officer, Art Clark in 1993. Samples are collected once a month, April, May, June, and October, as well as twice a month in July, August, and September. Samples are collected at 07:00 AM (± ½ hour) & 15:00 PM (± ½ hour). This program provides an understanding of the differences in water quality around the Bay. By monitoring all 40 sites at the same date and time, we get a synoptic look at the conditions across the Bay. Comparisons can then be made between sites and regions. This data is used for spatial trend analysis, for management and regulatory purposes (state water classification/303d listing/treatment plant permitting, etc.), and for the production of our annual Casco Bay Health Index.

Friends of Casco Bay Staff have been monitoring the water column by profile sampling from surface to the bottom at ten stations around the Bay since 1991. In 2016, the program shifted to sampling at only three of the historical ten sites. These three sites are considered "sentinel sites," a subset of the original ten sites that have been sampled consistently whenever weather or boat issues have been an impediment to sampling at all ten sites. Our **Sentinel Site Profile Monitoring Program** consists of sampling (every 2 meters to bottom) at 3 deep water sentinel sites, monthly. This 25-year dataset includes data via YSI sonde [temperature, dissolved oxygen, chlorophyll, salinity, pH, water depth] as well as water clarity (via Secci disk), and Total Nitrogen (TN) and Dissolved Inorganic Nutrients (DIN) collected at the surface and the bottom at each site (sent to laboratories for analysis). The water column profiles provide a snapshot of conditions at sites that are representative of different regions of the Bay: offshore, suburban, and urban. Monitoring involves measurements made from surface to bottom. These "profile trips" provide thermocline seasonality information. They can show differences in temperature or salinity at various depths, that are contributing to changes in water quality. Bottom water measurements can be illustrative of sediment quality. TN and DIN data are used for regulatory and management purposes.

Starting in June 2016, we established a permanent **Continuous Monitoring** station at Chebeague Island Ferry Dock on Cousins Island in Yarmouth (Class SB waters) using YSI data sondes and a pCO_2 sensor. Hourly data via sonde: temperature, dissolved oxygen, chlorophyll, salinity, pH; and via an additional sensor deployed adjacent to the sonde: hourly measurements of the partial pressure of carbon dioxide (pCO_2). The pH and pCO2 measurements are used to calculate dissolved inorganic carbon, total alkalinity, and the saturation state of aragonite. The Continuous Monitoring Station provides the frequency of data collection necessary to identify temporal trends in the Bay. Daily, seasonal and annual trends are analyzed, and correlations between water quality parameters and weather events are determined. This station also provides us with an understanding of carbonate chemistry dynamics in the Bay, as we work toward acquiring a more robust ocean acidification database. The water depth data can be used to help assess sea level rise.

TABLE 1. SCHEDULE OF TASKS AND PRODUCTS

	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Program Planning	<-----	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	----->
Conduct Annual QA Checks on Veteran Monitors			group *---	--------	---*---	indivi -------	dual ----------	---*					
Train New Monitors				*---	-------	--------	-----*						
Conduct Year-Round Boat Sampling by FOCB Staff	<-----	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	----->
Conduct Unattended Sonde & PCO2 Monitoring	<-----	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	----->
Conduct Sampling by Volunteer Monitors					*---	-------	-------	-------	-------	-------	---*		
Conduct Site Visits with Volunteers					*---	-------	-------	-------	-------	-------	---*		
Maintain Database	<-----	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	----->
Submit Data on Disk to CBEP & MEDEP				*									
Submit Reports to CBEP as Outlined in Work Scope for unattended monitoring											*		

A.7. DATA QUALITY OBJECTIVES FOR MEASUREMENT DATA

Table 2 summarizes the data quality objectives (DQO) defined by FOCB for data collected in the Environmental Monitoring Program. These data quality objectives are subject to change if deemed necessary by the Water Quality Advisory Committee and upon approval by the EPA.

Guidelines for monitoring precision, accuracy, representativeness, comparability, and completeness will be as follows:

A. Precision

Monitors in the CSWQM program will be asked to collect and titrate duplicate dissolved oxygen samples at QA sessions and during each sampling event. On the basis of statistical analyses and a control sheet, monitors will be instructed to do a third titration if the difference between the first two is greater than 0.6 mg/l (upper warning limit). The average of the two closer values is recorded. If the difference between the two titrations is greater than 0.9 mg/l (upper control limit) and no third titration is done, the results will be entered into the "comments" section only of the CSWQM program data file. If a volunteer reports values differing by greater than 0.6 mg/l two weeks in a row, the volunteer will be called to determine the cause of the problem. A site visit may be deemed necessary.

Duplicate samples during water column profile measurements for DO, water temperature, salinity, pH and Chlorophyll by YSI probes have been part of FOCB's SOP for winter profile procedures, usually conducted when the water temp, salinity and DO are homogenous throughout the profile. Samples are collected at the surface, one meter, two meters and then at the bottom. If temperature is within one degree C, the salinity within one part per thousand or DO within one milligram per liter then the sample is considered homogenous. As the meter is pulled up to the surface a second sample will be collected at a randomly selected depth for comparison to the first one sampled.

A duplicate sample from the same grab for DIN & TN will be conducted once per "profile trip" by FOCB staff at a randomly selected station and depth. The duplicate sample will be identified to only FOCB staff and not the analytical lab performing the analysis. The duplicate will be performed to provide a measure of precision between field collection and lab analysis.

TABLE 2. DATA QUALITY OBJECTIVES

Parameter	Method/Range	Program	Units	Sensitivity (a)	Precision	Accuracy	Calibration Method
Temperature	LaMotte Thermometer -5.0 to +45.0°C	Citizen Steward	degrees Celsius (°C)	0.5°C	±1.0°C (b)	±0.5°C (b)	NIST Certified Thermometer
	YSI 556 Multiparameter System -5.0 to +45.0°C	Citizen Steward (c)	degrees Celsius (°C)	0.01°C	±0.25°C (m)	±0.5°C (d)	NIST Certified Thermometer
	YSI 6600 Sonde -5.0 to +45.0°C	Profile & Continuous Monitoring	degrees Celsius (°C)	0.01°C	±0.25 (f)	±0.5°C (f)	NIST Certified Thermometer
	Hanna Waterproof pH meter Mod # HI 98128	Citizen Steward	degrees Celsius (°C)	0.1°C	±0.2°C (n)	±0.5°C (f)	NIST Certified Thermometer
	Turner Designs C-sense pCO_2 Sensor	Continuous Monitoring	degrees Celsius (°C)	0.1°C	±0.2°C	±0.5°C	NIST Certified Thermometer
pH	Hanna Waterproof pH meter Mod # HI 98128	Citizen Steward	standard pH units	0.01 units	±0.03 units (l)	±0.05 units	pH Buffer Reference Standards
	YSI 556 Multiparameter System 0.0 to 14.0 units	Citizen Steward (c)	standard pH units	0.01 units	±0.13 units (m)	±0.2 units	pH Buffer Reference Standards
	YSI 6600 Sonde 0.0 to 14.0 units	Profile & Continuous Monitoring	standard pH units	0.01 units	±0.1 units (f)	±0.2 units (f)	pH Buffer Reference Standards
Dissolved Oxygen	Micro Winkler Titration 0 to 20 mg/l	Citizen Steward	milligrams per liter (mg/l)	0.1 mg/l	±0.9 mg/l (b)	±0.3 mg/l (b)	Standard Winkler
	YSI 556 Meter 0 to 50 mg/l	Citizen Steward (c)	milligrams per liter (mg/l)	0.01 mg/l	±0.2 mg/l (m)	±0.2mg/l of reading up to 20mg/l (f)	Standard Winkler
	YSI 6150 ROX Optical DO Sensor	Profile & Continuous Monitoring	milligrams per liter (mg/l)	0.01 mg/l	±0.04 mg/l (k)	±0.1mg/l of reading up to 20mg/l (f)	Standard Winkler
Dissolved Oxygen (pre- & post-checks)	YSI 556 Meter 0% to 500% Saturation	Citizen Steward (c)	percent air saturation (% sat)	0.1% sat	±0.2 mg/l (m)	±5% sat (m)	Barometric Pressure
	YSI 6150 ROX Optical DO Sensor	Profile & Continuous Monitoring	percent air saturation (% sat)	0.1% sat	10% RPD {±3% sat} (m)	0 to 200%: ±1% of reading or 1% air saturation, whichever is greater; 200 to 500%: ±15% of reading	Barometric Pressure

Salinity	Hydrometer 0 to 42 ppt (1.0000 to 1.0700 specific gravity)	Citizen Steward	parts per thousand (ppt)	0.1 ppt (0.0005 specific gravity)	±1.0 ppt (b)	±0.82 ppt (b)	Orion 140 S-C-T Meter (ck=d vs. NIST Certified Conductivity Standards)
	YSI 556 Multiparameter System 0.0 to 70.0 ppt	Citizen Steward (c)	parts per thousand (ppt)	0.01 ppt	±0.5 ppt (f)	±1.6 ppt at 33 ppt; ±0.7 ppt at 10 ppt (f)	NIST Certified Conductivity Standards
	YSI 6600 Sonde 0 to 70 ppt	Profile & Continuous Monitoring	parts per thousand (ppt)	0.01 ppt	±0.5 ppt (f)	±1.0% of reading or 0.1 ppt, whichever is greater	NIST Certified Conductivity Standards
Conductivity (pre- & post-measurement checks)	YSI 556 Multiparameter System 0 to 100 mS/cm	Citizen Steward	milliSiemens per centimeter (mS/cm)	0.001 mS/cm to 0.1 mS/cm (range dependent)	±100 µmhos/cm (f)	±0.5% of reading +0.001 mS/cm	NIST Certified Conductivity Standards
	YSI 6600 Sonde 0 to 100 mS/cm	Profile & Continuous Monitoring	milliSiemens per centimeter (mS/cm)	0.001 mS/cm to 0.1 mS/cm (range dependent)	±100 µmhos/cm (f)	±0.5% of reading +0.001 mS/cm	NIST Certified Conductivity Standards
Limit of Visibility	Secchi Disk Depth 0 to 20 m	Citizen Steward	meters (m)	0.1 m	NA	NA	NA
Sample Depth	Marked Line 0 to 36 m	Citizen Steward	meters (m)	1 m	10% RPD	NA	NA
	YSI 6600 Sonde 0 to 200 m	Profile & Continuous Monitoring	meters (m)	0.001 m	NA	NA	barometric pressure

Parameter	**Method/Range**		**Units**	**Sensitivity**	**Precision**	**Accuracy**	**Calibration Method**
pCO_2	Turner Designs C-sense pCO_2 Sensor 0 to 1000 ppm	Continuous Monitoring	parts per million ppm	1.0 ppm	±0.5 – 1.0 ppm	3% of full range 30 ppm	NA (r) Factory calibrated annually
Chlorophyll Fluorescence (g)	YSI 6600 Sonde 0-400 µg/L Chl (h)	Profile & Continuous Monitoring	micrograms per liter (µg/L)	0.1 µg/L	±0.3 µg/L (l)	NA	NIST Certified Rhodamine B
Turbidity	YSI 6600 Sonde 0 to 1000 NTU	Profile & Continuous Monitoring	nephalometric turbidity units (NTU)	0.1 NTU	NA	+ 2 % of reading or 0.3 NTU, whichever is greater	NIST Certified Turbidity Standards
Dissolved Inorganic Nutrients	Bran Luebbe Autoanalizer 3	Profile & Continuous Monitoring	micromoles (µM)	0.01µM	< 20 µM (NO_3+NO_2) < 25 µM (NH4) < 30 µM (SIO_4) < 4 µM (PO_4) (m)	NA	NA
Total Nitrogen	Persulfate Method Whole Water Sample	Profile & Continuous Monitoring	(mg N/L)	0.01 mg N/L	NA	±0.02 mg N/L	NA

NA = Not Available

Note: Precision values shown within { } are values obtained from calibration records and/or annual QA sessions.

(a) Determined by the increments measurable with the stated method reflecting estimation where allowed.

(b) Data taken from EPA Volunteer Water Monitoring: A Guide for State Managers, 1990, EPA 440/4-90-010, p. 39; based on data provided by the Chesapeake Bay Citizen Monitoring Program.

(c) YSI 556 is used ONLY by FOCB staff for site visits to conduct individual QA/QC with volunteers.

(d) Data taken from FOCB1995 Water Column Profile Data Report, 1996, Friends of Casco Bay Citizen Stewards Water Quality Monitoring Program, Volume I, pp. 28-29.

(e) Data taken from 1995 Water Column Profile Data Report, 1996, FOCB CSWQM Program, Volume I, pp. 28-29.

(f) Data derived from 1999 - 2000 calibration records.

(g) Determination of chlorophyll with YSI 6025 probe can only be considered qualitative and are an estimate of chlorophyll concentrations *in situ.*

(h) YSI Chlorophyll sensor range: 0-400 ug/L Chl; 0-100 Percent Full Scale (%FS) Fluorescence Units

(i) Precision calculated from 2001 – 2015 pre & post calibration records

(j) Data taken from FOCB/CBEP *Twelve-Year Water Quality Data Analysis: 1993 – 2004,* section 2.2 p.6

(k) Precision calculated from 2009 – 2015 pre & post calibration records

(l) Precision calculated based on methods comparative study conducted 2/2011

(m) Data derived from 2007 - 2015 calibration records.

(n) Precision calculated based on comparative study of meters vs. NIST certified thermometer, conducted 2/2011

(o) Calibration will be performed by Turner Designs annually.

B. Accuracy

Accuracy of procedures and equipment used in the Citizen Stewards Water Quality Monitoring program, Sentinel Site Profile Monitoring Program and Continuous Monitoring station will be verified using standard reference materials. A detailed description of calibration procedures is given in Sections B15 & B16, and in Table 2.

C. Representativeness

Representativeness of the data collected in monitoring projects is considered and discussed in the project design and field plan, especially in sampling site selection. It will not be routinely monitored throughout the project, but will need to be considered when interpreting the data.

It is obvious that water flowing past a given location on land is constantly changing in response to inflow, tidal cycle, weather, etc. Periodic collection of data can help develop a better understanding of the variance associated with time series measurements of selected environmental variables. Such data collection can also provide increased resolution and sensitivity to localized and short term effects of events along tributary margins and in embayments.

All water quality monitoring sites in the Friends of Casco Bay Environmental Monitoring Program have been strategically located to best represent local and regional environmental conditions of Casco Bay. All Citizen Steward, Water Column Profile and Continuous Monitoring sites have been carefully grouped into sub-watersheds based on geography and water type as noted in the data analysis performed in 2001 ***Six-Year Water Quality Data Analysis Report*** and 2005 ***Twelve-Year Water Quality Data Analysis Report*** by P. Scott Libby from Battelle – Coastal Resource and Ecosystem Management. These sub-watersheds are defined in Table 3 p. 27 as: (CE) Cape Elizabeth, (EC) Eastern Coast, (FS) Foreside, (HS) Harpswell Sound, (HR) Harraseeket River, (MB) Middle Bay, (MQ) Maquoit Bay, (NMR) New Meadows River, (OFF) Offshore, (PC) Portland Coast, (PH) Portland Harbor, (PR) Presumpscot River, (QB) Quahog Bay, (RR) Royal River, (WB) Western Bay.

The Citizen Steward monitoring sites best represent surface water conditions within the Bay. The water column profile sites represents water quality from surface to bottom at one "offshore" location, one "urban" and one "suburban" location. The continuous monitoring site is centrally located and collects bottom water conditions 24/7 365 days a year to represent water quality conditions over time.

D. Comparability

Efforts will be made to use methods that are EPA-approved and comparable to those employed by other water quality monitoring programs. Where the methods are necessarily different, either method comparison tests will be performed using EPA-approved methods and the degree of comparability will be determined and reported, or comparison tests in the literature will be referenced. Comparisons will be necessary for the parameters of specific gravity, dissolved inorganic nutrients (DIN) and pCO2 when these parameters are not measured using EPA-approved methods.

Salinity will be measured using a hydrometer (Standard Methods, 16th Edition, Method 210B). From the actual specific gravity and temperature measurements of the water sample, a table will be used to calculate the water density and the corresponding salinity. To determine the comparability of salinity values measured by this method, comparison measurements will be made during QA sessions with a YSI model 6600 data Sonde using EPA method 120.1. The meter will be calibrated according to manufacturer's specifications using NIST certified conductivity standards.

Dissolved Inorganic Nutrients and Total Nitrogen will be collected as outlined in section B.10. Data collected through this program will be compared to past studies in Casco Bay performed by FOCB, the Maine Department of Environmental Protection, and University of Maine. Standardized sampling methodologies have been established across all agencies, Universities and advocacy groups who collect and rely on this important data. In addition, references to analytical methods are attached as appendices 3 and 4 of this QAPP.

pCO2 will be measured by means of a Turner Designs C-sense pCO2 *in situ* sensor. Since existing pCO2 data for Casco Bay is limited, we will rely on data and assistance from colleagues at the University of New Hampshire, Ocean Process Analysis Laboratory who have deployed a similar device in Casco Bay and for which a QAPP was recently approved by EPA and CBEP. Their instrumentation reports in uatm units which can be converted to ppm and vice a versa in order for us to compare data.

E. Completeness

Completeness for the CSWQM will be measured as the percentage of total samples collected that were analyzed as a whole and for individual parameters and sites. Volunteer monitors in the CSWQM program will be requested to collect data monthly in April, May, June, October, and bi-monthly July, August, September. Samples are collected at 07:00 AM (± ½ hour) & 15:00 PM (± ½ hour). Observations will be made 20 times per site per year at all sites monitored by volunteers. However, it is assumed that some weeks may be missed due to vacations, illness, and severe weather. A complete data set has been initially set as 16 sampling events during the seven-month sampling period.

Stations monitored from the BayKeeper boat will be sampled monthly year-round. Observations will be made 12 times per site per year. However, due to the possibility of severe weather, a complete data set has been initially set as 10 complete sampling events per year. During the period from April through October, the maximum interval between events will be 49 days and the minimum will be 14 days. During the period from November through March, a monthly schedule will be followed as closely as weather allows, with a minimum interval between sampling events of 14 days.

Sample collection for Total Nitrogen and Dissolved Inorganic Nutrients will occur monthly at the three water column profile sites. Completeness will be determined by the profile schedule.

A.8. TRAINING REQUIREMENTS/CERTIFICATION

The most important step in ensuring that volunteer monitors are successful in collecting reliable data is the provision of a well-planned monitor training program. Training for the CSWQM program will be conducted by FOCB. Training will involve three phases. During phase I, volunteers will be given extensive instructions on the protocols for measuring temperature (water and air), specific gravity, pH, dissolved oxygen and all ancillary observations. In phase II, volunteers will practice all sampling, testing, and safety procedures during hands on supervised instruction. Phase III of the training will be conducted for each volunteer at his/her monitoring site, allowing the volunteers to further practice the testing procedures and be observed by staff as a QA measure. Additional on-site training sessions may be necessary if a particular monitor is having difficulty. Only trained volunteers will participate in monitoring activities.

In addition to the training program, monitors will be provided with a copy of the FOCB Citizen Stewards Water Quality Monitoring Training Manual. This manual describes in detail the test procedures, proper care and handling of equipment, safety precautions, and data reporting procedures. All monitors have access to instructional videos for all test procedures from filling out the datasheet to performing dissolved oxygen titrations. These instructional videos and updated manuals are available 24/7 and can be accessed through our web site http://www.cascobay.org/water-quality-monitoring-resources/

Training for staff in water column profile procedures will be conducted on an as needed basis. Research Associate & Citizen Stewards Coordinator, Mike Doan will conduct all profile cruises along with the assistance of other staff, volunteers and occasional guests. All FOCB staff has been instructed during their initial orientation as an employee in the methods for water column profile data collection. Future staff and seasonal interns will go through a similar training as needed.

Training for the deployment, retrieval, data upload, equipment maintenance and calibration of unattended equipment will be performed by Research Associate & Citizen Stewards Coordinator, Mike Doan. Staff and student interns may assist Mike from time to time in the deployment and retrieval. In addition regular cleaning will occur during equipment retrieval every two weeks year-round. Mike will perform the necessary training with staff and interns and will supervise all pre and post calibration procedures to assure equipment accuracy and functionality.

A.9. DOCUMENTATION AND RECORDS

Both volunteer monitors and FOCB staff will collect and report data on the Data Collection Forms supplied by the Environmental Monitoring Program. All volunteer field measurements and observational data will be recorded on the CSWQM form (Figure 2). FOCB staff field measurements and profile data will be recorded on Side 1 (Figure 3) and Side 2 (Figure 4) of the Profile Data Collection Form. Profile data will also be logged to the YSI data sonde. Unattended monitoring deployment and calibration documentation will be recorded on our data Sonde calibration log (Figure 5).

During annual QA/QC sessions for returning volunteers a specially modified datasheet is used to track results of volunteers' performance as well as kit number assigned, chemical expiration dates, meter numbers, and expected values vs individual sample results to verify volunteers' precision and accuracy for sampling.

Documentation of unattended equipment calibration records will be performed pre and post deployment in order to keep a running account of all sensor performance, drift, data file names, and any notation of specific probes issues. All forms will be kept on file at the Office of Friends of Casco Bay and are open for review upon request.

Each monitor will be asked to make a copy of the data form from each sampling event and to send the original to the Program Coordinator of the CSWQM program monthly for review and data entry. The Program Coordinator will file the original in the program data file.

The copy of the data form will be retained by the volunteer in an accordion file provided by FOCB for the storage of water quality data and other program information. The purpose of these volunteer data files is to guard against loss and to facilitate discussion of any questions later about data reported. Volunteer data files will be reviewed for completeness during site visits.

FIGURE 2. CSWQM DATA COLLECTION FORM, SIDE 1

THE FRIENDS OF CASCO BAY CITIZENS' MONITORING PROGRAM
WATER QUALITY DATA SHEET (SIDE 1 OF 2) ☐

1 I.D.

Site name: ____________________ Collection date (mo/dy/yr): ___/___/___

Monitor name(s): ____________________ Time (24-hour time): __________ hours

____

2 WEATHER CONDITIONS

Air temperature: ⎵⎵.⎵ °C Wind direction: _____ (N,NE,E,SE,S,SW,W,NW)

Wind speed: ________ mph

Weather (check one) ☐ clear ☐ snow ☐ overcast ☐ fog/haze ☐ drizzle ☐ downpour ☐ partly cloudy

Rainfall in previous 24 hours (check one): ☐ none ☐ light (___ inches) ☐ heavy (___ inches)

Number of days with similar weather (including today): ______ days (must be >0)

3 SITE OBSERVATIONS

Tidal stage (check one): ☐ high ☐ high ebb ☐ ebb ☐ low ebb ☐ low ☐ low flood ☐ flood ☐ high flood

High tide: __________ hours

Low tide: __________ hours

Water surface (check one): ☐ calm ☐ ripple ☐ waves ☐ whitecaps

Indicators (check all that apply):
☐ fishkills ☐ dead crabs ☐ oil on surface ☐ debris
☐ erosion ☐ foam ☐ bubbles ☐ odors
☐ abnormal color ☐ birds ☐ animals ☐ other

Please elaborate on the above: ____

____

PH calibration results:
pH 7.01 ⎵.⎵⎵
pH 10.01 ⎵⎵.⎵⎵

4 FIELD MEASUREMENTS

Secchi depth: ⎵⎵.⎵ meters Water depth: ⎵⎵.⎵ meters

Water temperature: ⎵⎵.⎵⎵ °C pH: ⎵.⎵⎵ N, W, O, mtr (circle one)

Specific gravity: ⎵.⎵⎵⎵⎵ read at temp of ⎵⎵.⎵⎵ °C

Salinity: ⎵⎵.⎵ ppt

Dissolved oxygen: Test 1: ⎵⎵.⎵ mg/l Test 2: ⎵⎵.⎵ mg/l

Test 3: ⎵⎵.⎵ mg/l Avg: ⎵⎵.⎵ mg/l

Monitor signature(s): ____

____

FIGURE 3. PROFILE DATA COLLECTION FORM, SIDE 1

THE FRIENDS OF CASCO BAY CITIZENS' MONITORING PROGRAM
WATER QUALITY DATA SHEET (SIDE 1 OF 2) ☐

1
I D

Site name: ______________ Collection date (mo/dy/yr): ___/___/___

Monitor name(s): ______________ Time (24-hour time): ________ hours

____

2
WEATHER
CONDITIONS

Air temperature: __ __ . __ °C

Wind direction: _____ (N,NE,E,SE,S,SW,W,NW)

Wind speed: ________ mph

Weather (check one): ☐ clear ☐ snow ☐ overcast ☐ fog/haze ☐ drizzle ☐ downpour ☐ partly cloudy

Rainfall in previous 24 hours (check one): ☐ none ☐ light (___ inches) ☐ heavy (___ inches)

Number of days with similar weather (including today): ______ days (must be >0)

3
SITE
OBSERVATIONS

Tidal stage (check one): ☐ high ☐ high ebb ☐ ebb ☐ low ebb ☐ low ☐ low flood ☐ flood ☐ high flood

High tide: ________ hours
Low tide: ________ hours

Water surface (check one): ☐ calm ☐ ripple ☐ waves ☐ whitecaps

Indicators (check all that apply):

☐ fishkills ☐ dead crabs ☐ oil on surface ☐ debris
☐ erosion ☐ foam ☐ bubbles ☐ odors
☐ abnormal color ☐ birds ☐ animals ☐ other

Please elaborate on the above: ______________________________

____

____

4
FIELD
MEASUREMENTS

Secchi depth: __ __ . __ meters

Water depth: __ __ . __ meters

GoMOOS Nutrient Sampling

Bottle #	1	2	3	4	5	6
Depth (m)						
DIN Vial #						

Monitor signature(s): ______________________________

____

FIGURE 4. PROFILE DATA COLLECTION FORM, SIDE 2

THE FRIENDS OF CASCO BAY CITIZENS' MONITORING PROGRAM
WATER QUALITY DATA SHEET (SIDE 2 OF 2)

WATER COLUMN PROFILE DATA	TEMPERATURE (°C)	SALINITY (ppt)	DISSOLVED OXYGEN (mg/l)
Model number of meter			
Serial number of meter			
Depth (m): 0	.	.	.
1	.	.	.
2	.	.	.
4	.	.	.
6	.	.	.
8	.	.	.
10	.	.	.
12	.	.	.
14	.	.	.
16	.	.	.
18	.	.	.
20	.	.	.
22	.	.	.
24	.	.	.
26	.	.	.
28	.	.	.
30	.	.	.
32	.	.	.
34	.	.	.
36	.	.	.
38	.	.	.

REMARKS:

Staff use ONLY	Date	Initials
Sheet rec'd		
Data ck'd		
Data entered into database		
Entry ck'd vs sheet		

F:\Data\PMilhollandCommon\WPDOCS\WQ\DTSHT01pr2.wpd

FIGURE 5. DATA SONDE CALIBRATION LOG

Friends of Casco Bay
Sonde Calibration Log

Maintenance

Date of Calibration ___________________ Technician(s) ________________________

Optical DO Wiper Replaced? Y N Chlorophyll Wiper Replaced? Y N

Wiper parks 180° from optics? Y N Wiper parks 180° from optics? Y N

Replace Batteries? Y N

Sonde Number:

Comments:

Pre/Post – Deployment Calibration: (turn on pH mV and Sp Cond in Report menu)

	Pre-Deployment					Post-Deployment	
	Pre- Calib	At Calib	Error	Sensor Diagnostics			
%DO @ 100% sat	%	%	Y or N			%	
Baro Press (mm)		mm		DO Gain (0.8-1.7)		Bar Press (mm)	
DO @ Cal	Temp	Mg/l	Cal	DO Post Cal	Temp	Mg/l (read)	Cal (read)
Sp Cond (mS/cm)	mS/cm	mS/cm	Y or N	Cell Const (4.6-5.45)	Adv menu	mS/cm	
pH @ Buffer 7 ___			Y or N	pH 7 (0 ± 50 mV)		pH	
pH @ Buffer 10 __			Y or N	pH 10 (-180 ±50 mV)			
pH @ Buffer 4 ___			Y or N	pH 4 (+180 ± 50 mV)			
*Calculate pH Slope				pH slope (165-180)			
Chl @ ____µg/L	µg/L	µg/L	Y or N	v		µg/L	
Battery Voltage remove ext. power	V		Y or N			V	
Depth	M					M	

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv
Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Programming: File Name: ______________________________
(Unattended deployment)

Interval _________ Check Clock (Status) ___Y___N___ Start Time ____________

Duration ___365 days Start Date ____________ Free Mem _________days

Deleted data from sonde? ___Y___N

C:\Users\mdoan\Desktop\Winter 2016-2017\Sonde Calibration Log revised 12-07-16.doc

B.10. SAMPLING PROCESS DESIGN

The goal of the FOCB Citizen Stewards Water Quality Monitoring program is to coordinate a baywide citizen monitoring program which provides quality data to assist in the monitoring, protection and restoration of the waters of Casco Bay and its watershed. To meet this goal, quality assurance and quality control must be paramount in the program. These concepts are emphasized in volunteer and staff training as well as the development of sampling and analytical procedures.

1. General Procedures for Sampling by Citizen Monitors

All regular sampling in the CSWQM program will involve ambient measurements collected and processed in the field. A few stations will be sampled from volunteers' boats, but most monitors will sample nearshore stations referenced to nearby fixed structures (e.g. end of pier). Preferably they will sample from bridges, piers, bulkheads, floats, jetties, docks, etc. where there is at least ten feet of water at low tide. This minimum water depth requirement would allow a Secchi disk reading to be taken at almost any tide stage. Unfortunately, requiring a strict minimum depth is not feasible. Because of the limited number of ideal spots and because consistency is related to convenience, a number of stations will be sampled by wading-in from shore. The disadvantage is that Secchi disk readings won't be taken, and that intertidal areas can be more dynamic than sub-littoral areas and thus harder to characterize. These stations are also subject to sediment suspension that can affect parameter values. The advantage is that nearshore stations both intertidal and sub-littoral can be close to important nursery areas as well as providing habitat and a food source for adult marine organisms. These areas are also more likely to show the effects or presence of pollution from shoreline point and non-point sources.

Citizen monitors in the CSWQM program currently sample between thirty-five and forty stations, and this number is expected to remain fairly stable. All stations have been visited by FOCB staff to measure latitude and longitude using a GPS unit, to take a reference photo, and to establish a point at the station from which sampling can be done both safely and consistently. A list of all FOCB sites are noted in table 3.

All samples collected by citizen monitors will be of surface water and will be collected by a 5-gallon bucket. Monitors will be instructed to rinse the buckets three times before filling them for sampling. Sampling will be monthly from April through October except in July, August, and September when samples will be collected bi-weekly. Sampling will be conducted on a designated Saturday at 07:00 (7:00 AM) and 15:00 (3:00 PM) plus or minus ½ hour.

2. Procedures for Sampling from the BayKeeper Boat

In addition to the stations sampled by citizen monitors, three stations will be sampled from the BayKeeper boat by the Program Coordinator and other FOCB staff. (Volunteers are invited and encouraged to participate in boat sampling.) These stations are representative of Casco Bay and accessible in all weather conditions with exception of gale warnings, hurricanes etc. Profile sampling sites are noted in table 3 as P5BSD Broad Sound, representative of offshore deep water conditions. P6FGG Fort Georges is representative of class SC industrial/harbor conditions as well as being influenced by the Presumpscot River, one of five major river systems impacting Casco Bay. P7CBI Clapboard Island is representative of suburban Casco Bay in the largest boat anchorage in the State of Maine.

At these stations, water column profiles will be conducted through the use of a YSI 6600 multi-parameter data sonde. Samples will be logged at the surface, 1 meter, 2 meters then every two meters until the sensor touches the bottom. All data will be logged by a handheld YSI 556 data logger and stored internally in the YSI 6600 sonde. Sample depth will be determined by use of internal pressure transducer in the YSI 6600. The transducer is sensitive to fluctuations in barometric pressure therefore it is calibrated before use and post calibrated after use each day. Notation of changes in barometric pressure are recorded on the Sonde Calibration Log sheet. Samples being collected are for dissolved oxygen, water temperature, salinity, pH, and chlorophyll fluorescence. In addition discrete samples will be collected for dissolved inorganic nutrients and total nitrogen at surface and bottom. Limit of visibility (Secchi depth readings) will also be measured. Sampling from the BayKeeper boat will be conducted monthly year-round.

3. Procedures for Unattended Sonde and pCO_2 Monitoring

YSI 6600 datasonde and Turner Designs C-sense pCO_2 sensors will be deployed together in unattended mode, roughly 0.5m above the bottom at a municipal dock in Yarmouth, Maine. This dock is accessible year-round as it is one of two ferry landings for residents to access the Town of Chebeague Island, Maine. The instruments will be used to collect hourly conditions of water temperature, salinity, dissolved oxygen, pH, chlorophyll fluorescence, and pCO2 (partial pressure of CO_2). Equipment will be checked, cleaned of bio-fouling and data uploaded bi-weekly, year-round for this project. During each retrieval/deployment the deployed YSI 6600 datasonde will be switched with a second calibrated and cleaned YSI 6600 datasonde with identical probes in order to assure the best possible measurements are being collected. The pCO2 sensor will be carefully cleaned and checked for accuracy during each retrieval/deployment and recalibrated annually by Turner Designs.

4. Procedures for Collecting Dissolved Inorganic Nutrients from the BayKeeper Boat

Dissolved inorganic nutrient samples will be collected with a 60 ml syringe (from the sampling jar), filtered through a 0.45 µm Acrodisc* Premium syringe filter, into a high-density polyethylene liquid scintillation vial. Samples will then be kept insulated and out of direct sunlight, and frozen ASAP (within four hours of collection). The sampling procedures are as follows:

Dissolved Inorganic Nutrient and Total Nitrogen, Step-By-Step Field Procedures for sampling from the Baykeeper Boat

NOTE All DIN and TN samples obtained by staff from the Baykeeper boat will be collected by means of a Kemmerer water sampler for bottom water samples, and by 500ml amber Nalgene bottle for surface samples.

1) Set Sonde at surface of water (6" below surface is considered surface) to equilibrate with local conditions.
2) Rinse 500ml amber Nalgene bottle three times with surface water (within top 6") then fill a minimum of ¾ full, cap and set in cooler to be filtered after bottom sample has been collected.
3) Set trigger on Kemmerer water sampler and rinse with surface water
4) Continue profile until Sonde reaches bottom
5) Deploy sampler to the same water depth as noted by YSI 6600 pressure transducer, send messenger and retrieve sample.
6) Dispense a small volume of sample from Kemmerer to rinse another 500 ml amber Nalgene bottle three times then fill a minimum of ¾ full, cap and set in cooler
7) Once profile is complete, remove amber Nalgene bottles from cooler and process samples
8) Select Nalgene bottle with surface sample and gently roll bottle to mix contents
9) Slowly pour sample water into precleaned 125 ml Nalgene bottled (labeled TN with site code, and date) approximately ¾ full, cap and set aside in cooler
10) Rinse the outside of the 60 ml syringe with the sample water
11) Draw up a small amount of the sample water (10 ml ±) into the syringe, remove from bucket, pull plunger back, and shake to rinse
12) Expel the rinse water away from 500ml jar
13) <u>Repeat this three times</u>
14) Fill the syringe with sample water (from the 500ml jar), attach the filter, and rinse the (DIN) scintillation vial (and cap) three times.
15) Fill the DIN vial 2/3 full, leaving plenty of room for expansion upon freezing
16) Cap and place in cooler (out of direct sunlight).
17) Record DIN vial # on datasheet. Upon return to office, place vial in freezer bag, and in freezer ASAP.

B.11. SAMPLING METHODS REQUIREMENTS

A. Monitoring Parameters and Collection Frequency

Table 2 (above) summarizes the water quality parameters monitored through the Environmental Monitoring Program. Samples will be taken at all Citizens' Monitoring stations monthly April through October except in July, August, and September when samples will be collected bi-weekly. All measurements will be made by the monitors on-site, with the possible exception of dissolved oxygen (DO). When necessary, DO samples may be collected and fixed on-site, then titrated within eight hours after collection.

Stations monitored from the BayKeeper boat will be sampled monthly year-round Measurements for Secchi depth, total water depth, TN, DIN and water column profiles which include water temperature, salinity, pH, dissolved oxygen, and chlorophyll fluorescence will be taken at these stations.

Data collected at the unattended monitoring site will be obtained hourly, year-round. Parameters include water temperature, salinity, pH, dissolved oxygen, chlorophyll fluorescence, and pCO2.

Table 3. Site Locations for Friends of Casco Bay Water Quality Monitoring

Site Name	Site Number	Water Body Name	Water Class	Town	Profile DIN & TN Sites	Latitude	Longitude
B&M Railroad Trestle	BMR02	Portland Coast	SC	Portland		43.6763	-70.2507
Bethel Point	BTH04	Quahog Bay	SB	Harpswell		43.7909	-69.9120
Broad Sound - **Profile**	P5BSD	Eastern Bay	SB	Cumberland	*	43.7323	-70.0664
Cape Small Harbor	CSH07	Eastern Coast	SB	Phippsburg		43.7323	-69.8445
Chebeague Island, Stone Pier	CHB10	Western Bay	SB	Cumberland		43.7516	-70.1082
Cousins Island Wharf	CIW85	Western Bay	SB	Yarmouth		43.7520	-70.1393
Cousins Island - **Continuous**	CIU01	Western Bay	SB	Yarmouth		43.7520	-70.1390
Clapboard Island - **Profile**	P7CBI	Western Bay	SB	Falmouth	*	43.7193	-70.2026
Cliff Island Public Landing	CLF13	Western Bay	SB	Portland		43.6980	-70.1070
Cousins River, Muddy Rudder	CRV63	Royal River	SB	Yarmouth		43.8123	-70.1528
Custom House Wharf	CST15	Portland Harbor	SC	Portland		43.6567	-70.2500
Dyers Cove, Quahog Bay	DYQ17	Quahog Bay	SB	Harpswell		43.8237	-69.9175
East End Beach	EEB18	Portland Coast	SC	Portland		43.6713	-70.2419
Fort Gorges - **Profile**	P6FGG	Portland Coast	SC	Portland	*	43.6623	-70.2259
Gun Point	GUN65	Quahog Bay	SB	Harpswell		43.7679	-69.9467
High Head Yacht Club	HHY22	Harpswell Sound	SB	Harpswell		43.8009	-69.9599
Indian Rest	IND66	New Meadows	SB	Harpswell		43.8590	-69.9070
Knightville Landing	KVL84	Portland Harbor	SC	South Portland		43.6440	-70.2580
Little Flying Point - LL Bean	LFP26	Maquoit Bay	SB	Freeport		43.8310	-70.0460
Lookout Point	LPT74	Middle Bay	SB	Harpswell		43.8070	-69.9934
Mackworth Causeway	MAC30	Foresides	SC	Falmouth		43.6923	-70.2364
New Meadows Lake	NML87	New Meadows	SB	Brunswick		43.9315	-69.8624
New Meadows Marina	NMM79	New Meadows	SB	Brunswick		43.9101	-69.8697
Orrs & Bailey Island Yacht Club	OBY35	Harpswell Sound	SB	Harpswell		43.7525	-69.9866
Peabbles Cove	PBL36	Cape Elizabeth	SB	Cape Elizabeth		43.5887	-70.2083
Peaks Island, Public Landing	PKP38	Western Bay	SB	Portland		43.6560	-70.1996
Pinkham Point, Quahog Bay	PKT42	Quahog Bay	SB	Harpswell		43.7973	-69.9274
Portland Headlight	PTH59	Cape Elizabeth	SB	Cape Elizabeth		43.6257	-70.2131
Portland Yacht Club	PYC43	Foresides	SB	Falmouth		43.7295	-70.2060
Portland Yacht Services	PYS44	Portland Harbor	SC	Portland		43.6626	-70.2420
Royal River C5	RRC46	Royal River	SB	Yarmouth		43.7919	-70.1413
Royal Yankee Marina	RRY47	Royal River	SB	Yarmouth		43.7954	-70.1725
RT9 Presumpscot Bridge	PRV70	Presumpscot	SC	Falmouth		43.7169	-70.2640
SMCC Pier	SMT50	Portland Coast	SC	South Portland		43.6510	-70.2290
South Freeport Town Landing	SFP51	Harraseeket River	SB	Freeport		43.8204	-70.1059
Stroudwater Bridge	STR54	Portland Harbor	SC	Portland		43.6587	-70.3109
The Basin	BAS68	New Meadows	SB	Phippsburg		43.8054	-69.8495
Winter Point	WIN82	New Meadows	SB	West Bath		43.8759	-69.8632

<u>**NOTE:**</u> All sites listed above are volunteer sites unless marked as "**Profile" or "Continuous"**

Detailed procedures for measuring pH, salinity, chlorophyll fluorescence, pCO2 and water clarity are described in sub-chapter D since the methods being used are not EPA-approved. For pH, a Hanna electrometric meter will be employed. For salinity, a gravimetric procedure using a hydrometer will be employed rather than the electrometric method. For salinity the non-electrometric methods are more appropriate for the CSWQM program. These methods have been approved for use by citizen programs in other EPA regions, i.e. Region 3, Chesapeake Bay Citizen Monitoring Program and Region 6, Galveston Bay Foundation TEST Program.

The methods used to measure dissolved oxygen and water temperature are EPA-approved methods and are described below.

Dissolved Oxygen (DO)

Dissolved oxygen is measured with a Dissolved Oxygen test kit using the azide-modified Winkler Titration method.

Collection and Fixation:

1. In order to avoid contamination, a 60-ml water bottle is thoroughly rinsed with the water from the sampling bucket three times. The rinse water is discarded.

2. The bottle is tightly capped and submerged in the sampling bucket. The cap is removed, and the bottle is allowed to fill. Any air bubbles clinging to the sides of the submerged bottle are removed by tapping. The cap is replaced while the bottle is still submerged. After retrieval, the bottle is examined to make sure that no air bubbles are trapped inside. Once a sample without any air bubbles has been collected, Steps 3 & 4 are performed immediately.

3. 8 drops of Manganous Sulfate Solution and 8 drops of Alkaline Potassium Iodide Azide are added to the sample. The bottle is capped and inverted gently several times to mix. A precipitate forms. After the precipitate has settled below the shoulder of the bottle, the bottle is inverted again. The precipitate is allowed to settle again.

Titration: The titration should be completed no longer than 8 hours following fixation. When necessary, samples may be collected and fixed in the field for later titration. Samples should be protected from light and excess heat.

4. 8 drops of Sulfuric Acid (1:1) are added to the sampling bottle. The sample is mixed by gently shaking until both the reagent and the precipitate have dissolved. A clear-yellow to brown-orange color develops, depending on the oxygen content of the sample. After the addition of the acid, the analysis must be completed within 45 minutes.

5. A 25-ml graduated cylinder is filled to the 20 ml line with the sample solution. The solution is then transferred to the titration tube.

6. The plunger of a direct-reading titrator, a small syringe, is depressed to expel air. The titrator is inserted into the plastic fitting of a bottle of Standard Sodium Thiosulfate Solution (0.025N). The bottle is inverted, and the plunger of the titrator is slowly withdrawn until the bottom of the plunger is past the zero mark on the titrator scale. A plastic tip is then attached to the titrator. The plunger is pressed slowly until the plastic tip is full and the lowermost rim of the black rubber shoulder of the plunger is opposite the zero mark.

   If air bubbles appear in the titrator barrel during the filling process, the titrator is removed from the reagent bottle. The plunger is pressed until the bubbles are expelled. The titrator is then reattached to the reagent bottle. Any solution expelled during this process is discarded.

   Occasionally air bubbles appear on the tip of the plunger which can not be removed by the above process. If this process has been repeated three times and air bubbles remain, they may be removed by drawing about a centimeter of solution into the titrator and then forcibly expelling the solution back into the reagent bottle. This step is repeated until there are no more air bubbles.

7. 1 drop of Sodium Thiosulfate is added to the titration tube and mixed by swirling the tube. Another drop of the Sodium Thiosulfate is added and swirled again. The titration process is continued, adding one drop at a time, until the yellow-brown solution in the titration tube just begins to fade or get lighter. The color of the solution at this point should be about the shade of pale straw.

8. 8 drops of Starch Indicator Solution are added to the titration tube, which is mixed by swirling. The solution turns from light yellow to dark blue.

9. The titration process is continued (as described in Step 7) with the remaining Sodium Thiosulfate, until the test solution turns from blue to clear. No more Sodium Thiosulfate is added than is necessary to produce the color change.

   If 10 units of Sodium Thiosulfate are added without accomplishing the final color change, the titrator is refilled as described in Step 6 and the titration is continued.

10. The scale on the side of the titrator is used to count the total number of units of Sodium Thiosulfate used in the experiment. If it is necessary to refill the titrator, the total is 10 units plus whatever units were used from the second filling. The number of units equals the milligrams per liter (mg/l) of oxygen dissolved in the sample.

Air Temperature

Air temperature is measured thermometrically using an alcohol-filled thermometer.

1. The LaMotte shielded thermometer must be hung in the shade and not touching anything. It must be protected from direct sunlight and/or wind as much as possible.

2. At least 3 minutes, no more than 5 minutes, are allowed for the thermometer reading to stabilize.

3. The temperature is read while the thermometer is still in the shade, and the temperature is recorded to the nearest 0.5°C.

Water Temperature

Water temperature is measured electrometrically using a Hanna pH meter with temperature thermistor.

1. The Hanna meter is hung (submerged) in the center of the bucket (water sample) immediately after it is collected. The bucket is protected from direct sunlight and/or wind as much as possible.

2. At least 3 minutes are allowed for the thermometer reading to stabilize.

3. The temperature is read while the thermometer is immersed in the water sample, and the temperature is recorded to the nearest 0.1°C.

B. Methodology for Stations Monitored from BayKeeper Boat

For stations monitored year-round from the BayKeeper boat, water temperature, salinity, dissolved oxygen, pH and chlorophyll fluorescence will be measured electrometrically. The procedures are described below. Although electrometric methods of measuring temperature are not EPA-approved, the procedure is included here because it is part of the salinity and dissolved oxygen measurements. For simplicity, the procedure for measuring salinity is described separately from those for measuring water temperature and dissolved oxygen. In practice, all five parameters are measured at each profile depth before moving the probes to the next depth.

Water Temperature & Dissolved Oxygen

Water temperature and dissolved oxygen are measured electrometrically using a YSI Model 6600 Data Sonde with a digital display.

All calibrations performed on the YSI Mod. 6600 datasonde are executed with the use of a YSI hand held data logger Mod. 650 MDS and YSI PC6000 software, or YSI Ecowatch software. Data collected by use of YSI 6600 datasonde will log the following parameters simultaneously:

Date M/D/Y	Time hh:mm:ss	Depth m	Temp C	Salinity ppt	DO Conc mg/L	DO% %	DO Charge	pH	Chlorophyll μg/l	ODO mg/L	Battery Volts

Methods for Capturing Data Are as Follows:

1. Visually inspect the dissolve oxygen (DO) probe for any obvious damage.

2. At each station the probe is lowered to the first depth to be measured. PC 6000 software is initialized and mode of data acquisition is selected to ASonde@. All data captured at this time will be logged within the Data Sonde minimizing battery power required by the laptop or handheld datalogger. At the A#@ prompt, type MENU and ENTER. Main menu will appear.

3. At the prompt select OPTION #1, the RUN category.

4. At the prompt select OPTION #1, DISCRETE SAMPLE.

5. At the prompt select OPTION #1, START SAMPLING.

6. Sonde will prompt with a message indicating probes stabilizing in 4..3..2..1..

7. The probes will take a few seconds to equilibrate to all parameters selected.

8. Logging for all 12 parameters will occur once every 4 seconds simultaneously but no data will be captured until the operator has observed three or more continuous lines of data. Once the operator has determined that this objective has been met the operator must select key stroke #1on the key pad of the laptop or select the "Enter" key of the handheld data logger. This command will capture the last set of data logged ONLY for that specific second and store the data in a pre-assigned file.

9. Sonde is then lowered to the next desired depth and the same capturing procedures are used until all desired data has been collected.

10. Duplicate samples will be collected and noted on data sheet at a preselected depth determined by random selection. Data collected at that depth for the first sample as well as the duplicate must be within DQO criteria as stated on pages 8-10.

11. Before moving from sampling site, the data file is viewed for completeness. Any data missed will constitute the execution of a second attempt to capture data at that specific site.

12. Upon satisfaction of successfully completing data collection at a station, operator will inspect Sonde for any damage, and will exit PC6000 software to minimize battery usage.

Note: Pre-calibration of Sonde is not compromised by exiting PC6000 software. Sonde will be checked during post-calibration procedures for any faulty data acquisitions.

D. Detailed Procedures for pH, Salinity, Water Clarity and $_{P}CO_2$ Not EPA Approved

Hanna Waterproof pH tester, HI 98128 meters are measured electrometrically with automatic temperature compensation.

Hanna procedures:

As soon as you pull the sample bucket out of the water, the water in it will begin to equilibrate with the temperature in the air. After about eight minutes, the equilibration can cause inaccuracies in your water temperature reading. The way to avoid this problem is to take the water temperature and pH readings within the first eight minutes after collecting water with the sample bucket.

1. Put the bucket somewhere where it's protected from direct wind and sun as much as possible.
2. Set the handle of the bucket upright and clip it in place with a clothespin. Hang the pH meter from the handle so that it sits in the middle of the bucket and is roughly upright (not flat on the surface of the water). The waterline should be somewhat between the "C/F" markings on the meter.
3. Turn on the meter by pressing and releasing the Power/Mode button. Give the pH meter at least five minutes to equilibrate, but don't let it sit for more than eight minutes.
4. Read the pH and temperature with the meter still immersed in the water (tilt it so that you can see it – use a magnifying glass if you find it helpful). The pH is the top value on the meter and the temperature is the bottom value
5. Record these values in the appropriate places on your data sheet, and circle MTR next to the pH value. Once these values have been recorded, turn off the meter by holding the Power/Mode button until OFF is displayed, then release. Please be sure to rinse the meter thoroughly with tap water.

Specific Gravity

Specific gravity will be measured using a hydrometer (Standard Methods, 16th Edition, Method 210B).

1. A clean hydrometer jar is rinsed three times with water from the sampling bucket, and then filled about 3/4 full with the sample to be measured.

2. The thermometer is hung in the jar so that it is totally immersed.

3. The hydrometer is inserted into the jar with a twisting motion. Care is taken that it will not hit the bottom hard and break, and that drops are not splashed on to the hydrometer stem above water level. The hydrometer is allowed to float freely.

4. The temperature of the water sample in the jar is read and recorded to the nearest 0.1°C. The thermometer is removed.

5. The specific gravity is read and recorded to the nearest 0.0005 using the lines printed between the labeled graduations. The reading is taken at the point where the scale crosses the surface of the water sample in the jar, not the top of the meniscus. The reading is taken at eye level since viewing up or down at an angle can give an incorrect reading.

6. A table is used to convert the hydrometer reading at the measured temperature to salinity. (This conversion is verified by computer calculation upon entry into the database.)

<u>Secchi Depth: Water Clarity Determination</u>

An indication of water clarity will be obtained using a Secchi disk.

1. The reading is taken while the monitor is standing with the sun to her or his back and is not wearing sunglasses.

2. The Secchi disk is lowered into the water until the disk barely disappears from sight. The depth reading, in meters, is noted based on the length of suspension line that is submerged.

3. The disk is lowered further, then slowly raised. The depth at which it reappears (barely perceptibly) is noted.

4. An average is calculated from the two depth readings obtained above. The average of the two readings is considered to be the limit of visibility or index of transparency. The reading is recorded to the nearest 0.1 m.

Methodology for measuring pCO2

Measurements of pCO2 will be achieved through the use of a Turner Designs C-Sense sensor and a PME logger.

1. Attach logger to a laptop by USB cable. Open deployment software in logger and set measurement frequency to 60 minutes. Detach cable form laptop and logger.
2. Attach sensor cable to sensor and logger. Sensor is now taking measurements.
3. Deploy sensor and logger with unattended sonde.
4. During deployment, sensor should be cleaned periodically by gently spraying a diluted detergent/water mix via a water pump and hose. DO NOT TOUCH SENSOR. Refer to Turner Designs manual for specific instructions.
5. During deployment, data will be uploaded periodically by removing the sensor form the logger, attaching the USB cable and opening the *Concatenate* software.
6. Select the current file to concatenate.
7. Copy file to laptop.
8. Concatenated file will be converted to Excel.
9. Annually, sensor will be sent to Turner Designs for calibration.

Please see Appendix 5 for Turner Designs manual

B.12. SAMPLE HANDLING AND CUSTODY REQUIREMENTS

This section currently applies to dissolved inorganic nutrients, and total nitrogen. At this time, all other monitoring procedures are conducted by the monitors in the field. The CSWQM program commitment includes the investigation of additional testing. If other tests are identified which require sample custody procedures, they will be developed and added to this section.

As a minimum, the sample custody form shown in Figure 6 will be used.

For dissolved inorganic nutrients (DIN) and total nitrogen (TN) samples collected by FOCB staff on the Baykeeper boat during profile trips, all samples will be placed immediately on ice. Upon return from field sampling, all vials will be frozen and stay frozen until relinquished to University of Maine lab personnel for DIN and Chesapeake Bay Lab for TN. Samples will be collected in 20ml Nalgene jars for DIN and 30ml Nalgene jar for TN and frozen until delivery to the lab. Samples will be stored for no more than 25 days prior to delivery to the lab.

Data collected through this effort is combined with data collected during the profiles of the water column; together, these present the largest and most complete Nitrogen dataset in the state. This dataset will be used by the state of Maine in the effort to produce a nitrogen standard.

1. Sample Transfer Requirements from FOCB to Lab(s)

Dissolved Inorganic Nutrient samples are collected in the field by FOCB staff and are stored in a cooler on ice during research cruises. Once all samples have been collected, samples are then transported to FOCB lab to be frozen until shipped to the lab. Prior to shipping samples to the lab they are collated by ID code and checked for completeness. All sample ID's and data are checked prior to shipment to U Maine School of Marine Science Lab. For shipment, all samples are packed on ice in a cooler along with chain of custody forms and driven to U Maine lab for relinquishment to Maura Thomas, Research Associate and Director of the Lab.

Total Nitrogen samples are collected in the field and stored in a cooler on ice during research cruises. Upon completion of cruise, samples are stored in FOCB freezer. Samples are shipped on ice quarterly via FedEx in small Styrofoam shipping boxes, with a chain of custody form, to Jerry Frank at Chesapeake Biological Laboratory (CBL) in Solomons, MD.

FIGURE 6. CSWQM SAMPLE CUSTODY FORM

FRIENDS OF CASCO BAY	CHAIN OF CUSTODY RECORD	Page ___ of ___
PROJECT:	COLLECTOR(S): (Signatures)	
LOCATION:		
DISTRIBUTION: • ORIGINAL - To accompany samples	• COPY - To Program Coordinator	

Station Number	Replicate	Date	Time	Sample Type	Container Vol.	Container Type	Preservative	Analysis Required	Due Date	Remarks	No. of CFU's

Relinquished by: (Signature)	Received by: (Signature)	Date	Time	Method of Shipment:
Relinquished by: (Signature)	Received by: (Signature)	Date	Time	Destination:
Relinquished by: (Signature)	Received by: (Signature)	Date	Time	

Dispatched by: (Signature)	Date	Time	Received for Laboratory by: (Signature)	Date	Time

B.13. ANALYTICAL METHODS REQUIREMENTS

Procedures for measuring dissolved oxygen, and water temperature are EPA-approved and are described in Section B11. For pH and salinity, EPA sampling procedures were not appropriate for widespread use in the Environmental Monitoring Program. The alternative methods used for these parameters and for the Secchi disk procedure are outlined in section B11:

TABLE 4. LABORATORY METHODS AND FIELD ANALYSIS PARAMETER TABLE

Parameter	Method	Reference (a)	Equipment
Temperature	Thermometric	Std. Methods 2550 B	Alcohol-filled thermometer
	Electrometric	Std. Methods 2550 B	Hanna Waterproof pH meter Mod # HI 98128
	Electrometric	Std. Methods 2550 B	YSI 556 Multiparameter System YSI Model 6600 Sonde
	Electrometric		Turner Designs C sense pCO2 Sensor
pH	Electrometric	Std. Methods 4500-H B	Hanna Waterproof pH meter Mod # HI 98128 YSI Model 6600 Sonde YSI 556 Multiparameter System
Dissolved Oxygen	Modified Winkler Titration	Std. Methods 4500-OC	Micro method; 60 ml bottle
	Electrometric	Std. Methods 4500-OG	YSI 556 Multiparameter System YSI Model 6600 Sonde
Salinity	Gravimetric	(c)	
	Electrometric	Std. Methods 2510 B	YSI 556 Multiparameter System YSI Model 6600 Sonde
Turbidity	Nephalometric	Std. Methods 2130 B	YSI Model 6136
Chlorophyll	flourometric	(e)	YSI Model 6025
Limit of Visibility	Secchi Disk Depth	(c)	

Sample Depth	Marked Line	NA	
	Electrometric Transducer	(e)	
pCO2	Non-Dispersive Infrared (NDIR)		
Dissolved Inorganic Nutrients (DIN)	Bran Luebbe Autoanalizer 3	(f)	
Total Nitrogen (TN)	Persulfate Method	Std. Methods 353.2 (f)	

NA = not available.

(a) Methods referenced are from 40 CFR 136.3

(b) U. S. Environmental Protection Agency. 1978. Microbiological Methods for Monitoring the Environment, Water and Waste, p. 124. EPA-600/8-78-017. Environmental Monitoring and Support Laboratory, Cincinnati, OH.

(c) The EPA-approved method is not appropriate for all purposes of the CSWQM program. Comparative measurements will be made with EPA-approved methods during QA sessions where possible.

(e) Sample Depth is also recorded by use of a pressure transducer integral to YSI 6600 Sonde.

(f) Analysis of dissolved inorganic nutrients is done at the University of Maine School of Marine Sciences Townsend Lab. The method is described in: Whitledge TE, Veidt DM, Mallow SC, Patton CJ, Wirick CD (1986) Automated nutrient analyses in seawater. Publ Brookhaven Natl Lab (BNL) NY 38990.

(g) YSI Environmental Operations Manual – 6 Series, (2000)

(h) Total Nitrogen will be determined through the persulfate method, a persulfate oxidation technique for nitrogen where, under initially alkaline conditions, nitrate is the sole nitrogen product. Digested samples are passed through a granulated copper-cadmium column to reduce nitrate to nitrite. The nitrite then is determined by diazotizing with sulfanilamide and coupling with N-1- naphthylethylenediamine dihydrochloride to form a colored azo dye. Color is proportional to nitrogen concentration. See Appendix 4 for more details.

TABLE 5, LIST OF LABORATORIES CONTRACTED BY FOCB

Total Nitrogen Analysis performed by:
University of Maryland Center for Environmental Science
Chesapeake Biological Laboratory
P.O. Box 38
Solomons, MD 20688
Contact: Jerry Frank
(410) 326-7252
frank@umces.edu

Dissolved Inorganic Nutrient Analysis performed by:
University of Maine
School of Marine Sciences
5706 Aubert Hall
University of Maine
Orono, ME 04469
Contact: Maura Thomas
(207) 581-4314
mthomas@maine.edu

B.14. QUALITY ASSURANCE & QUALITY CONTROL REQUIREMENTS

A. The CSWQM program will be constantly evaluated to determine the major causes of missed observations and data quality deficiencies. Based on the experience of our program, the most common causes of monitoring deficiencies are:

- Failure of monitors to sample at scheduled times
- Failure of monitors to return data to the Program Coordinator

Occasional problems have also arisen due to:

- Failure of monitors to clearly identify sites, sampling dates, and times on data forms
- Failure of equipment
- Unsafe weather conditions

Monitoring deficiencies due to a lack of sufficient chemical reagents, sometimes reported by other programs, have not been observed in the CSWQM program. Monitors are given a fresh supply of reagents at the beginning of each season in quantities that should be sufficient to last through the season. Monitors have demonstrated an extremely responsible attitude in reporting reagent shortages on a timely basis.

The following protocols have been proposed to eliminate as many problems as possible.

Quality Assurance

We have assumed that all monitors may miss a few weeks during the year due to vacation, illness and emergency situations, or severe weather. In order that as few sampling events will be missed as possible, alternate, and/or teams of monitors will be trained and identified to the monitors who have primary responsibility for sampling the sites. In addition, a few monitors will be asked to volunteer as regional coordinators for their section of the Bay. If a primary monitor anticipates missing a sampling event, it is the monitor's responsibility to contact the alternate(s) assigned to that site. If an alternate is not available, the primary monitor will contact the regional coordinator for that region. Only if the regional coordinator can not find a trained monitor to cover the site will the Program Coordinator be contacted to find a replacement.

Monitors will be requested to return their data forms to the Program Coordinator as soon as possible after sampling in pre-addressed envelopes supplied by FOCB. (More detail on the handling of data forms is given in Section D.23) The Program Coordinator will contact monitors who are not sending in their data forms on a timely basis.

Each primary monitor will be supplied at the beginning of the season with a supply of preprinted labels for the site to which the monitor is assigned. The labels will be preprinted with the site code and site name, and with the codes and names of the primary and alternate monitors for that site. The monitors will be instructed that when sampling the site, they should attach a label to the data form and circle their name. If an alternate monitor is going to sample the site, they should receive the supply of labels along with the kit from the primary monitor. If a monitor other than the regular primary or alternate is going to sample the site, they should receive the supply of labels from the primary monitor and write their name in. This should ensure that the site will always be referred to by a consistent name which does not duplicate the name of another site.

Upon receipt of the data forms, the Program Coordinator will check them for missing or obviously incorrect data, including the sampling date and time. As described in Section A9, monitors will be contacted by phone (or e mail) to answer questions about data that appear to be in error.

All equipment, meters, and kits will be checked by the Program Coordinator to ensure that operations are within technical specifications before being issued. Thereafter, equipment will be evaluated at QA sessions, and any faulty kits and equipment will be replaced. All records on the equipment checks, maintenance, and replacement will be kept on file by the Program Coordinator. The Program Coordinator should keep replacement equipment and reagents on hand at all times, and will also distribute equipment and reagents to the regional coordinators to establish local depots.

The FOCB Citizens Water Quality Monitoring Training Manual describes the proper handling and maintenance of equipment. These aspects will be emphasized during the training and annual QA sessions. Monitors will be asked to contact the Program Coordinator if any equipment fails to operate properly. The Program Coordinator will arrange for delivery or pickup, or send requested replacements by return mail immediately.

The activities to be included in the QA exercises constitute performance and system audits. All of the performance and system audits described in this plan, including training sessions, QA sessions, and field site visits will be performed.

Volunteer monitors will be required to attend the CSWQM training program and complete minimum training requirements before monitoring. The minimum training requirements include the following:

- Demonstrations with detailed instructions of the following parameters: temperature, Calibration of the Hanna pH meter, pH sampling, dissolved oxygen, salinity, and Secchi depth procedures.
- Hands-on practice of all sampling, testing, and safety procedures.
- On-site training session with each monitor covering monitoring and safety procedures.

Additional on-site sessions will be conducted, if necessary, until proficiency in all required techniques is demonstrated by the monitor. Training will be conducted by FOCB trainers with input and help from the DEP and from SMCC faculty. A training checklist (Figures 7 and 8) will be completed for each volunteer trainee, and these checklists will become a part of the training certification and maintained in the volunteer's records.

Group QA sessions will be held before the start of each seven-month monitoring season by the Program Coordinator. Monitors will be required to attend one session per year. (Due to the relatively short length of the sampling season in Maine, it is impractical to hold semiannual QA sessions as some more southerly groups do.) Monitors are sometimes unable to attend one of the group QA sessions due to scheduling conflicts or to residence out of the area during the winter. For these monitors, the Program Coordinator will arrange for an individualized Aon-the-road@ QA session at the monitor's site or home using a QA kit developed by FOCB to duplicate the exercises performed in the group QA sessions.

The results of the group and individual QA exercises will provide a measure of how well monitors perform individually and as a group. Data collected at the QA sessions will be used to assess the accuracy and precision of the data collected in this program (see Section B16 for more details). Results and analysis from the QA sessions will be kept on file by the Program Coordinator.

Quality Control

Several measures have been put in place to incorporate quality control in the Citizen Stewards Monitoring Program. During our initial training classes and during annual retraining classes volunteers are asked to collect and titrate dissolved oxygen samples in triplicate, measure and calculate three different levels of seawater to demonstrate their ability to use and read a hydrometer in the field for salinity measurements, and perform duplicate measurements for Secchi depth.

B. Profile Monitoring

Quality Assurance for the Profile portion of the monitoring program is robust. All YSI datasonde equipment is calibrated pre deployment and checked post deployment All calibrations are recorded in the calibration log books as are sensor replacement, battery replacement, general condition of sonde, and sensor replacement due dates. Each calibration log tracks sensor performance and if the sensor does not meet data quality objectives (p8-10) the sensor will be replaced.

Since all Profile sampling is collected by boat there may be times of poor weather conditions or mechanical difficulties that may preclude our research crew from getting on the water. Projected sampling dates are scheduled mid-month which allows for two weeks to reschedule a sampling trip if necessary. Since 1993 only 3 occasions have occurred where our crew was unable to collect their monthly profile data, all three were due to unforeseen mechanical issues with our research boat at the end of the month.

Quality Control measures for the YSI 6600 during profiled monitoring consist of logging duplicate measurements at the two meter mark during all profiles. This consists of sampling at the surface, at the one meter depth, two meters then every two meters until the instrument touches the bottom. As the meter is then pulled up from the bottom it is stopped again at the two meter level and a second set of data are logged. For QC measures the two logged datasets are compared, if they differ more than 1.0 C for temperature, 1 ppt for salinity, 1.0 mg/l for dissolved oxygen, then the data will be flagged in the database.

Duplicate samples and field blanks will be performed on DIN & TN samples during a randomly selected profile monitoring event to measure field and lab quality control. One duplicate surface or bottom sample will be randomly chosen and collected to measure field sampling and processing procedures.

C. Continuous Monitoring

Turner Designs C-Sense pCO2 Sensor

Quality Assurance & Quality Control
The C-Sense pCO2 sensor will be returned to Turner Designs annually for calibration. During deployment, the sensor will be cleaned by gentle application of dilute laundry detergent (as described in the sensor manual) on at least a monthly basis. Additionally, a check of the sensor against another instrument, and possibly the use of a blank, will be done as opportunity allows.

YSI 6600 datasonde

Quality Assurance
All YSI datasonde equipment is calibrated pre deployment and checked post deployment against NIST certified calibration standards. All calibrations are recorded in the calibration log books as are sensor replacement, battery replacement, general condition of sonde, and sensor replacement due dates. Each calibration log tracks sensor performance and if the sensor does not meet data quality objectives (p8-10) the sensor will be replaced.

Each datasonde is sent to YSI headquarters for annual maintenance in order for YSI to confirm sensor accuracy and perform routine maintenance along with any software upgrades if necessary.

Quality Control
Equipment deployed during the unattended monitoring program is exchanged on a biweekly basis. Prior to the physical exchange of equipment, data collected by the installed YSI6600 in the lobster trap will be compared to data logged by the replacing YSI6600 to insure data consistency. This comparison will allow for seamless data and a means to measure equipment performance. For QC measures the two logged datasets are compared, if they differ more than 1.0 C for temperature, 1 ppt for salinity, 1.0 mg/l for dissolved oxygen, then the data will be flagged in the database.

FIGURE 7. CSWQM MONITOR TRAINING RECORD, SIDE 1

FRIENDS OF CASCO BAY - CITIZENS WATER QUALITY MONITORING PROGRAM
MONITOR TRAINING RECORD, SIDE 1

NAME: ______________________ MONITOR #: ___ ___ ___ ___ ___
ADDRESS: ______________________
TOWN, STATE: ______________________ ZIP: __________
TELEPHONE #'S: HOME: ______________________ WORK: __________
E MAIL ADDRESS: ______________________ CELL: __________

INFORMATION ON ASSIGNED SITE
SITE NAME: ______________________ SITE #: ___ ___ ___ ___ ___
AKA: ______________________ KIT #: ___ ___

INITIAL TRAINING SESSION DATE: ___ ___/___ ___/___ ___
TRAINER(S): ______________________

	Demonstrated by Trainer (Y/N)	Performed by Monitor (Y/N)	Comments
Observations:			
Weather			
Wind Direction & Speed			
Water Surface			
Tide Stage (calculation of)			
General			
Test Procedures:			
Air Temperature			
Water Temperature			
pH Calibration			
pH			
DO Sampling			
DO Titration			
Salinity			
Secchi Depth			

Additional Information:
____
____
____
____
____
____
____
____
______________________ Photo: ☐ (Ck if yes)

FIGURE 8. CSWQM MONITOR TRAINING RECORD, SIDE 2

FRIENDS OF CASCO BAY - CITIZENS WATER QUALITY MONITORING PROGRAM
MONITOR TRAINING RECORD, SIDE 2

NAME:________________________________ MONITOR #:

CURRENT SITE INFORMATION
SITE NAME:____________________________ SITE #:
AKA:_________________________________ KIT #:

SITE VISIT DATE: / /
TRAINER(S):_________________________________

	Performed by Monitor (Y/N)	Comments
Observations:		
Weather		
Wind Direction & Speed		
Water Surface		
Tide Stage (calculation of)		
General		
Test Procedures:		
Air Temperature		
Water Temperature		
pH Calibration		
pH		
DO Sampling		
DO Titration		
Salinity		
Secchi Depth		

Site Description: ________________________________

Latitude: : : Longitude: : :

________________ is hereby certified as a Water Quality Monitor.

Trainer's signature **Date** **Monitor's signature** **Date**

B.15. & B.16. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND CALIBRATION, MAINTENANCE REQUIREMENTS

The calibration equipment used for comparison measurements during QA sessions will be available from FOCB. FOCB will maintain and calibrate the YSI Model 556 multi parameter system (MPS), Orion Model 140 Salinity-Conductivity-Temperature meter and the more precise YSI Model 6600 Data Sonde. FOCB will also provide the NIST certified thermometer and portable pH meter. Backups for all of the above equipment can be provided, as availability allows by SMCC, Bowdoin College, Normandeau Associates, or Pine Environmental Services.

Calibration and maintenance procedures will be as follows:

<u>Temperature</u>

Monitored with:

- Armored, alcohol-filled thermometer; Model 545; range -5.0 to +45.0°C in 0.5°C increments. LaMotte Company; Cat. No. 1066.
- Hanna Waterproof pH Tester, Model HI 98128; range -5.0 to +50.0°C in 0.1°C increments. Ben Meadows Co; Cat. No. 78289

Monitored from BayKeeper boat and unattended sonde with:

- YSI Model 6600 Data Sonde with YSI Model 6560 Conductivity/Temperature probe; temperature range -5.0 to + 45.0°C in 0.01°C in 0.01°C increments; accuracy ±0.15°C.

Calibrated with:

- Thermometer factory-certified against National Institute of Standards and Technology (NIST) standards and traceable to NIST; range -10.0 to +55.0°C in 0.1°C increments. Brooklyn Thermometer Company Inc.; Cat. No. 3231RM-A-FC.

Or: ANSI/SAMA accuracy thermometer calibrated and certified against equipment whose calibration is traceable to NIST; range -1.0 to +51.0°C in 0.1°C increments. VWR Scientific Products; Cat No. 61027-205.

The monitors' thermometers will be calibrated before initial use and during QA sessions thereafter. Comparisons will be made with a calibration thermometer for two different temperature solutions within the -5 to +45°C range. The YSI DO meter will be calibrated on each day of use with a calibration thermometer for one solution within the -5 to +45°C range. The ANSI/SAMA thermometers will be calibrated annually with the NIST thermometer for two different temperature solutions within the -5 to +45°C range.

Monitors will be instructed to visually inspect the armored alcohol filled thermometers and thermisters on the Hanna waterproof meters for separation of red or green fluid before entering the field, to handle thermometers carefully, to avoid storing them in hot places, and to rinse them with fresh water after use.

pH

Monitored from BayKeeper boat with:

-YSI Model 6600 Data Sonde with YSI Model # 6561 pH Probe; range 0.0 to 14.0 units. pH units in 0.01 unit increments.

-Hanna Waterproof pH Tester, Model HI 98128; range 0.00 to 14.00 units. pH units in 0.01 unit increments. Ben Meadows Co; Cat. No. 78289

The Hanna pH meters will be calibrated during QA sessions by comparative measurements using a portable pH meter and a seawater sample. The Hanna & YSI pH meters will be calibrated on each day of use using three pH buffer reference standards.

Monitors will be evaluated during QA sessions for their ability to accurately interpret pH readings. pH meter levels outside the expected range of known solution will be removed from service until it can be repaired or replaced.

Monitors will be given instructions on how to take care of their pH meters. Instructions for all monitors regarding pH meter care can be reviewed in video and written form at www.cascobay.org

Salinity

Monitored with:

- LaMotte hydrometer with 500-ml hydrometer jar; range l.0000 to 1.0700 specific gravity in 0.0005 increments (0 to 42 ppt salinity). LaMotte Company; Cat. Nos. 3-0011 (hydrometer) and 3-0024 (jar).

Monitored from BayKeeper boat and unattended datasonde with:

- YSI Model 6600 Data Sonde with YSI Model 6560 Conductivity/Temperature probe; Salinity range 0 to 70 ppt; accuracy ± 1.0% of reading or 0.1 ppt, which ever is greater.

YSI and Orion S-C-T meters calibrated with:

- NIST certified conductivity standard, 10,000 & 50,000 µmhos, YSI No. 3163 & 3169 respectively. VWR Scientific Products; Cat. No. 23202-285.

The hydrometers will be calibrated using three different saline solutions within the 0 to 35 ppt range. Calibrations will be performed before initial use and at QA reviews. The YSI and Orion S-C-T meters will be calibrated on each day of use using NIST certified conductivity standards.

Monitors will be evaluated for their ability to correctly read the hydrometer. They will be shown how to calculate the salinity from the specific gravity measurement using the conversion table. Monitors will be instructed to record the specific gravity from the scale in the hydrometer stem at the point where the scale crosses the level of the water sample in the jar, not at the top of the meniscus. Monitors will also be instructed to read the hydrometer with their eyes level with the water surface in the hydrometer jar; viewing up or down at an angle can give an incorrect reading.

Hydrometers are fragile instruments and are subject to breakage. The hydrometers will be carefully packaged when distributed to the monitors - they will be enclosed in the plastic cylinder in which they are shipped and secured in a foam insert in the supplied carrying case. Monitors will be instructed to use care when handling the hydrometer and to return it directly to its protective case immediately after use. The hydrometer and hydrometer jar should be rinsed with fresh water and dried after use.

Dissolved Oxygen

Monitored with:

- Precision Dissolved Oxygen test kit, azide modification of Winkler titration method; range 0.0 to 20.0 mg/l in 0.1 mg/l increments. Reagents sufficient for 25 tests at 0.0 to 20.0 mg/l range. LaMotte Company; Cat. No. 5856/XDO.

Monitored from BayKeeper boat with:

-YSI Model 6600 Data Sonde with YSI Model 6562 Rapid Pulse DO Probe; DO range 0 to 50 mg/l; accuracy ± 2% of reading or 0.2 mg/l of reading (which ever is greater) up to 20 mg/l; ± 6% of reading from 20 mg/l to 50 mg/l.

Calibrated with:

- Standard Winkler titration with azide modification. EPA-approved method 360.2.

The test kits and the YSI Model 6600 Data Sonde will be calibrated against each other during QA sessions. The YSI Model 556 & 6600 will also be calibrated semiannually against the standard Winkler titration. One of these calibrations will be done shortly before the first QA session of the year. On each day of use the DO meter will also be calibrated with water-saturated air.

To ensure the reliability of the results obtained using the LaMotte Dissolved Oxygen kit under conditions that preclude measuring against a standard each time a test is conducted, monitors will be trained on certain precautions to be followed. Monitors will be instructed to perform duplicate measurements each sampling time. They will be told to store the reagents in a dark, cool place. They will be cautioned about possible contamination and instructed in how to prevent it: never return any unused titrant to the reagent bottle, check for particulate matter in the reagent bottle, and thoroughly rinse all equipment after each use.

Water Clarity

Monitored with:

- Secchi disk, 20 cm diameter, stretch-resistant line. LaMotte Chemical Products; Cat No. 0171-CL.

Secchi disks with black and white quadrants are used to determine the limit of visibility. The lines supplied by LaMotte are marked at 0.5 meter intervals up to 20 meters. Additional markings at 0.1 meter intervals (of a different color from the 1.0 meter marks) will be added by FOCB up to twelve meters before the disks are distributed to the monitors. Few stations require more than seven meters of line for measuring either water depth or Secchi depth but at some site locations water depth may exceed seven meters. The accuracy of the depth markings will be checked before initial use and during QA sessions thereafter.

Partial Pressure Carbon Dioxide

PCO2 is measured by use of a Turner Designs C-Sense sensor. This sensor is factory calibrated and can only be repaired/calibrated by Turner Designs. The instrument is sent to Turner Designs annually for calibration check and maintenance.

B.17. INSPECTION/ACCEPTANCE REQUIREMENTS FOR SUPPLIES

In 1992 and 1993 FOCB staff worked extensively with vendors to find equipment appropriate for CSWQM program that met the QA/QC requirements as outlined in Section A.7.

In collaboration with technical support personnel from LaMotte Co. and the Friends of Casco Bay, the Casco Bay Tidal Water Monitoring Kits, Mod.# XX00143 & Mod.# XX00144, were established and put into circulation. Each kit is supplied with the necessary equipment to perform tests for dissolved oxygen, temperature, salinity, pH, & water clarity.

All equipment and chemical reagents for the Casco Bay Tidal Water Monitoring Kits are inspected annually during QA training, immediately upon return from any volunteers leaving the program, and at the end of the season. Any equipment determined to have failed will be replaces prior to use in the field.

All chemical reagents for the kits are inspected for expiration dates when purchased and will be used only if they are within the recommended shelf life. All reagents will be replaced annually to insure the best quality obtainable. At annual QA sessions with volunteers, lot numbers and expiration dates are recorded on special QA data sheets. If a vendor reports any reagent to be defective, it will be removed from those kits.

All supplies for DIN sampling are purchased through VWR scientific. Each vial supplied to staff and volunteers are prelabeled with a unique identifiable code. Each volunteer will be supplied with (20) 20 ml scintillation vials, (20) Pall Life Sciences *Acrodisc*, single use 0.45 µm filters, (2) 60 ml B&D syringes and 1 Large Zip Loc freezer bag for sample storage in freezer. Also included in DIN supply kit is a chain of custody form.

Sample supplies needed for TN collection are furnished by The Chesapeake Biological Laboratory (CBL) and consist of a 30 ml Nalgene jar per site. Samples are stored in a cooler when in the field and are then frozen at FOCB lab prior to relinquishment to CBL.

B.18. DATA ACQUISITION REQUIREMENTS

For the CSWQM Program U.S.G.S. topographic maps and/or NOAA Navigational charts No. 13290 & 13292, or approved chart reproductions AWater Proof Chart@ # 101E are used to identify site locations. Printed copies with marked site ID’s are provided to each volunteer and will be filed in a site folder containing further descriptive information pertaining to that specific site.

B.19. DATA MANAGEMENT

The data will be reviewed by the Program Coordinator for decimal point errors, missing site and/or monitor numbers, apparently anomalous data, and general problems. Monitors will be contacted by phone to answer questions about data that appear to be in error or missing. Contact with the volunteers regarding data problems is the responsibility of the Program Coordinator.

After adjustment and review, the data will be entered into the MURPHY 2010 database program, a computer program developed by FOCB. Among other checks and calculations, MURPHY adjusts pH data measured using the narrow-range, cresol red indicator (for data collected prior 2005 when the program adopted the use of Hanna pH meters for all monitors) to compensate for known errors resulting from interferences with cresol red at medium to high salinities. The raw data is decreased by factors ranging from 0.21 units at 14 ppt salinity to 0.27 units at 32 ppt salinity. Both the raw and corrected data are stored in the database.

Where salinity data have been measured using a hydrometer, MURPHY uses the specific gravity and temperature readings to calculate salinity values which can be used to confirm the salinity values calculated by the monitors. MURPHY also uses temperature, salinity, and dissolved oxygen concentration data to calculate values for percent saturation dissolved oxygen.

Checks will be made by FOCB between the data listing and the raw data whether the data were entered by FOCB or by the monitor. The data will be evaluated for the mean, minimum, and maximum values for each parameter with site and time series plots of data every three months. A data documentation file will be kept current. Data will be presented using the graph and report formats developed for the MURPHY program and through the development of a Casco Bay Health Index created by Research Associate, Mike Doan. Copies of the data printouts will be sent to the monitors so that they may review them and report any errors to the Program Coordinator.

All data generated by the CSWQM program will be sent to Maine DEP & CBEP on disk by the Program Coordinator annually. Data will also be sent to members of the general public upon request.

C.20. ASSESSMENT AND RESPONSE ACTIONS

All data reported for the CSWQM program will be subject to checks by the CSWQM Program Coordinator for errors in transcription, calculation, or computer input. Additionally, all data forms will be reviewed to ensure that they are complete and signed by the volunteers. All data forms must be signed and dated on the back of the original data form by the reviewer. Any changes made to the data form must be initialed and dated, and any action taken as a result of the data review must be recorded on the data form below the reviewer's signature.

Only data that meets the following conditions will be accepted and entered into the CSWQM Data File:

- Monitors have appropriate levels of training for the tests being conducted.
- Monitors have successfully participated in required training or QA reviews.
- Equipment has been checked and approved prior to or during an annual QA review.
- Data forms are signed by monitors, and date, time, station number, and station description are recorded.
- All required equipment calibrations have been completed and recorded.
- Data entries are legible.

C.21. REPORTS

Status reports will be submitted monthly by the Program Coordinator to the Director of the Casco Bay Estuary Partnership. The content of these reports will be determined by the work plan amended yearly and approved by CBEP. The reports will include any significant progress or changes for the following QA elements:

- Status of the monitoring program including the stage of planning and implementation.
- Results of any performance checks.
- Identification of significant QA/QC problems and recommended solutions.
- Outcome of corrective actions.
- Completeness of CSWQM data set to date.
- Updated list of trained monitors and monitoring sites.

D.22. DATA REVIEW, VALIDATION AND VERIFICATION REQUIREMENTS

As part of the data review and validation, all field and lab data will be reviewed and discussed by the Program Coordinator to determine if the data meet the objectives as outlined in the QAPP. Decisions will be made to accept or reject the data before presenting the information in any presentations or reports. Errors in data entry will be corrected and any outliers will be flagged for further review. Any data deemed to be not acceptable will be noted in the comments fields of the CSWQM database and will be removed from any statistical calculations.

The data will be used by Friends of Casco Bay to support its mission; *To improve and protect the environmental health of Casco Bay*. Data will also be provided to support the efforts of the Casco Bay Estuary Partnership under the guidance of the Casco Bay Plan. In addition, data will also be provided to the Maine Department of Environmental Protection for use in state 305B reports and to members of the greater academic community and/or general public upon request.

D.23. VALIDATION AND VERIFICATION METHODS

Data validation and verification is a multi-step process performed by two or more people. Data will be reviewed by the Program Coordinator before being entered by volunteers, student interns or FOCB staff into the CSWQM MURPHY 2010 database. After being entered, the data sheets will then be checked against the data entry in the database by someone other than the person who initially entered the data. If entry errors are found, edits will be made and the data sheet will be re-checked (by someone other than the entry person) vs the database. If entry checked vs the database are parallel the data sheet will then be filed in a site specific folder for future data queries. All data entry procedures require signoff by the data entry personnel as illustrated in table 6.

TABLE 6. VALIDATION & VERIFICATION SIGN-OFF

Staff use ONLY	Date	Initials
Sheet rec'd		
Data ck'd		
Data entered into database		
Entry ck'd vs sheet		

D.24. RECONCILIATION WITH DATA QUALITY OBJECTIVES

Data quality objectives and validation procedures for this program have been designed to ensure that volunteers and/or the Program Coordinator will be able to identify and correct problems in data collection and reporting. Should the results of data validation measures or quality assurance reviews indicate that the integrity of data is questionable and data quality objectives are not being met, the data set (or that portion which is deficient) must be flagged as unacceptable for inclusion in the CSWQM Data File.

Quality assurance and control reviews are part of this monitoring program and are designed to ensure that work is performed by volunteers who are well trained and understand the objectives and methods being used. QA sessions will be conducted by FOCB trainers and reviewed by the Program Coordinator. Results recorded at QA reviews will be discussed with the monitors during each session, and any difficulties or differences in technique can be corrected immediately. If a monitor's performance fails to meet the data quality objectives or demonstrates a lack of safety measures, the monitor will be required to have additional training. Also, defective equipment or outdated reagents detected during QA sessions will be replaced.

The responsibility for deciding to take any corrective action rests with the Program Coordinator. The Program Coordinator is responsible for ensuring that all corrective measures recommended from QA reviews are implemented by monitors. The Program Coordinator has the authority to question data, call for re-training, and recommend replacement of monitors when necessary.

The data from the unattended deployment and profiles, both from the sonde and the C-Sense, with be reviewed for quality and unexpected values. Measurements that were clearly taken when the instruments were not deployed, such as during delivery to or removal from the station, will be removed. All other anomalous readings will be flagged. The Research Associate will be responsible for these tasks.

APPENDIX 1

FRIENDS OF CASCO BAY
ENVIRONMENTAL MONITORING PROGRAM
WATER QUALITY ADVISORY COMMITTEE

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Division of Environmental Assessment
Bureau of Water Quality
Maine Department of Environmental Protection
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Director, School of Marine Sciences
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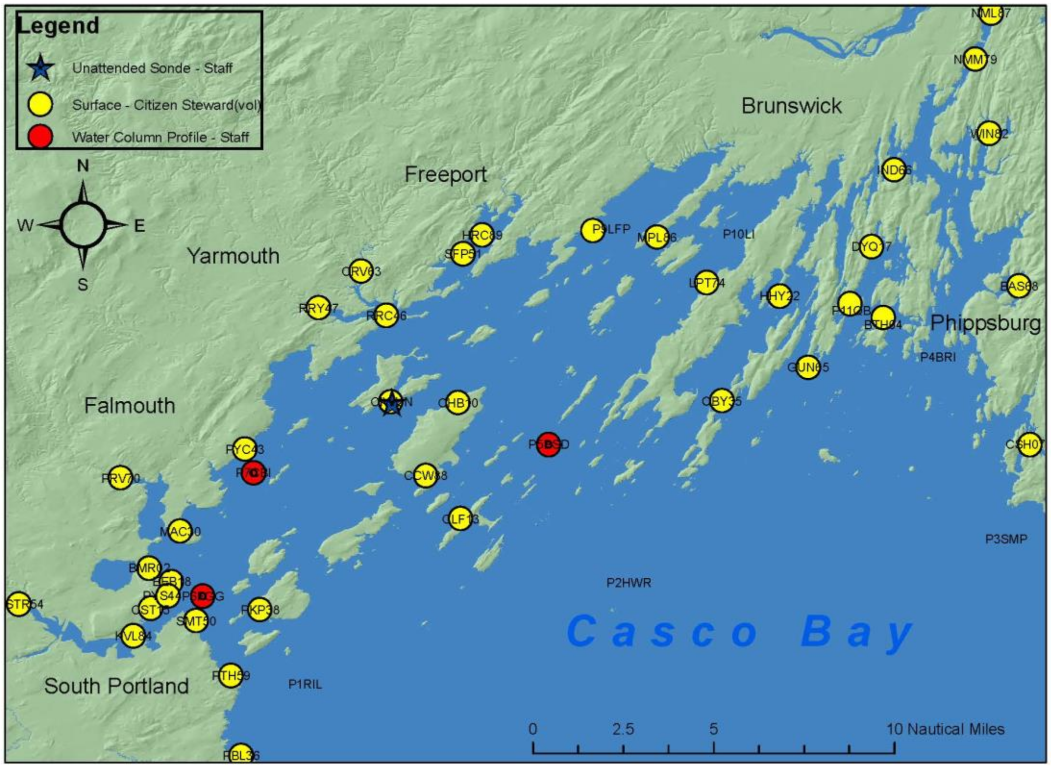
Brian P. Tarbox
Faculty, Biology Department
Southern Maine Community College
2 Fort Road
South Portland, ME 04106
btarbox@smccme.edu
(207) 741-5767

APPENDIX 2
FOCB Water Quality Monitoring Sites



APPENDIX 3

Reference for the University of Maine Dissolved Inorganic Nutrients Standard Operating Procedures

Whitledge TE, Veidt DM, Mallow SC, Patton CJ, Wirick CD (1986) Automated nutrient analyses in seawater. Publ Brookhaven Natl Lab (BNL) NY 38990.

Note: A complete electronic version of this document can be furnished by FOCB staff upon request. Below is the table of contents as reference.

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APPENDIX 4

Reference for the University of Maryland
Center for Environmental Science
Chesapeake Biological Laboratory
Total Nitrogen Analysis

Analysis will be conducted by the Nutrient Analytical Services of the Chesapeake Biological Laboratory in Solomons, MD.

Total Nitrogen will be determined through the persulfate method, a persulfate oxidation technique for nitrogen where, under initially alkaline conditions, nitrate is the sole nitrogen product. Digested samples are passed through a granulated copper-cadmium column to reduce nitrate to nitrite. The nitrite then is determined by diazotizing with sulfanilamide and coupling with N-1- naphthylethylenediamine dihydrochloride to form a colored azo dye. Color is proportional to nitrogen concentration.

D'Elia, C.F., P.A. Steudler, and N. Corwin. 1977. Determination of total nitrogen in aqueous samples using persulfate digestion. Limnol. Oceanogr. 22: 760-764.

Valderrama, J.C. 1981. The simultaneous analysis of total nitrogen and total phosphorus in natural waters. Mar. Chem. 10: 109-122.

The results are presented as mg N/L, the analysis is sensitive to 0.01 and the MDL is reported 0.05.

The most recent SOP can be found here:

http://www.umces.edu/sites/default/files/TDN%20Enzyme%20Catalyzed%20%20Nitrate%20SOP%202017-1.pdf

C-sense

in situ pCO_2 Sensor

User's Manual

April 30, 2015
P/N 998-2410
Revision D

TURNER DESIGNS
1995 N. 1st Street
San Jose, CA 95112
Phone: (408) 749-0994
FAX: (408) 749-0998

Table of Contents

WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE) DIRECTIVE

Turner Designs is in the business of designing and selling products that benefit the well-being of our environment. Accordingly, we are concerned with preserving the surroundings wherever our instruments are used and happy to work with customers by complying with the WEEE Directive to reduce the environmental impact resulting from the use of our products.

WEEE Return Process:

To arrange the return of an end-of-life product, proceed as follows:

If you purchased your instrument through a Turner Designs Distributor please contact your local representative. They will instruct you where to return the end-of-life product.

If you purchased your instrument directly from Turner Designs please contact Turner Designs Customer Service

By Phone: 1-408-212-4041 or Toll Free: (877) 316.8049

By Email: Customer Service at support@Turner Designs.com

Turner Designs will provide a WEEE RMA Number, a Shipping Account Number, and a Ship to Address. Package and ship the product back to Turner Designs.

The product will be dealt with per Turner Designs' end-of-life recycling program in an environmentally friendly way.

1. Introduction

C-sense is a compact, lightweight, plug-n-play sensor designed for measurement of the partial pressure of CO_2 gas in liquids. Combining an oil resistant hydrophobic membrane and a temperature compensated non-dispersive infrared (NDIR) detector, C-sense measures the partial pressure of CO_2 in water, oil, and water and oil mixtures.

C-sense operates through the diffusion of gas across a hydrophobic membrane into an isolated headspace. While any resident gas may enter the headspace, the wavelength of the infrared sensor is specific to CO_2 absorption. The amount of absorption of that wavelength is proportional to the concentration of CO_2 gas in the headspace.

C-sense automatically compensates for changes in temperature, however, the effects of water vapor and variable total dissolved gas pressure (TDGP) can be significant and should be considered. TDGP is the total pressure exhibited by all gasses within the water column. When this pressure greatly exceeds the pressure at which the C-sense was calibrated, the output of the C-sense should be corrected. This correction is outlined in Appendix D, “Correcting for High TDGP.”

Water vapor absorbs at the same wavelength as CO_2 and therefore the presence of water vapor in the headspace can cause an overestimation of the CO_2 concentration. This effect can’t be corrected for without measuring relative humidity within the headspace. For a discussion of how water vapor affects the operation of the C-sense, see Appendix E, “Effects of Water Vapor on Measuring pCO_2.”

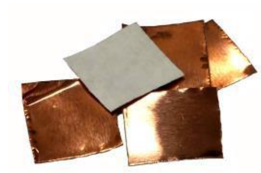
Operation of C-sense requires supplying 6-12 VDC and recording an output of 0-5 VDC. The output of the sensor is directly proportional to the concentration of pCO_2. In order to obtain quality measurements, a user needs to understand the effects of the equilibration time and warm-up time of the NDIR detector in the context of the intended sampling protocol.

2. Instrument Setup

2.1 Instrument Checklist

Each sensor purchase comes complete with:

- C-sense Analog Sensor with a 4-pin Impulse connector (MCBH(WB)-4-MP-SS)
- Copper tape cut outs (30 ea.) P/N: 2400-506
- USB drive with documentation



2.2 Optional Accessories

- Pigtail Cables with Locking Sleeve
  0.6 meter pigtail cable with locking sleeve P/N: 105-2410
  5 meter pigtail cable with locking sleeve P/N: 105-2411
  10 meter pigtail cable with locking sleeve P/N: 105-2412
  25 meter pigtail cable with locking sleeve P/N: 105-2413
  50 meter pigtail cable with locking sleeve P/N: 105-2414

- Water-Pumped Head P/N: 2400-700

2.3 Gas Concentration Ranges Available

0–1000 ppm P/N: 2400-001

0–2000 ppm P/N: 2400-002

0–4000 ppm P/N: 2400-004

0–10,000 ppm P/N: 2400-010

Other C-sense ranges available by special order

2.4 Deployment

Turner Designs recommends the sensor be deployed horizontally in order to reduce or eliminate particulates in the water column from settling on the semi-permeable membrane and to release gas bubbles trapped or formed on the membrane surface.

An alternative solution to these potential sources of error is the use of the Water Pumped Head (PN: 2400-700). The shear forces generated by pumping water past the membrane will prevent settling of particulates as well as force bubbles out of the sample volume. In addition, the Water Pumped Head has the advantage of decreasing equilibration times.

2.5 Functional Test for C-sense

To perform a functional check on the C-sense, connect the colored wires from the pigtail to the power supply and multi-meter as shown in Figure 1 below.

Additional Equipment required for functional tests:
DC Power Supply, 6 - 12 VDC, >100 mA
Multi-meter to read 0 - 5 VDC

Note: Supply voltages greater than 13.5 VDC will result in damage to the sensor.

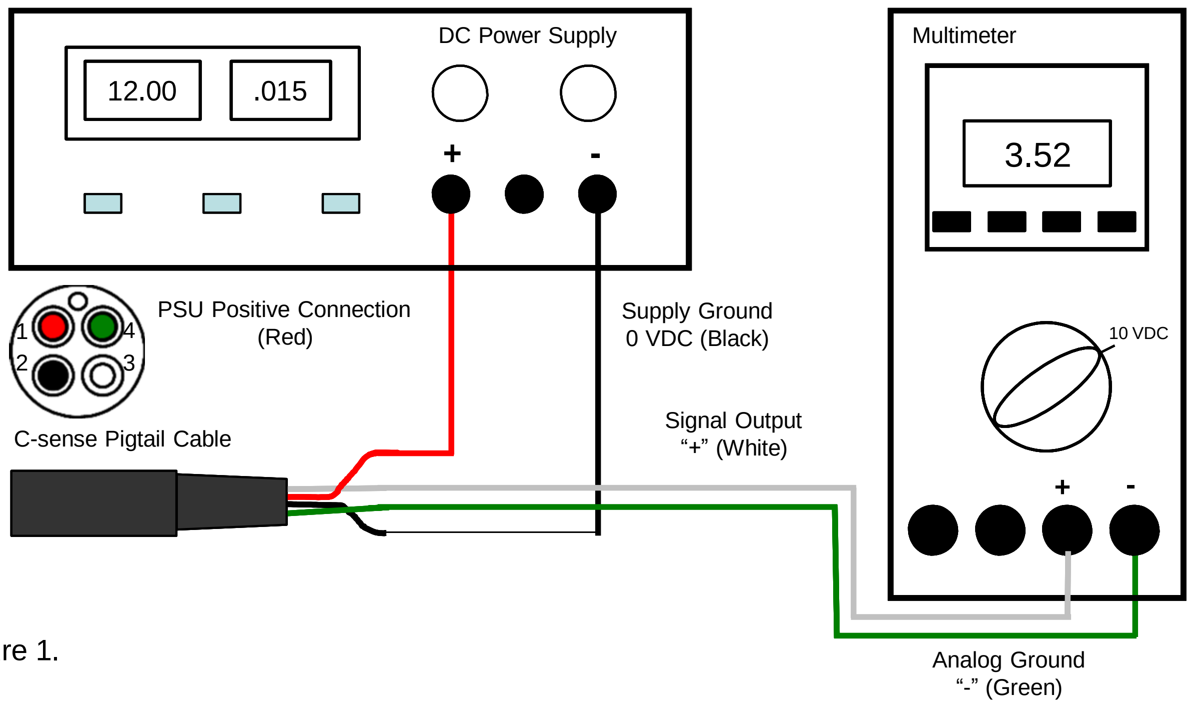


Figure 1.

With the C-sense connected as shown in Figure 1, answer the following questions to verify the sensor is functional:

1. Is there voltage output?
   The C-sense has a 45 second "warm-up" period during which the output values will be zero or near zero. After 45 seconds the output voltage should be at a level that corresponds to at least 400 ppm. This voltage can be calculated using the equation on your C-sense calibration sheet.

   For instance, if the equation on your calibration sheet is:

   y = 806.85x – 42.403

where y is the concentration of CO_2 in ppm, and x is the voltage from the C-sense in volts, set the concentration to 400 ppm and solve for x.

$x = (400 + 42.403)/806.85 = 0.5483$

Therefore, this C-sense sensor should output 0.5483 volts when the pCO_2 concentration is 400 ppm.

2. Does the voltage output change?
   To cause a change in the output voltage breathe across the membrane for at least one second. Human breath contains ~40,000-50,000 ppm of CO_2, therefore this should result in a significant increase in output voltage.

Note: Moving the sensor in air may not result in any change.

3. Maintenance

3.1 Gas Transfer Interface

The only component of the C-sense requiring maintenance is the gas transfer interface, a semi-permeable hydrophobic membrane. The membrane assembly is extremely sensitive and should never be disassembled or touched. The membrane and sensor face are engineered to minimize biofouling, however, under most conditions biofilms will slowly form on the surface of the membrane resulting in:

- An increase in equilibration time due to decreased permeability of the membrane.
- Reduced accuracy of CO_2 estimates due to production of CO_2 by organisms contained within the biofilm.

Care should be taken to ensure that the interface is not damaged through scratching or extreme gas overpressure. Small surface scratches on the interface can result in sudden failure and flooding of the instrument under large pressures, either hydrostatic or dissolved gas pressure. The outlined procedure for cleaning the interface (section 3.2) should be strictly adhered to.

In environments where total dissolved gas pressure (TDGP) is substantially above atmospheric pressure, caution is required when removing the sensor from water. As water pressure compresses the membrane against a pressure plate when submerged, any gas pressure buildup on the reverse side of the membrane can result in bulging of the membrane when removed from immersion. In cases of high TDGP, it is recommended to slowly bring the sensor to the surface while monitoring gas pressure. The excess gas pressure will slowly dissipate as the sensor approaches waters in equilibrium with the atmosphere. In addition, high TDGP causes significant error in the estimate of pCO_2 by the C-sense. See Appendix D for a discussion on how to correct for TDGP.

3.2 Cleaning the Interface

Biofilms can develop on the interface and alter the signal and response time of the instrument. Regular cleaning will minimize this effect. To clean the membrane interface:

1) Prepare a cleaning solution in an open container with 50 ml of liquid laundry detergent added to 20 liters of fresh water.
2) Place the sensor into the container and, using a small water pump, direct the flow of solution onto the membrane surface for 30 minutes.
3) Drain the container and refill with fresh water only.
4) Rinse the interface with fresh water using the water pump for 10 minutes.
5) Repeat steps 3 and 4.
6) If biofilms remain, repeat the process while extending step 2 to between 2 and12 hours.

Caution: Do NOT touch the membrane for any reason. The use of any object (sponge for example) to clean the interface can result in scratching by dragging particles across the membrane surface.

4. Troubleshooting

4.1 No output voltage:

- Check power connections and ensure power supply is between 6 and 12 V DC.
- Check connector diagram to ensure instrument is wired correctly. The sensor is reverse polarity protected, however, applying power to the output signal pin may result in failure.

4.2 Output reading remains at 0 V, 0.8 V or other voltage:

- Detector fault. The most probable cause is rapid change in conditions, typically temperature; wait for signal to return (5-15 seconds).
- Water damage. Check for water underneath the membrane as well as the location of a possible puncture. In the case of water damage, factory membrane and detector replacement is required. Contact Turner Designs Technical Support support@TurnerDesigns.com for an RMA.

4.3 The instrument does not read 400 ppm in air:

- A common thought is that the sensor will read 400 ppm in air. This is false. Typically readings are around 450 ppm outside and anywhere from 500-1500 ppm in buildings and labs.

4.4 During lab testing (in air) the sensor reads too high or shows large fluctuations:

- Human breath contains ~40,000-50,000 ppm CO_2, ensure sensor head is pointed away from human exhalation.

4.5 Equilibration time is really slow

- Biofilm or other foreign substance could be on the membrane. Follow the cleaning procedure in section 3.2.

4.6 Membrane appears loose or bulged:

- This can happen if the sensor was removed from high total dissolved gas pressure water too rapidly and the gas pressure behind the membrane greatly exceeded the hydrostatic pressure. Contact Turner Designs Designs Technical Support support@TurnerDesigns.com.

5. Warranty

5.1 Warranty Terms

Turner Designs warrants the C-sense and accessories to be free from defects in materials and workmanship under normal use and service for a period of 12 months from the date of shipment from Turner Designs with the following restrictions.

- Turner Designs is not responsible for replacing parts damaged by accident or neglect. Damage to the sensor or other internal electronics as a result of flooding from either a punctured membrane or an improperly user-applied o-ring seal is not covered under this warranty. Care must be taken to deploy instruments according to procedures described in this manual to minimize the possibility of damage due to flooding. Damage from corrosion is not covered. Enhanced corrosion activity and damage may result from improper electrical isolation between the C-sense and any supporting platforms attached to the instrument. Damage caused by customer modification of the instrument is not covered.

- This warranty covers only Turner Designs products and is not extended to equipment used with our products. We are not responsible for incidental or consequential damages, except in those states where this limitation is not allowed. This warranty gives you specific legal rights and you may have other rights which vary from state to state.

- Damage incurred in shipping is not covered.

- Failure of gas permeable membranes are not covered under this warranty.

- Welded mounting tabs and other mechanisms used to mount Turner Designs instruments to ships, buoys, mooring lines etc., are not covered under this warranty. Turner Designs expects the best and safest engineering practices to be applied by knowledgeable and experienced persons during the deployment and recovery of their instruments and cannot be held liable for any injuries or damages incurred during use of their instruments.

5.2 Warranty Service

To obtain service during the warranty period, the owner shall take the following steps:

1. Write, email or call Turner Designs Technical Support and describe as precisely as possible the nature of the problem.

   Phone: 1 (877) 316-8049

   Email: support@Turner Designs.com

2. Carry out any adjustments or tests as suggested by Technical Support.

3. If proper performance is not obtained you will be issued a Return Materials Authorization number (RMA) to reference. Package the unit, write the RMA number on the outside of the shipping carton, and ship the instrument, prepaid, to Turner Designs. If the failure is covered under the warranty terms the instrument will be repaired and returned free of charge, for all customers in the contiguous continental United States.

   For customers outside of the contiguous continental United States who purchased equipment from one of our authorized distributors, contact the distributor. If you purchased directly, contact us. We will repair the instrument at no charge. Customer pays for shipping, duties, and documentation to Turner Designs. Turner Designs pays for return shipment (custom duties, taxes and fees are the responsibility of the customer).

5.4 Out-of-Warranty Service

Follow steps for Warranty Service as listed above. If Technical Support can assist you by phone or correspondence, we will be glad to, at no charge. Repair service will be billed on a fixed price basis, plus any applicable duties and/or taxes. Shipment to Turner Designs should be prepaid. Your bill will include return shipment freight charges.

Address for Shipment:

Turner Designs, Inc.

1995 N. 1st Street

San Jose, CA 95112

Appendix A: Sensor Specifications

Parameter	Specification
Accuracy	3% of full scale
Power Consumption	80 mA @ 6 VDC (100 mA during warmup)
Input Voltage	6 - 12 VDC
Signal Output	0 - 5 VDC Analog
Operating Temperature Range	-2 to 35 °C Water Temperature
Detector	Non-Dispersive Infrared (NDIR)
Detector Stabilization Time	45 seconds - 3 minutes
t_{63} equilibration time	4 minutes
Housing Material	Delrin®
Dimensions (LxD)	8.0 x 1.97 in. (20.3 x 5.0 cm)
Depth Rating	600 meters
Weight	<1 lb, 430 g

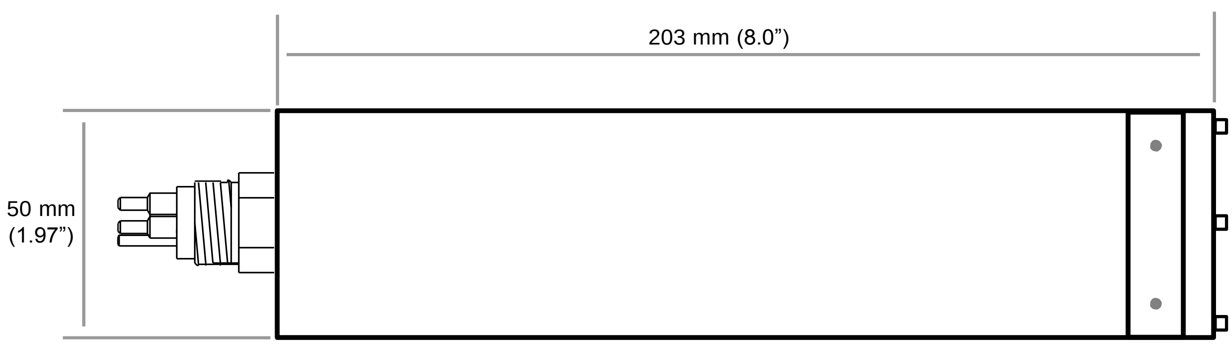


Figure AA1. Outer dimensions of the C-sense.

Appendix B: Wiring Guide

Pin Number	Color	Function	Connection
1	Red	Supply Voltage (6-12 VDC)	Positive Connection - PSU
2	Black	Supply Ground (0 VDC)	Ground Connection - PSU
3	White	CO_2 Analog Signal Out "+" 0-5 VDC	Multimeter Positive Connection
4	Green	Analog Ground "-" 0 VDC	Multimeter Negative Connection

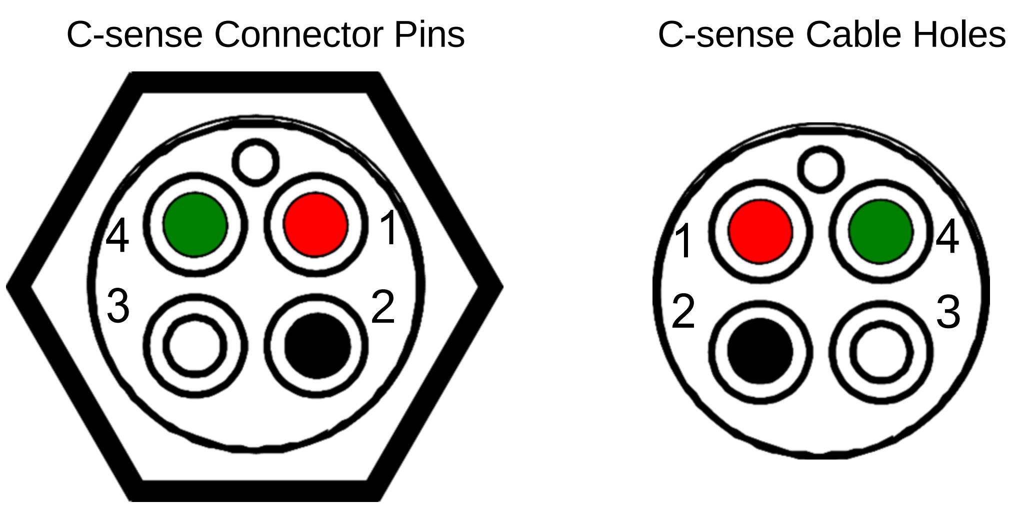


Figure AB1. Pinout diagram from the back of the C-sense. The connector is a 4-pin Impulse male: MCBH(WB)-4-MP-SS.

Appendix C: Calculating pCO_2 from C-sense Voltage Output

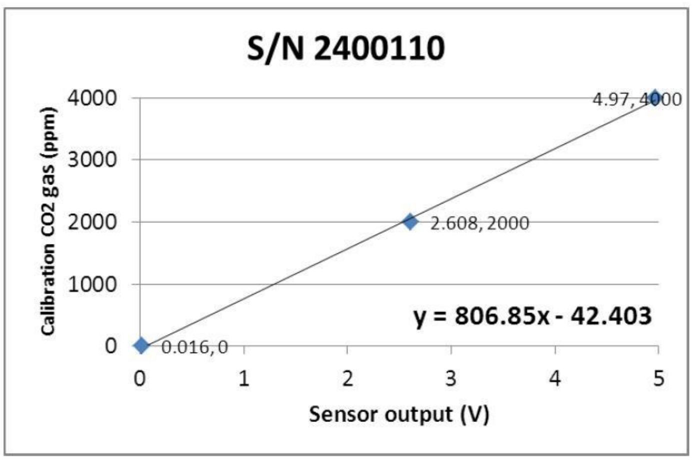
Below is a calibration sheet with the equation to convert voltage output from a 0-4000 ppm C-sense into pCO_2 concentration in ppm. The slope and offset in this equation are determined at the factory and are specific to C-sense serial number 2400110. Be sure to use the slope and offset specific to your sensor when making this calculation.

TURNER DESIGNS
Reliable Instruments for an Unreliable World

CERTIFIED QUALITY MANAGEMENT SYSTEM ISO 9001:2008 DNV

C-sense Serial #2400110
Calibration curve

Calibrated on February 20, 2014
at 100.7 kPa pressure



In the equation above, y is the concentration of CO_2 in ppm and x is the voltage coming from the C-sense. Using the 2 points defined on the graph at 2.608 VDC and 4.97 VDC as an example:

$y = 806.85(2.608) - 42.403 = 2061.9$ ppm

$y = 806.85(4.97) - 42.403 = 3967.6$ ppm

Appendix D: Correcting for High TDGP

The C-sense output is not compensated for gas pressure and, as a result, errors can be introduced when the total dissolved gas pressure (TDGP) in the liquid being measured is significantly different from the pressure at which the instrument was calibrated. Measuring TDGP at all times is preferred, but the accuracy of the C-sense precludes significant improvement in measuring pCO_2 by doing so in most cases. The instruments are calibrated at or near average sea-level atmospheric pressure of 101.3 kPa.

There are several reasons for deviations of TDGP in natural waters:

1) Whenever the ocean and atmosphere are in contact, equilibration of TDGP is occurring. Therefore, changes in atmospheric pressure drive changes in the TDGP of the water column.
2) Both natural and anthropogenic processes are responsible for adding to the TDGP of natural waters by generating turbulence at the air-sea interface. An example of a natural process would be breaking waves, while an anthropogenic process would be the disturbance of the water column by mechanisms associated with maritime transport (e.g. boat wakes, prop wash)
3) Natural processes of respiration and photosynthesis

Correcting the C-sense signal for deviations in TDGP is simple, provided TDGP is known or can be reasonably estimated. Each C-sense is calibrated at 20º C and an atmospheric pressure at or near 101.3 kPa. The actual pressure during calibration is stated on the calibration sheet and should be used in the following equation to calculate a corrected pCO_2 (pCO_2cor) from a measured pCO_2 (pCO_2mea):

$$\frac{pCO_2cor}{\text{calibration pressure}} = \frac{pCO_2mea}{TDGP}$$

or,

$$pCO_2cor = \frac{(pCO_2mea * \text{calibration pressure})}{TDGP}$$

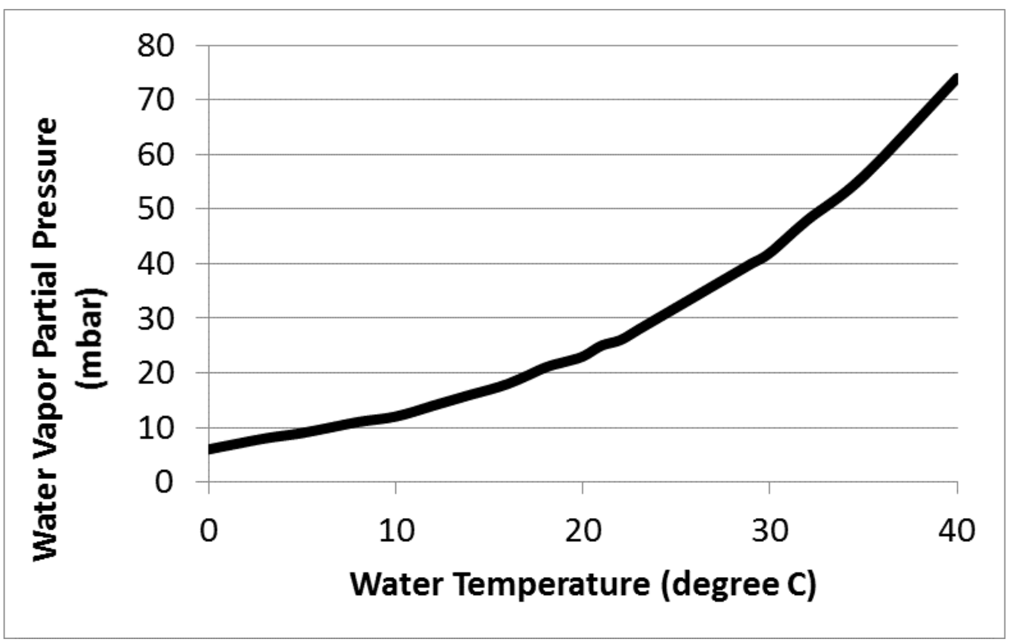
Appendix E: Effects of Water Vapor on Measuring pCO_2

C-sense employs a semi-permeable membrane to equilibrate a gas head space within the sensor with surrounding water. All gases dissolved in the water transfer across the membrane into the head space, including water vapor. The amount of water vapor in air is commonly referred to as humidity. For a sensor submerged in water, the relative humidity of an equilibrated gas head space is approximately 100%. Measurement of pCO_2 in this condition of 100% humidity is called a “wet” measurement.

There are two effects of water vapor on the pCO_2 reading of the sensor, elevated total dissolved gas pressure, TDGP, and a phenomenon called “pressure broadening of absorbance lines.”

The broadening of spectral absorbance lines is a minor effect of water vapor on the absorbance of CO_2 at low CO_2 levels and at low temperatures. For example, the error in pCO_2 for a 1000 ppm sample at 30º C is on the order of 4-6 ppm. At half this temperature the error drops to 2-3 ppm.

The more significant error due to water vapor is the contribution to TDGP. The figure below shows the total partial pressure exerted by water vapor as a function of temperature of the water. As water temperature increases the partial pressure of H_2O increases in a non-linear fashion.



Example:

pCO_2 measured = 1000 ppm
Calibration pressure = 1000 mbar
Atmospheric pressure = 1000 mbar
Temperature of water = 20º C

If the sensor was measuring CO_2 in the air, there would be no correction needed for pressure as the calibration pressure and atmospheric pressure are the same.

In water however, the TDGP is greater than atmospheric pressure due to the added partial pressure of H_2O. From the previous figure, at 20º C, an additional 20 mbar of gas pressure will be present in the water (and sensor gas head space). This equals a TDGP of 1020 mbar.

Using the following equation where pCO_2cor is corrected pCO_2 and pCO_2mea is the value measured by the C-sense:

$$pCO_2cor = \frac{(pCO_2mea * \text{calibration pressure})}{TDGP} = 1000 \text{ ppm} * \frac{1000 \text{ mbar}}{1020 \text{ mbar}}$$

pCO_2cor = 980.4 ppm

Corrected pCO_2: ~980 ppm.

Appendix F: Conversion of Common CO_2 Units

Gaseous CO_2 is commonly measured in units of parts per million (ppm). This is the ratio of the number of CO_2 molecules per million molecules of air. The ppm of CO_2 in air does not change with pressure. The ppm CO_2 is also referred to as the mixing ratio, xCO_2.

In natural waters, CO_2 (g) is often reported as a partial pressure, pCO_2, with units of microatmospheres (µatm). Unlike xCO_2, pCO_2 is dependent on the total dissolved gas pressure. The two terms are related by pressure and the following equation:

$$pCO_2 = xCO_2 * P$$

Where P is the pressure measured in atmospheres.

To convert an output from the C-sense of 430 ppm to µatm, divide the ppm (µmol/mol) value of 430 by $1x10^6$.

$$\frac{430\ \mu mol / mol}{1x10^6\ \mu mol / mol} = 4.3x10^{-4} \text{ (unitless)}$$

Then multiply that unitless ratio by the TDGP in units of µatm. If TDGP is 1.0005 atm, first convert to µatm by multiplying by $1x10^6$, resulting in 1000500 µatm.

$$4.3x10^{-4} * 1000500\ \mu atm = 430.2150\ \mu atm$$

From this example it follows that differences in the value of pCO_2 in units pf ppm and units of µatm, are a function of the TDGP. When TDGP is close to or at atmospheric pressure, the value of pCO_2 in units of ppm and µatm are similar. As the TDGP becomes more significant, so does the difference between pCO_2 in units of ppm and µatm.

A third unit of measure for CO_2 is the fugacity (fCO_2). The fugacity corrects for non-ideal gas behavior and can be estimated from approximate expressions along with the temperature and pCO_2. In most cases fCO_2 is within a few µatm of the pCO_2.

Appendix G: Logging Options for the C-sense

At present, there are two supported logging options for the C-sense

- DataBank Datalogger: For instructions on how to interface the C-sense with the Handheld DataBank or the DataBank Station, see the Quick Start Guide at the following web address:

  http://www.Turner Designs.com/t2/doc/tech-notes/998-2906.pdf

- Campbell Scientific CR1000: For instructions on how to interface the C-sense with the CR1000 datalogger, see the technical note at the following web address:

  http://www.Turner Designs.com/t2/doc/tech-notes/S-0162.pdf

- PME C-sense Logger: For instructions on how to interface the C-sense with the PME C-sense Logger, see the manual at the following web address:

  http://pme.com/wp-content/uploads/2015/02/C-sense-Logger-Manual.pdf.