Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #8
(21 March 2006 to 13 June 2006)

Prepared for:

Jacques Whitford Limited

Prepared by:

AMEC Earth & Environmental
32 Troop Ave.
Dartmouth, Nova Scotia
B3B 1Z1
Ph: (902) 468-2848
Fax: (902)

30 April 2009

DISCLAIMER

In conducting this study and preparing this report, AMEC has applied due diligence commensurate with normal scientific undertaking of a similar nature. In no event shall the consultant, its directors, officers, employees or agents be liable for any special, indirect or consequential damages, including property damage or loss of life, arising out of the use, interpretation or implementation of the data or any information enclosed in the report by any party, including without limitation, loss of profit, loss of production, loss of use, costs of financing, and liability to others for breach of contract.

PREFACE

The Halifax Harbour Water Quality Monitoring Project (HHWQMP) is an ongoing project, part of the Halifax Harbour Solutions Project (HRM and JWEL, 2002). It commenced in June 2004, before any of the proposed sewage treatment changes were put into effect, and is slated to continue for a year following the commission of the final plant (June 2009). The project is based on weekly sampling at over 30 sites located from the Bedford Basin to the Outer Halifax Harbour. Water samples taken at 1 m and 10 m depths are analyzed for a range of parameters. In addition, continuous profiles of basic hydrographic properties (salinity, temperature and density), dissolved oxygen and fluorescence are collected. The sample and profile data are presented in weekly reports along with ancillary data including water level, wind, rainfall and other parameters. The weekly reports are generated as inserts into a binder (JWEL and COA, 2004). The detailed datasets are also archived to CD and provided to the client. A detailed description of the program is contained in the introduction section of the report binder.

The weekly data sets are reviewed on a quarterly basis (13 weeks). The main objective of the quarterly reports is to summarize and evaluate the weekly data sets in terms of water quality objectives and concerns. The quarterly report also provides an opportunity to review the effectiveness of various aspects of the program and recommend changes that will improve the program. Project reports and data are available on the Halifax Regional Municipality (HRM) website: http://www.halifax.ca/harboursol/waterqualitydata.html

The HHWQMP program involves an extensive network of personnel including boat operators, field technicians, laboratory technicians and their associated equipment and procedures. The study team also includes managers, oceanographers and water quality experts. The routines, procedures, report and data archive formats are evolving as the project proceeds. These are documented in the project report binder.

Table of Contents

List of Figures

List of Tables

1 Introduction

This quarterly report is a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 21 March 2006 to 13 June 2006 (weekly reports 92 to 104). The data for the period are discussed in terms of compliance/exceedence of applicable water quality guidelines (Halifax Harbour Task Force, 1990), and how they affect recommendations for program modification. An emphasis in this report is a continued assessment of the efficacy of the sampling program and of the potential introduction of systematic sampling bias in the data. This is a necessary step in the more detailed statistical analysis of the data that can occur subsequently. In this report, the data from the center of Bedford Basin (Station G2) is also compared with data collected at a nearby site by the Bedford Basin Phytoplankton Monitoring Program (BBPMP), a project involving scientists with the Department of Fisheries and Oceans at Bedford Institute of Oceanography. This report discusses the eighth quarter, but includes an annual summary. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters. In the interest of making the quarterly reports useful as a stand alone document, there is a significant amount of repetition of background information among the quarterly reports.

2 Weekly Reporting

The basic weekly report format is discussed in detail in the introduction of the project report binder and in Quarterly Report #1 (QR1, JWL and COA, 2004). Slight modifications and enhancements to the weekly reports continue to be made as experience dictates. In this quarter there have been no changes to the weekly reports.

From time to time, errors are discovered in the weekly reports after they have been issued. In addition, the sampling program is modified periodically, necessitating changes in the weekly reports. An Errata/Changes section is included in the Introduction section of the report binder and is updated on a quarterly basis. This documents any issues which could affect the interpretation of the data, as well as documenting changes in the data collection or analysis.

3 Sampling Program

Survey sampling is conducted on a weekly basis from one of several vessels, operated by Connors Diving Services Ltd., based at the Armdale Yacht Club. The details of the sampling program are discussed in the introduction section of the project report binder and QR#1. The locations of the 34 regular sampling sites are included for reference in Figure 1. These sites are a combination of historically occupied sites (Jordan, 1972), some project specific sites and identified recreational (yacht club/beach) sites. Sampling involves the collection of continuous profile data and discrete water samples at 1 and 10 m water depth. The level of analysis varies from site to site: CTD only (CTD only sites);

CTD and coliform bacteria (Coliform stations); or CTD, Bacteria, and additional contaminant analysis (Chemistry stations). The additional sampling at the Chemistry sites occurs on a bi-weekly basis. In addition to the regular sites, Figure 1 includes a sample site in Dartmouth Cove, established in response to public concern. At this site, a 1 m water sample and profile data are obtained. The water sample is analyzed for the full suite of parameters. This site is sampled once a month during the summer. A summary of the sampling and analysis schedules and relevant established criteria in place at the end of eighth quarter (13 June 2006) are in Table 1. There have been no changes to the sampling for this quarter. This table indicates that there are several analyses, including TOG and metals, which are now performed only for “supplemental samples”. The "supplemental sample" procedure that has been established allows water samples to be taken at additional sites, based on visual observations, at the discretion of the field team. During this quarter, no chemistry stations were missed, six bacteria stations were missed (1 and 10 m depths), for a total of twelve missed bacterial samples and five CTD profiles were missed. The bacteria stations were missed due to environmental conditions (i.e. fog and waves), and on one occasion due to the sampler breaking down. The CTD profiles were missed due to user and/or instrument error. The specifics of the missed stations are described in the weekly reports. During this quarter, four stations (DYC, F2, HC, and SYC) were sampled for Winkler titration for a total of seven samples. (How do I know this)

3.1 Sampling Order

Sampling generally occurs on Tuesday, with Wednesday and Thursday as contingency days. Every week the sampling order is varied to minimize biasing the collected data with respect to known diurnal variations in sewage load and sunlight. A variable circuit is used that results in ‘quasi’ random sampling, subject to certain operational constraints. This procedure is discussed in QR#1. The sampling order for each week in the eighth quarter is presented in Table 2.

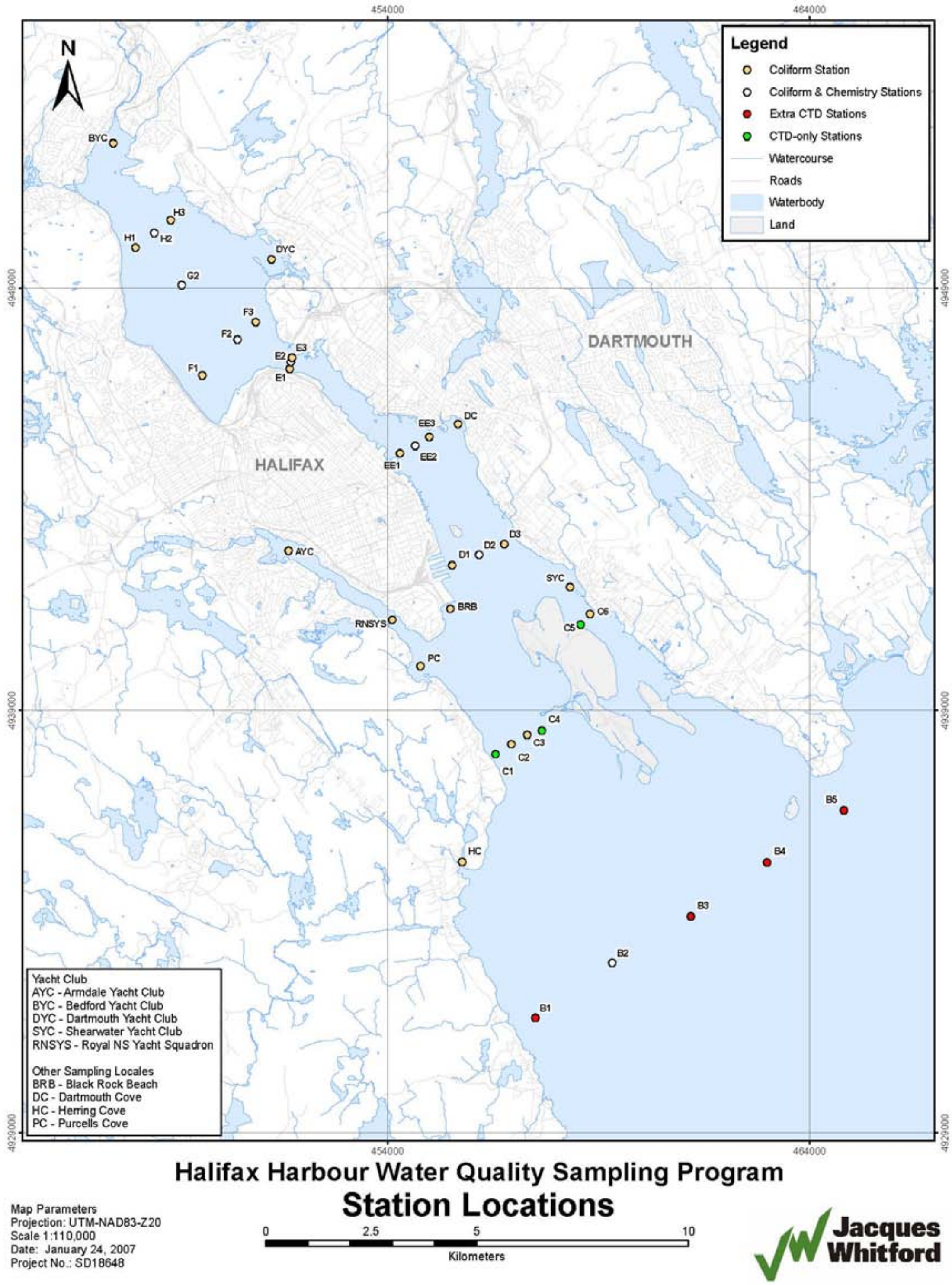


Figure 1. Halifax Inlet Sample Locations

Table 1. Summary of measured parameters as of 13 June 2006.

	EQL		Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
	value	units				
Profile Data					All	weekly
Salinity	n/a	PSU	n/a	n/a		
Temperature	n/a	C°	n/a	n/a		
Chlorophyll *a*	n/a	mg/m^3	n/a	n/a		
Dissolved Oxygen	n/a	mg/L	8 7 6	SA SB SC		
Secchi depth	n/a	m	n/a	n/a		
Bacteria Samples					Bacteria + Chemical	weekly
Fecal Coliform	0	cfu/ 100mL	14 200	SA SB		
Chemical Samples						
CBOD	5	mg/L	none		Supplemental sites	unscheduled
Ammonia Nitrogen	0.05	mg/L	none		Chemical sites	bi-weekly
TSS	2.0	mg/L	<10% background	all	Chemical sites	bi-weekly
Total Oil and Grease	5	mg/L	10	all	Supplemental sites	unscheduled
Metal scan					Supplemental sites	unscheduled
Cadmium	3	ug/L	9.3	all		
Chromium	20	ug/L	50.0	all		
Copper	20	ug/L	2.9	all		
Lead	5	ug/L	5.6	all		
Manganese	20	ug/L	100.0	all		
Nickel	20	ug/L	8.3	all		
Zinc	50	ug/L	86.0	all		
Aluminum	100	ug/L	none			
Antimony	20	ug/L	none			
Arsenic	20	ug/L	none			
Barium	50	ug/L	none			
Beryllium	20	ug/L	none			
Bismuth	20	ug/L	none			
Boron	500	ug/L	none			
Cobalt	10	ug/L	none			
Lithium	20	ug/L	none			
Iron	500	ug/L	none			
Molybdenum	20	ug/L	none			
Selenium	50	ug/L	none			
Strontium	50	ug/L	none			
Thallium	1	ug/L	none			
Tin	20	ug/L	none			
Titanium	20	ug/L	none			
Uranium	1	ug/L	none			
Vanadium	20	ug/L	none			

Table 2. Sample collection order (green sites are CTD only, blue indicates no CTD data, red indicates sample only)

Date	21-Mar-06	28-Mar-06	4-Apr-06	11-Apr-06	18-Apr-06	25-Apr-06	2-May-06	9-May-06	16-May-06	23-May-06	30-May-06	6-Jun-06	13-Jun-06
Survey	92	93	94	95	96	97	98	99	100	101	102	103	104
1	AYC	AYC	AYC	D1	C2	AYC	AYC	AYC	BRB	C1	BRB	D1	D1
2	RNSYS	RNSYS	RNSYS	EE1	C1	RNSYS	RNSYS	RNSYS	D2	C2	D1	EE1	D2
3	BRB	PC	PC	E1	C3	PC	PC	PC	D1	B2	D2	E1	EE2
4	D1	BRB	EE1	F1	C5	C1	C4	C4	EE2	HC	EE2	F1	EE1
5	D2	D1	D1	G2	C6	C2	C3	C3	EE1	C3	EE1	G2	E2
6	EE2	D2	BRB	H1	SYC	HC	B2	B2	E2	C4	E2	H1	E1
7	EE1	C5	C2	BYC	D3	B2	HC	HC	E1	C5	E1	BYC	F2
8	F2	C6	C1	H2	EE3	C3	C1	C1	F2	C6	F2	H2	F1
9	F1	SYC	HC	H3	E3	C4	C2	C2	F1	SYC	F1	H3	G2
10	G2	D3	B2	DYC	F3	C5	BRB	BRB	G2	D3	G2	DYC	H1
11	H1	EE1	C3	F3	DYC	C6	D1	D1	H2	D2	H1	F3	H2
12	H2	E1	C4	F2	H3	SYC	D2	EE1	H1	EE3	H2	F2	BYC
13	BYC	F1	C5	E3	BYC	D3	EE2	E1	BYC	EE2	BYC	E3	H3
14	H3	G2	C6	E2	H2	EE3	EE1	F1	H3	E3	H3	E2	DYC
15	DYC	DYC	SYC	EE3	H1	E3	E2	G2	DYC	E2	DYC	EE3	F3
16	F3	H1	D3	EE2	G2	F3	E1	H1	F3	F2	F3	EE2	E3
17	E3	H2	D2	D3	F1	DYC	F2	BYC	E3	F1	E3	D3	EE3
18	E2	BYC	EE2	D2	F2	H3	F1	H2	EE3	G2	EE3	D2	D3
19	E1	H3	EE3	SYC	E1	BYC	G2	H3	D3	H1	D3	SYC	SYC
20	EE3	F2	E3	C6	E2	H2	H1	DYC	SYC	H2	SYC	C6	C6
21	D3	F3	E2	C5	EE1	H1	H2	F3	C6	BYC	C6	C5	C5
22	SYC	E3	F2	C4	EE2	G2	BYC	F2	C5	H3	C5	BRB	BRB
23	C6	E2	F3	C3	D2	F1	H3	E3	C4	DYC	C4	C4	C4
24	C5	EE3	DYC	B2	D1	F2	DYC	E2	C3	F3	C3	C3	C3
25	C4	EE2	H3	HC	BRB	E1	F3	EE3	HC	E1	B2	B2	B2
26	C3	C4	H2	C1	RNSYS	E2	E3	EE2	C2	EE1	HC	HC	HC
27	B2	C3	BYC	C2	AYC	EE1	EE3	D2	C1	D1	C1	C1	C1
28	HC	B2	H1	BRB		EE2	D3	D3	PC	BRB	C2	C2	C2
29	C1	HC	G2	PC		D1	SYC	SYC	RNSYS	PC	PC	PC	PC
30	C2	C2	F1	RNSYS		D2	C6	C6	AYC	RNSYS	RNSYS	RNSYS	RNSYS
31	PC	C1	E1	AYC		BRB	C5	C5		AYC	AYC	AYC	AYC
No sample					B2, HC, PC, C4		EE1		B2				

3.2 Sampling Bias

There are two issues regarding potential bias in the dataset. The first is the relative bias between sites—whether the statistics from one site can be compared with those from another site. The second is the absolute bias with respect to the environmental forcing, or how well the dataset represents typical conditions in the Harbour. Our sampling has operational constraints which introduce a morning/early afternoon bias to the entire dataset. It is impractical to address this fully, except to document it. The following section is a first look at potential bias with respect to time of day, water level, and rainfall during the seventh quarter.

3.2.1 Time of Day

Sewage flows have significant regular diurnal variations, which can affect the water quality in the Harbour on short timescales. In addition to variations in sewage load, the most obvious diurnal variation is in sunlight. Sunlight is perhaps the major contributor to the die off of bacteria, and can have effects on other parameters, particularly chlorophyll (fluorescence) and dissolved oxygen. The short term variation in sewage load is primarily an issue in the Inner Harbour, relatively close to the outfalls, however sunlight affects the entire Harbour. In Halifax there is also a significant diurnal tidal component affecting water levels. This is considered in the subsequent section.

Figure 2 represents the sampling time at each site since the start of the program in June 2004. The data from the eighth quarter are shown in red. In this figure the sample sites are generally sorted from north to south. There are a few patterns that emerge, which have been documented previously. The stations at the north end of Bedford Basin have a smaller range of sampling times. This is because logistics dictates that the surveys never start or end in the Basin. In general, the range of sampling times increases with distance south, a function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a site is sampled first, it still takes time to travel there. Given that sampling begins at the same time every week, these effects are unavoidable. Given the necessary operational constraints, the sampling scheme has resulted in a reasonably uniform distribution in the Inner Harbour (Section D through Section E), where diurnal fluctuations would likely be greatest.

The diagram also indicates that overall there has been an early morning bias in the Outer Harbour Stations, a result of weather conditions. Each week, a primary and an alternate sampling route are provided to the field team. If the primary route has the Outer Harbour sampled early in the day, the alternate route will have it sampled late in the program. The decision on which route to take is made between the field team and the boat operator considering the weather forecast for the day. Wind, waves and visibility can limit operations in the Outer Harbour and since the wind and wave conditions tend to be worse in the afternoon, a morning bias is introduced. Unusually, in this quarter, the sampling is quite balanced. The diurnal variations in conditions in the Outer Harbour are expected to be the least of any harbour region, so this bias is less significant.

In this quarter, there were some additional trends. Due to transit time considerations, the Arm is now sampled either first or last. This quarter, of the thirteen surveys, there were six that started in the Arm. Therefore the morning/afternoon sampling is nearly balanced, but there is no mid-day sampling. Also, due to delays in the 18 April survey, there were sites in the Basin, Inner Harbour and NW Arm sampled later than has previously been done. All sites are fairly uniformly sampled.

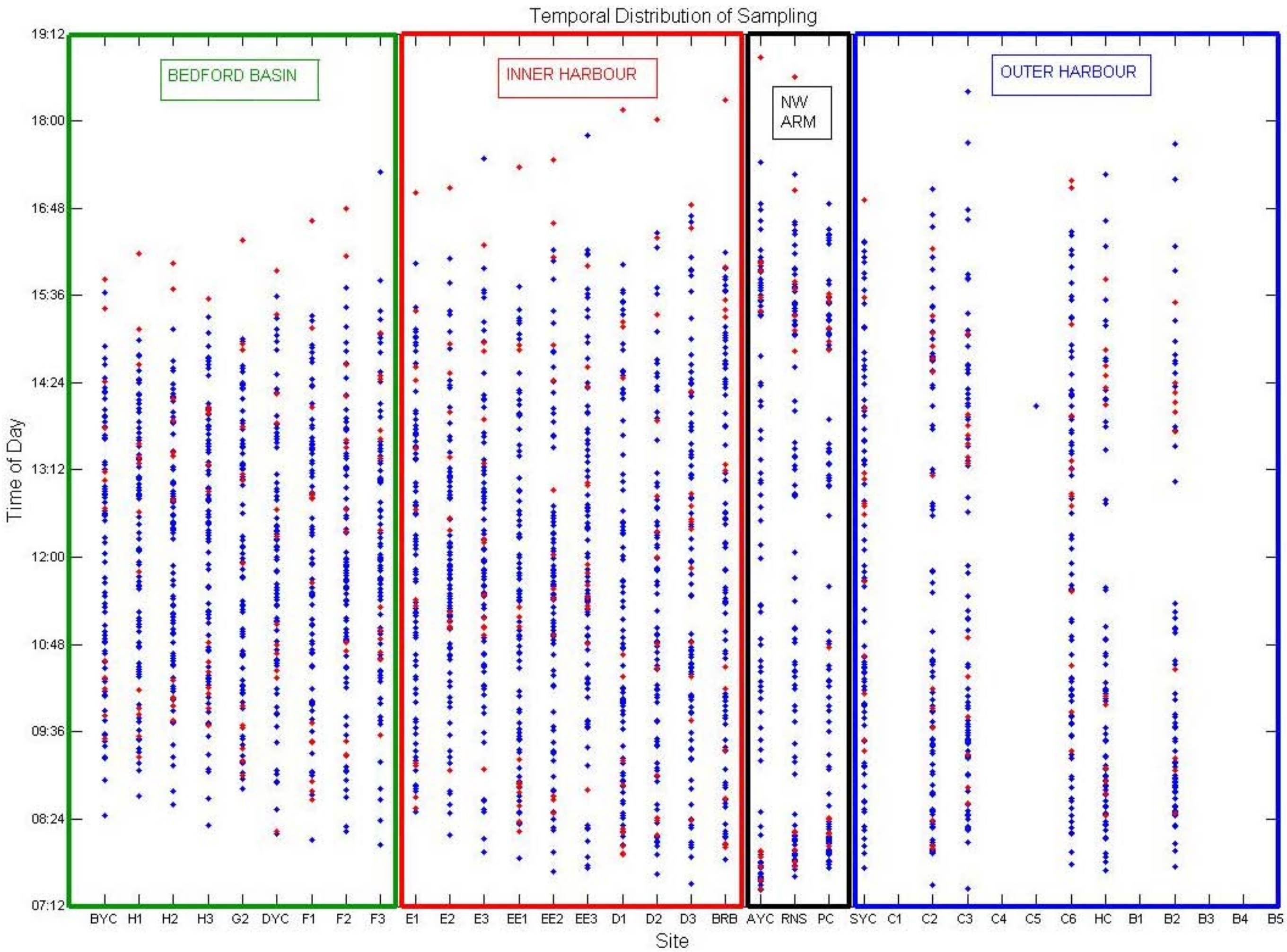


Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 21 March 2006 to 13 June 2006.

3.2.2 Water Levels

The water level at the time of sampling can affect the results. The two most obvious considerations are whether a particular sample was taken upstream or downstream (based on flood/ebb direction) from the nearest outfall, and the variation in initial dilution, caused by variations in submergence depth, from shallow outfalls. These are both issues primarily in the Inner Harbour.

Water level variations in the Harbour are caused by the tides and meteorological forcing. The meteorologically-induced changes are of longer period and, except in extreme storms, are much smaller in magnitude than the tides. Because of their longer duration their effect on Harbour flushing can be significant and their impact on water quality may warrant investigation in the future. Note that the tidal currents in the Harbour are, for the most part, not that strong and may be over ridden by local/regional meteorological effects (Hurlbut et al., 1990). This means, for example, that the surface current may not always be going out on a falling tide. However, the occurrence of surges is relatively random and the possibility of inducing a systematic sampling bias is small compared with that of the very regular higher frequency tides. The tides in Halifax Harbour are classified as semidiurnal, meaning that there are two high and two low tides in a day.

There is also a potential bias introduced by regular weekly sampling. Sampling which occurs on the same day every second week (i.e. the chemistry sampling) could occur at the same point in the fortnightly tidal cycle (i.e. the same tidal range). An initial assessment of the tidal signal in Halifax Harbour indicates that the fortnightly cycle is sufficiently irregular (i.e. the tides are sufficiently "mixed"), that this problem is unlikely, particularly given the variation in sampling day (Tuesday or Wednesday, sometimes Thursday). This issue will be monitored and may be revisited more rigorously at a later time.

The probability distribution of water level (above chart datum) as derived from the tide gauge at the Naval Dockyard in Halifax (CHS station 490) for the period March 2006 to June 2006 is shown in Figure 3**.** The red line connecting the bars is the baseline, recreated in each panel of Figure 4, against which water levels during sampling are compared. The overall water level distribution is slightly bi-modal. The central minimum probability roughly corresponds to the mean tide level. However the distribution is actually relatively flat, between 0.6 m and 1.6 m. In an ideal situation each site would be sampled in a distribution similar to the overall distribution.

Figure 4 shows the distribution of water levels at each site at the time of sampling (blue bars) compared to the overall water level distribution for the quarter, as described above (red line). The sampling distributions show that given the relatively small number of samples, a relatively full range of water levels has been sampled at each site. There are some minor discrepancies. The mid water levels appear to be somewhat under-sampled in Bedford Basin and the Inner Harbour. This is unlikely an issue, as tidal currents in the Basin are very low (i.e. tidal excursions are small), and there are no large shallow water outfalls. The exception to this is the Fairview Cove Combined Sewer Overflow (CSO) which flows during large storms. The NW Arm, and the C and B2 section samples are under-sampled for the 1.2 m level.

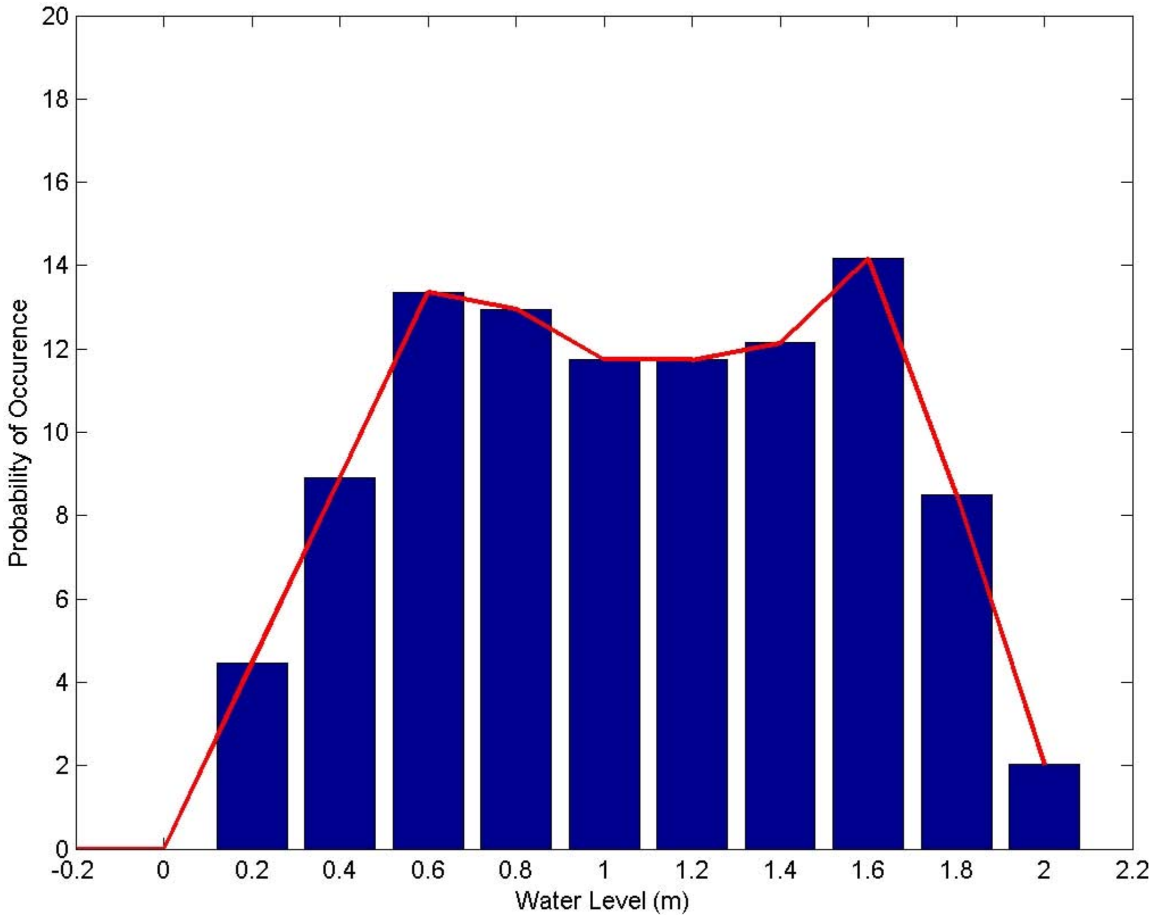


Figure 3. Probability distribution of water levels in Halifax, March to June 2006.

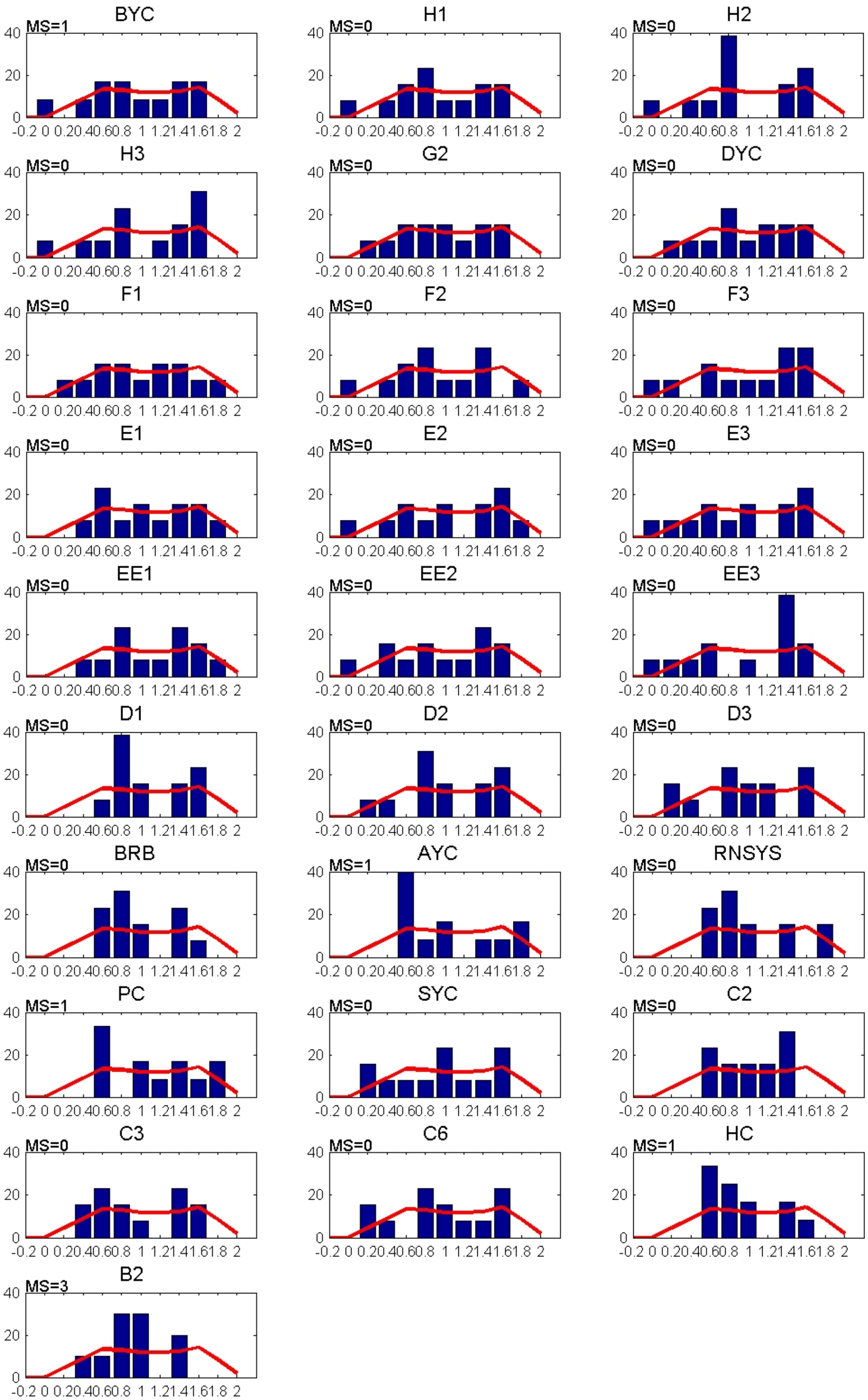


Figure 4. Water level distribution at each site during sampling 21 March 2006 to 13 June 2006. Note: MS = Missed samples

3.2.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. Following a rain event, effluent flow increases in a combined sewage system; collected material in the sewage pipes can be flushed; and the Harbour, in response to the increased fresh water input, can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a great effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall and persist for a period after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event and the condition of the watershed. For purposes of discussion we have, somewhat arbitrarily, selected a three day (72 hour) precipitation window for our analysis. The red line in Figure 5 depicts the probability distribution of precipitation integrated over the current and previous two days for this quarter (21 March 2006 to 13 June 2006). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling has been reasonably representative with respect to precipitation, though there have been some large rainfall events missed. Over the entire period, about 38% of days had precipitation less than 5 mm in the 72 hour window and the sampling day distribution includes all of these “dry days”. We have under-sampled days with moderate precipitation (20-25 mm) and had no sampling days in the few high precipitation days between 30 and 50 mm. However, there was sampling at 55 mm of precipitation, on survey 100 (16 May 2006).

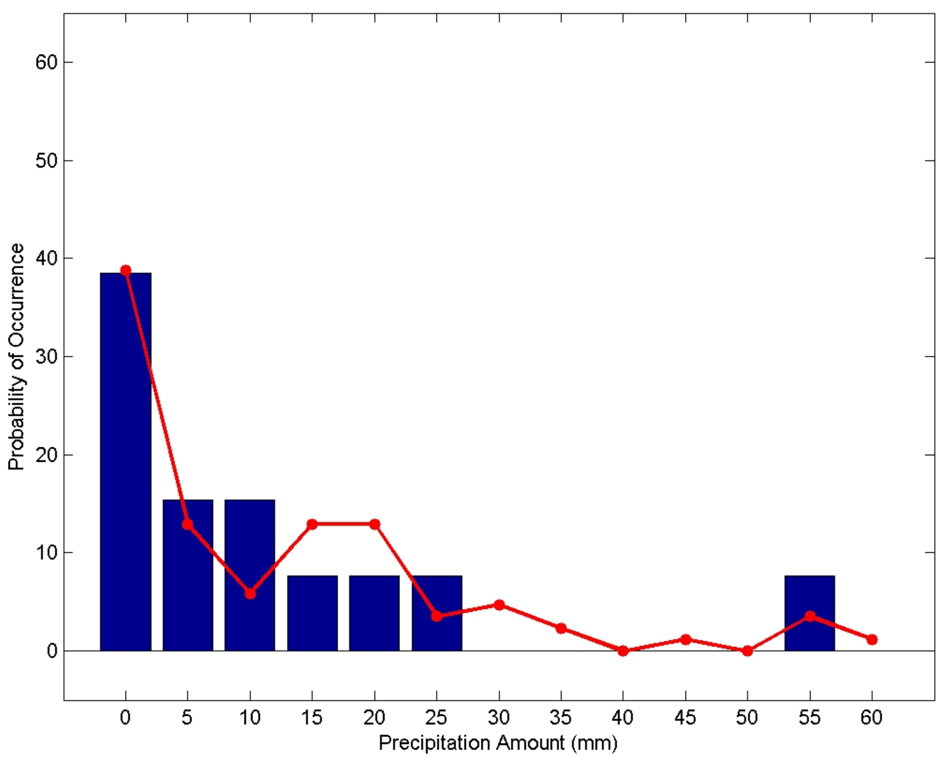


Figure 5. Probability distribution of cumulative 72 hour rainfall, 21 March 2006 to 13 June 2006.

3.3 Program Changes

There have been no program changes this quarter.

3.4 Supplemental Samples

Based on recommendations from QR#2, a supplemental sample protocol has been instituted to take opportunistic samples of visible water quality features in the Harbour. These samples are acquired on a discretionary and exploratory basis when an interesting feature, such as a visible front or plume, is encountered. It is anticipated that these samples will have lower water quality than most normal samples. As such, the samples are processed for the full range of parameters specified at the beginning of the program, including parameters which have been eliminated from normal sampling due to lack of detection. During this quarter there were no supplemental samples, but four stations (DYC 16 may, F2, HC, and SYC 30 may) were sampled for Winkler titration for a total of seven samples.

3.5 Sampling Protocol

Sampling protocol/sample handling has been dictated by experience and specific lab directions. CTD casts are performed according to the manufacturer's recommendation and data analysis follows standard procedures. These protocols are documented in the project binder with weekly and quarterly reports.

4 Water Quality Results and Discussion

Results of the water quality sampling are discussed in the following sections with emphasis on compliance with water quality guidelines, and any need for modifications to the program.

4.1 Fecal Coliform

The Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada, 1992) evaluate the compliance with bacterial water quality criteria based on geometric mean. The geometric mean, G, of n values is defined as:

$$G(x_1, x_2, x_3, \ldots, x_n) = (x_1 \cdot x_2 \cdot x_3 \cdot \ldots \cdot x_n)^{1/n}$$

To compute geometric mean, some adjustments to the data are required. Zeros are not valid in the calculation, so ones (1's) are substituted for all zero values. The result of this is that there will be no zero counts reported at any site. An appropriate interpretation of a reported mean value of one, then, is that it is equivalent to "less than or equal to" one. Out of range values are reported by the lab as >10,000 in the units reflective of the resolution of the analysis being performed (see Out of Range Values section below and in QR#1). For statistical purposes, these values are, relatively arbitrarily, replaced by 14,999. This is simply a number >10,000 which is easily identified.

Maps representing the geometric mean values over all samples for the eighth quarter are presented in Figure 6. In this figure, values in red exceed swimming guidelines (200 cfu/100 mL); values in blue exceed shellfishing guidelines (14 CFU/100 mL); and values in green indicate suitability for either activity. Separate maps are presented for the 1 and 10 m samples. In the following discussion, it is helpful to refer to the station map in Figure 1.

For the 1 m samples, and to a lesser extent, the 10 m samples, the geometric mean coliform values are high in the Inner Harbour. This is similar to the last quarter. The magnitude of these values, however are slightly lower than the last quarter. The spatial distributions at both depths are centered on the EE section, suggesting that the net effect of two layer flow in the Inner Harbour is not significant in this quarter. South of the Narrows, the maximum values at any site are in the 1 m sample, except at AYC and B2 where they are very similar, while north of the Narrows the highest values are in the 10 m sample (except BYC, at the mouth of the Sackville River, where they are very similar). This relatively familiar distribution suggests a net “estuarine” flow with contaminated Inner Harbour water flowing in a lower layer into the Basin. The values in the Narrows (section E) are similar at both depths, again suggesting that the effect of the implied two layer flow is less in the Inner Harbour in this quarter than it has been in some others.

The geometric mean values exceeding the swimming guidelines occur in much of the Inner Harbour at 1 m, which is classified SC, with no bacteria guidelines, and extend into the edges of adjacent “class SB” areas of the Outer Harbour and the Northwest Arm, where swimming levels are desired. At 10 m only EE section has values exceeding the swimming guidelines. Significantly, there were low, but quite consistently detectable levels all the way out to site B2. A more rigorous discussion of guideline exceedence follows.

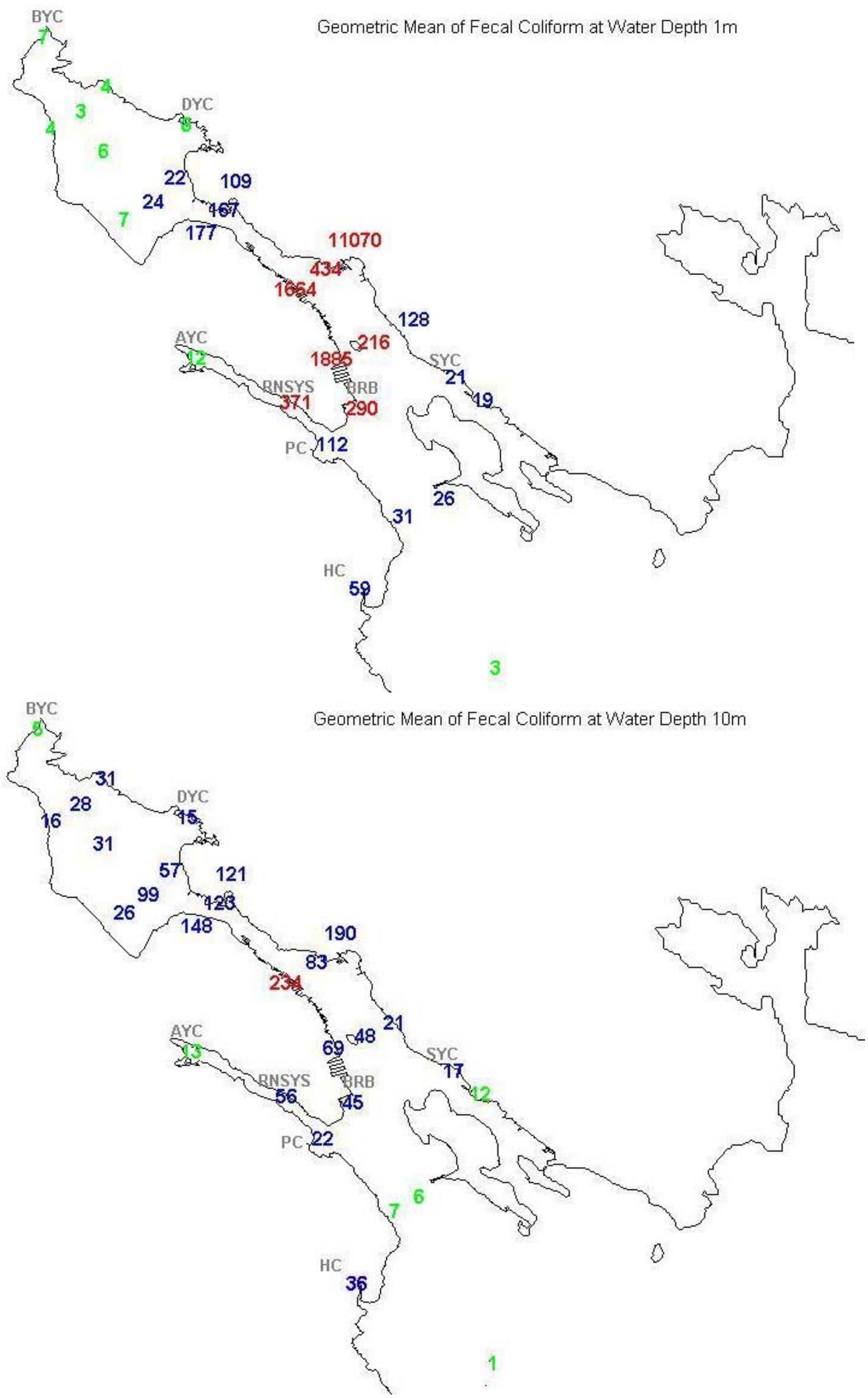


Figure 6. Fecal coliform geometric means (cfu/100mL), 21 March 2006 to 13 June 2006.

4.1.1 Guideline Exceedance

As presented in QR#1, the Harbour Task Force fecal coliform guidelines (Harbour Task Force, 1990) are interpreted using the methodology presented in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada, 1992). The guidelines specify that in swimming areas, the geometric mean of at least five fecal coliform values taken within 30 days should not exceed 200 cfu/100mL, and any sample with values >400 cfu/100mL should trigger re-sampling. Our weekly sampling regime generally meets the criteria of five samples within 30 days.

Interpreting this procedure in our context results in a weekly assessment, at three levels:

1. ACCEPTABLE, defined as a geometric mean <200 cfu/100mL
2. QUESTIONABLE, geometric mean <200 cfu/100mL but one or more samples >400 cfu/100mL
3. UNACCEPTABLE, geometric mean >200 cfu/100mL.

If there are missed samples within the 30 day period, the analysis uses a reduced number of samples, rather than extending the time beyond thirty days. Tables 3 and 4 show the results of the analysis for the 1 m and 10 m samples respectively. The tables represent the floating 30 day geometric mean and, in parentheses, the number of samples (max 5) used in the average. The values are colour coded to represent acceptable (green), questionable (yellow) and unacceptable (red) levels.

As seen in the tables below, for this quarter, the near surface water (1 m) at D1 and all the EE section in Inner Harbour would be deemed unacceptable for primary body contact essentially all of the time. The distribution of sites with the highest fecal coliform counts reflects their proximity to major sewage outfalls: the EE section to the Peace Pavillion outfall, Historic Properties outfall, and many other smaller outfalls along the waterfront; site D1 to the Pier A outfall. Two of the largest outfalls in the Harbour are the Duffus St. and Tufts Cove outfalls on opposite sides of the Narrows 1-2 km south of the E section. While these are large sources quite close to the E sites, the effect of these outfalls on the E section depends greatly on the complex dynamics in the Narrows. As discussed above, in this quarter the overall geometric mean values (Figure 6) in the E section are not particularly high and are similar in both the 1 m and 10 m samples. Tables 3 and 4 indicate, however, that the probability of exceeding swimming guidelines at E3 is greater in the 1 m samples than the 10 m samples.

In the Inner Harbour, the mean values at 10 m have a similar spatial distribution to those in the 1 m samples, i.e. higher values at D1 and the EE section, but with somewhat lower values overall. At 10 m the swimming guidelines are exceeded for over half the time at EE1 and EE3. As discussed above, in the Basin the vertical situation is reversed, with higher values in the 10 m samples. Of the yacht club and beach sites sampled, the recreational guidelines were exceeded in the 1 m sample for 9, 7 and 4 of the 13 weeks at RNSYS, Black Rock Beach and Purcells Cove respectively. The guidelines were not exceeded at the other recreational sites.

Table 3. 30 day geometric mean (number of samples) of 1 m fecal coliform concentrations (CFU/100 ml).

	Outer Harbour				Eastern Pass.		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey92	1 (5)	34 (5)	53 (5)	29 (5)	15 (5)	19 (5)	98 (4)	1645 (4)	153 (5)	88 (5)	1470 (5)	300 (5)	29565 (5)	92 (5)	130 (5)	92 (5)
Survey93	1 (5)	29 (5)	28 (5)	21 (5)	14 (5)	23 (5)	71 (4)	2738 (4)	175 (5)	93 (5)	1082 (5)	289 (5)	22920 (5)	78 (5)	107 (5)	59 (5)
Survey94	1 (5)	15 (5)	26 (5)	14 (5)	14 (5)	15 (5)	139 (4)	2968 (5)	180 (5)	66 (5)	1172 (5)	215 (5)	5648 (5)	112 (5)	229 (5)	104 (5)
Survey95	1 (5)	17 (5)	25 (5)	15 (5)	10 (5)	15 (5)	155 (4)	1047 (5)	122 (5)	49 (5)	837 (5)	125 (5)	6648 (5)	70 (5)	163 (5)	62 (5)
Survey96	1 (4)	12 (4)	36 (5)	26 (5)	21 (5)	39 (5)	191 (5)	3045 (5)	230 (5)	78 (5)	786 (5)	96 (5)	5402 (5)	47 (5)	112 (5)	56 (5)
Survey97	2 (4)	26 (4)	29 (5)	15 (5)	19 (5)	19 (5)	196 (5)	2958 (5)	147 (5)	90 (5)	892 (5)	95 (5)	5875 (5)	45 (5)	73 (5)	60 (5)
Survey98	2 (4)	21 (4)	22 (5)	14 (5)	17 (5)	10 (5)	273 (5)	1898 (5)	129 (5)	81 (5)	1213 (4)	203 (5)	5875 (5)	214 (5)	86 (4)	92 (5)
Survey99	2 (4)	61 (4)	12 (5)	12 (5)	8 (5)	6 (5)	246 (5)	1565 (4)	89 (5)	80 (5)	1476 (4)	276 (5)	10443 (5)	275 (5)	131 (4)	154 (5)
Survey100	2 (3)	96 (4)	13 (5)	8 (5)	14 (5)	12 (5)	451 (5)	2258 (4)	123 (5)	89 (5)	1943 (4)	682 (5)	13577 (5)	609 (5)	282 (4)	436 (5)
Survey101	8 (4)	129 (5)	17 (5)	11 (5)	16 (5)	14 (5)	377 (5)	747 (4)	110 (5)	104 (5)	2228 (4)	783 (5)	19194 (5)	457 (5)	122 (4)	292 (5)
Survey102	5 (4)	114 (5)	17 (5)	21 (5)	26 (5)	17 (5)	652 (5)	1210 (4)	184 (5)	87 (5)	2315 (4)	1118 (5)	11412 (5)	457 (5)	153 (4)	302 (5)
Survey103	8 (4)	161 (5)	35 (5)	45 (5)	31 (5)	40 (5)	645 (5)	1159 (4)	261 (5)	190 (5)	2225 (5)	996 (5)	15317 (5)	201 (5)	178 (5)	230 (5)
Survey104	12 (4)	187 (5)	62 (5)	79 (5)	59 (5)	87 (5)	542 (5)	1265 (5)	722 (5)	394 (5)	2772 (5)	1642 (5)	17013 (5)	343 (5)	164 (5)	61 (5)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey92	7 (5)	10 (5)	7 (5)	7 (2)	5 (5)	3 (5)	5 (5)	5 (5)	14 (4)	93 (4)	241 (5)	4 (5)
Survey93	11 (5)	17 (5)	8 (5)	4 (3)	6 (5)	4 (5)	3 (5)	5 (5)	11 (5)	55 (4)	112 (5)	5 (5)
Survey94	7 (5)	27 (5)	12 (5)	4 (4)	5 (5)	2 (5)	2 (5)	4 (5)	5 (5)	69 (4)	313 (5)	6 (5)
Survey95	11 (5)	27 (5)	19 (5)	3 (5)	7 (5)	3 (5)	2 (5)	4 (5)	5 (5)	62 (4)	228 (5)	6 (5)
Survey96	13 (5)	21 (5)	30 (5)	3 (5)	12 (5)	6 (5)	3 (5)	6 (5)	4 (5)	62 (4)	62 (5)	5 (5)
Survey97	13 (5)	23 (5)	51 (5)	4 (5)	12 (5)	5 (5)	4 (5)	6 (5)	7 (5)	277 (4)	187 (5)	13 (5)
Survey98	13 (5)	43 (5)	81 (5)	5 (5)	17 (5)	4 (5)	4 (5)	4 (5)	7 (5)	200 (4)	489 (5)	23 (5)
Survey99	11 (5)	42 (5)	86 (5)	7 (5)	10 (5)	4 (5)	4 (5)	2 (5)	7 (5)	217 (4)	431 (5)	53 (5)
Survey100	8 (5)	79 (5)	130 (5)	6 (5)	7 (5)	3 (5)	4 (5)	2 (5)	6 (5)	258 (4)	677 (5)	61 (5)
Survey101	4 (5)	55 (5)	62 (5)	6 (5)	3 (5)	2 (5)	2 (5)	2 (5)	3 (5)	185 (5)	482 (5)	41 (5)
Survey102	3 (5)	38 (5)	24 (5)	5 (5)	2 (5)	1 (5)	1 (5)	2 (5)	2 (5)	76 (5)	310 (5)	12 (5)
Survey103	4 (5)	30 (5)	17 (5)	6 (5)	3 (5)	4 (5)	3 (5)	4 (5)	4 (5)	99 (5)	178 (5)	9 (5)
Survey104	6 (5)	18 (5)	11 (5)	8 (5)	4 (5)	7 (5)	5 (5)	7 (5)	8 (5)	58 (5)	295 (5)	7 (5)

Note: Red indicates exceedance of swimming criteria (geometric mean >200). Yellow denotes "questionable" water quality, resampling is indicated (mean < 200, but one or more samples >400). Green indicates compliance with criteria.

Table 4. 30 day geometric mean (number of samples) of 10 m fecal coliform concentrations (CFU/100 mL).

	Outer Harbour				Eastern Pass.		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey92	2 (5)	16 (5)	17 (5)	10 (5)	20 (5)	58 (5)	67 (4)	152 (5)	106 (5)	86 (5)	559 (5)	142 (5)	336 (5)	78 (5)	192 (5)	105 (5)
Survey93	1 (5)	23 (5)	16 (5)	13 (5)	22 (5)	92 (5)	73 (4)	276 (5)	124 (5)	96 (5)	681 (5)	224 (5)	410 (5)	60 (5)	164 (5)	85 (5)
Survey94	1 (5)	17 (5)	13 (5)	10 (5)	15 (5)	54 (5)	106 (4)	285 (5)	97 (5)	54 (5)	547 (5)	190 (5)	263 (5)	109 (5)	286 (5)	106 (5)
Survey95	1 (5)	18 (5)	9 (5)	12 (5)	7 (5)	35 (5)	64 (4)	156 (5)	66 (5)	31 (5)	342 (5)	188 (5)	188 (5)	75 (5)	97 (5)	117 (5)
Survey96	1 (4)	16 (4)	13 (5)	22 (5)	16 (5)	55 (5)	92 (5)	234 (5)	124 (5)	50 (5)	371 (5)	134 (5)	76 (5)	61 (5)	78 (5)	115 (5)
Survey97	1 (4)	33 (4)	8 (5)	12 (5)	15 (5)	31 (5)	79 (5)	195 (5)	95 (5)	44 (5)	391 (5)	139 (5)	83 (5)	79 (5)	66 (5)	95 (5)
Survey98	1 (4)	12 (4)	6 (5)	7 (5)	13 (5)	18 (5)	61 (5)	123 (5)	89 (5)	43 (5)	342 (4)	135 (5)	88 (5)	231 (5)	116 (5)	137 (5)
Survey99	1 (4)	24 (4)	6 (5)	6 (5)	11 (5)	12 (5)	52 (5)	136 (5)	109 (5)	24 (5)	302 (4)	152 (5)	122 (5)	171 (5)	102 (5)	135 (5)
Survey100	1 (3)	32 (4)	4 (5)	4 (5)	15 (5)	11 (5)	51 (5)	123 (5)	89 (5)	24 (5)	338 (4)	127 (5)	146 (5)	253 (5)	211 (5)	174 (5)
Survey101	1 (4)	36 (5)	3 (5)	2 (5)	7 (5)	6 (5)	21 (5)	42 (5)	46 (5)	8 (5)	147 (4)	85 (5)	306 (5)	369 (5)	148 (5)	130 (5)
Survey102	1 (4)	60 (5)	5 (5)	3 (5)	9 (5)	8 (5)	19 (5)	36 (5)	35 (5)	7 (5)	131 (4)	67 (5)	212 (5)	382 (5)	144 (5)	166 (5)
Survey103	1 (4)	81 (5)	5 (5)	4 (5)	7 (5)	6 (5)	24 (5)	13 (5)	18 (5)	5 (5)	118 (5)	39 (5)	231 (5)	210 (5)	76 (5)	119 (5)
Survey104	1 (4)	110 (5)	4 (5)	4 (5)	10 (5)	8 (5)	17 (5)	8 (5)	9 (5)	7 (5)	81 (5)	24 (5)	247 (5)	255 (5)	65 (5)	114 (5)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey92	19 (5)	47 (5)	24 (5)	6 (2)	21 (5)	20 (5)	21 (5)	18 (5)	15 (4)	43 (4)	106 (5)	8 (5)
Survey93	16 (5)	71 (5)	38 (5)	9 (3)	15 (5)	21 (5)	21 (5)	21 (5)	10 (5)	48 (4)	122 (5)	7 (5)
Survey94	15 (5)	123 (5)	49 (5)	10 (4)	13 (5)	14 (5)	14 (5)	17 (5)	8 (5)	76 (4)	115 (5)	10 (5)
Survey95	18 (5)	136 (5)	57 (5)	13 (5)	21 (5)	11 (5)	14 (5)	19 (5)	4 (5)	54 (4)	103 (5)	13 (5)
Survey96	25 (5)	102 (5)	59 (5)	18 (5)	25 (5)	19 (5)	19 (5)	32 (5)	5 (5)	54 (4)	52 (5)	12 (5)
Survey97	33 (5)	117 (5)	127 (5)	28 (5)	40 (5)	20 (5)	36 (5)	56 (5)	4 (5)	59 (4)	44 (5)	18 (5)
Survey98	38 (5)	170 (5)	116 (5)	23 (5)	54 (5)	18 (5)	34 (5)	49 (5)	4 (5)	42 (4)	49 (5)	13 (5)
Survey99	45 (5)	111 (5)	106 (5)	29 (5)	80 (5)	25 (5)	58 (5)	69 (5)	4 (5)	27 (4)	52 (5)	14 (5)
Survey100	61 (5)	152 (5)	100 (5)	32 (5)	98 (5)	40 (5)	68 (5)	87 (5)	7 (5)	18 (4)	34 (5)	12 (5)
Survey101	45 (5)	150 (5)	66 (5)	21 (5)	80 (5)	21 (5)	42 (5)	49 (5)	4 (5)	10 (5)	26 (5)	13 (5)
Survey102	33 (5)	136 (5)	53 (5)	13 (5)	30 (5)	16 (5)	16 (5)	16 (5)	3 (5)	7 (5)	32 (5)	12 (5)
Survey103	35 (5)	92 (5)	41 (5)	13 (5)	36 (5)	10 (5)	22 (5)	25 (5)	5 (5)	5 (5)	22 (5)	17 (5)
Survey104	29 (5)	111 (5)	46 (5)	11 (5)	29 (5)	10 (5)	27 (5)	27 (5)	4 (5)	6 (5)	31 (5)	16 (5)

Note: Red indicates exceedance of swimming criteria (geometric mean >200). Yellow denotes "questionable" water quality, resampling is indicated (mean < 200, but one or more samples >400). Green indicates compliance with criteria

There appears to be a distinct temporal trend in fecal coliform through the quarter at the 1 m samples in the main part of the harbour (Inner and Outer Harbour). In the main harbour there is a general increase in bacterial concentrations starting at about halfway through the quarter. Bedford Basin and the Northwest Arm do not exhibit this trend. Combining observations at 1 m and 10 m, the 30 day mean values go from a count of 7/10/11 sites that are unacceptable at the start, mid and end of the quarter respectively. This is counter to the expected trend of decreasing concentrations as water warms and sunlight increases (USEPA, 1985). It appears that unusual circulation events resulting in high concentrations at sites both up harbour (survey 98) and down harbour (survey 101) as well as runoff events (survey 100), resulted in very high concentrations at less likely locations thereby skewing the 30 day averages. Descriptions of these events can be found in the weekly survey reports.

4.1.2 Out-of-Range Values

The adaptive lab procedure, using different fecal coliform detection ranges for different sites, developed as a result of previous recommendations, has reduced the number of out-of-range values significantly. For this quarter there was only one out-of-range value in week 98 (2 May 2006) at E2 at 1 m. This was an event that displaced surface water up harbour. There would be more data lost at the low end if the detection range was increased (higher values, lower resolution) for this site, so it will not be changed.

4.2 Ammonia Nitrogen

Ammonia Nitrogen is an important component in the nutrient balance in an estuary, and has potential for toxic affects, however, there is currently no marine water quality guideline for ammonia (CCME, 1999). The values obtained for this period are shown in Table 5. The laboratory "estimated quantification level" (EQL) for ammonia nitrogen is 0.05 mg/L. For the purpose of computing statistics, the EQL/2, or 0.025 mg/L was used for values below detection. Missed sample are excluded from the calculations.

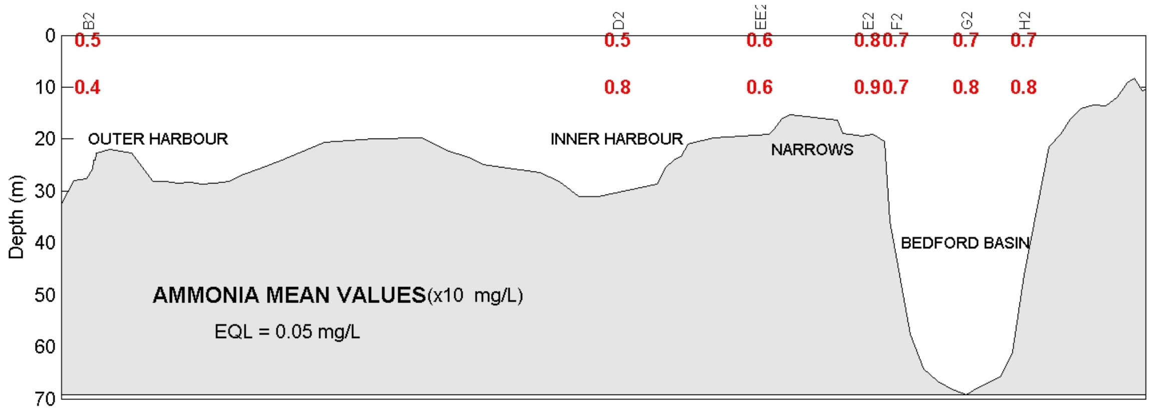
Overall, in this quarter, 59 % of samples had detectable levels of ammonium. Most of the undetectable levels occurred in the first two chemistry surveys of this quarter. Over time, there has been discussion of patterns in the data but the variability is large and the detectibility is marginal. It does appear that the highest values tend to occur in the Narrows and Bedford Basin consistent with a sewage/runoff source. This is consistent with observations this period (Figure 7). In this quarter, the highest mean values occurred at site E2, though the levels are only slightly lower both up and down harbour from this site. The clearest spatial trend is that the values in the Outer Harbour (B2), both the mean and max values, are somewhat lower than the rest of the harbour..

In this quarter, while there is week-to-week variability, it again seems random and there appears to be no definite temporal trend. The values vary from survey to survey, from no detectible samples (<0.05 mg/L) on 28 March 2006 (survey 93), to detectible level in all samples with an overall mean of 0.13 mg/L on 25 April 2006 (survey 97). There appears to be no obvious reason for the relatively high levels on 25 April 2006. Overall, there does not appear to be a strong correlation between Ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data.

Table 5. Ammonia Nitrogen summary (mg/L)
Note: green highlights indicate values below detection limits (0.05 mg/L), value assumed 0.025 mg/L.

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
28 Mar 06	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
11 Apr 06	0.025	0.025	0.08	0.025	0.025	0.025	0.025	0.03	0.08
25 Apr 06	0.08	0.08	0.12	0.14	0.11	0.14	0.11	0.11	0.14
9 May 06	0.06	0.09	0.06	0.11	0.05	0.06	0.05	0.07	0.11
23 May 06	0.09	0.07	0.06	0.14	0.12	0.11	0.18	0.11	0.18
6 Jun 06	0.025	0.025	0.025	0.025	0.06	0.08	0.025	0.04	0.08
mean	0.05	0.05	0.06	0.08	0.07	0.08	0.07	0.07	
max	0.09	0.09	0.12	0.14	0.12	0.14	0.18		0.18

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
28 Mar 06	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
11 Apr 06	0.025	0.025	0.025	0.025	0.05	0.025	0.025	0.03	0.05
25 Apr 06	0.08	0.11	0.10	0.21	0.13	0.18	0.23	0.15	0.23
9 May 06	0.06	0.07	0.08	0.11	0.06	0.08	0.025	0.07	0.11
23 May 06	0.025	0.18	0.08	0.09	0.11	0.11	0.11	0.10	0.18
6 Jun 06	0.025	0.07	0.07	0.08	0.025	0.05	0.06	0.05	0.08
mean	0.04	0.08	0.06	0.09	0.07	0.08	0.08	0.07	
max	0.08	0.18	0.10	0.21	0.13	0.18	0.23		0.23



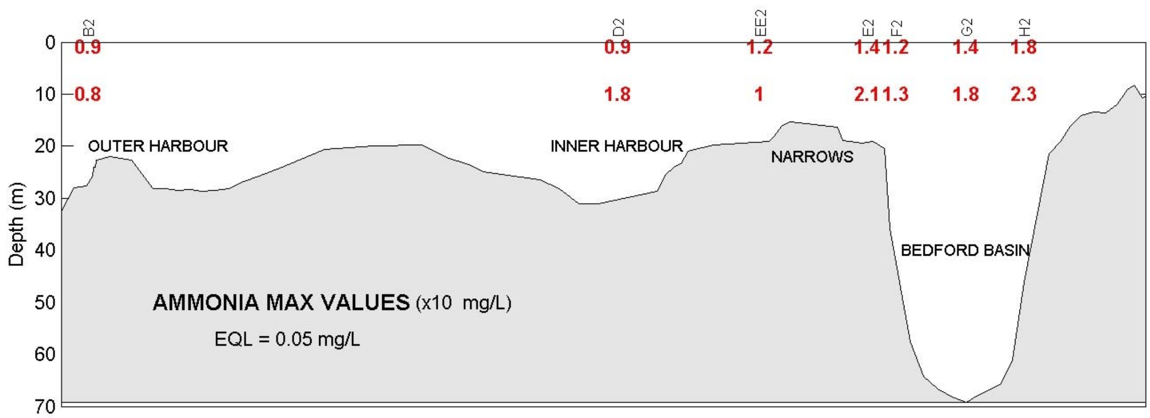


Figure 7. Mean and maximum value of ammonia nitrogen (X10 mg/L) over all eighth quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

There was no $CBOD_5$ analyses performed this quarter. Further to a recommendation in QR#2, $CBOD_5$ analysis ceased on 25 May 2005, due to lack of detectable values. $CBOD_5$ analysis continues for supplemental samples, where there have been detectable values.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 6. There were three samples taken at B2 that were below the EQL of 1 mg/L. As with total nitrogen, for samples below the detection limit, a value of one half the EQL (0.5 mg/L) is used for statistical purposes. In addition, the quarterly mean and max values are plotted on an along harbour bathymetric section in Figure 8. This quarter the average values were generally in the range of 2-7.6 mg/L. There is no clear spatial pattern; however H2 (1 m) and EE2 (10 m) show periodic higher values.

Table 6. Summary of TSS Data (mg/L)

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
28 Mar 06	3	5	8	6	7	8	10	6.7	10
11 Apr 06	5	4	7	7	7	6	8	6.3	8
25 Apr 06	0.5	9	7	4	7	1	5	4.8	9
9 May 06	0.5	1	2	4	5	6	4	3.2	6
23 May 06	3	4	1	4	1	2	3	2.6	4
6 Jun 06	6	11	7	5	6	5	10	7.1	11
mean	3.0	5.7	5.3	5.0	5.5	4.7	6.7	5.1	
max	6	11	8	7	7	8	10		11

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
28 Mar 06	4	7	10	9	9	8	6	7.6	10
11 Apr 06	7	8	10	7	4	10	7	7.6	10
25 Apr 06	4	5	2	5	6	6	7	5.0	7
9 May 06	0.5	4	4	3	5	4	4	3.5	5
23 May 06	1	2	2	2	1	2	4	2.0	4
6 Jun 06	3	3	14	4	3	3	3	4.7	14
mean	3.3	4.8	7.0	5.0	4.7	5.5	5.2	5.1	
max	7	8	14	9	9	10	7		14

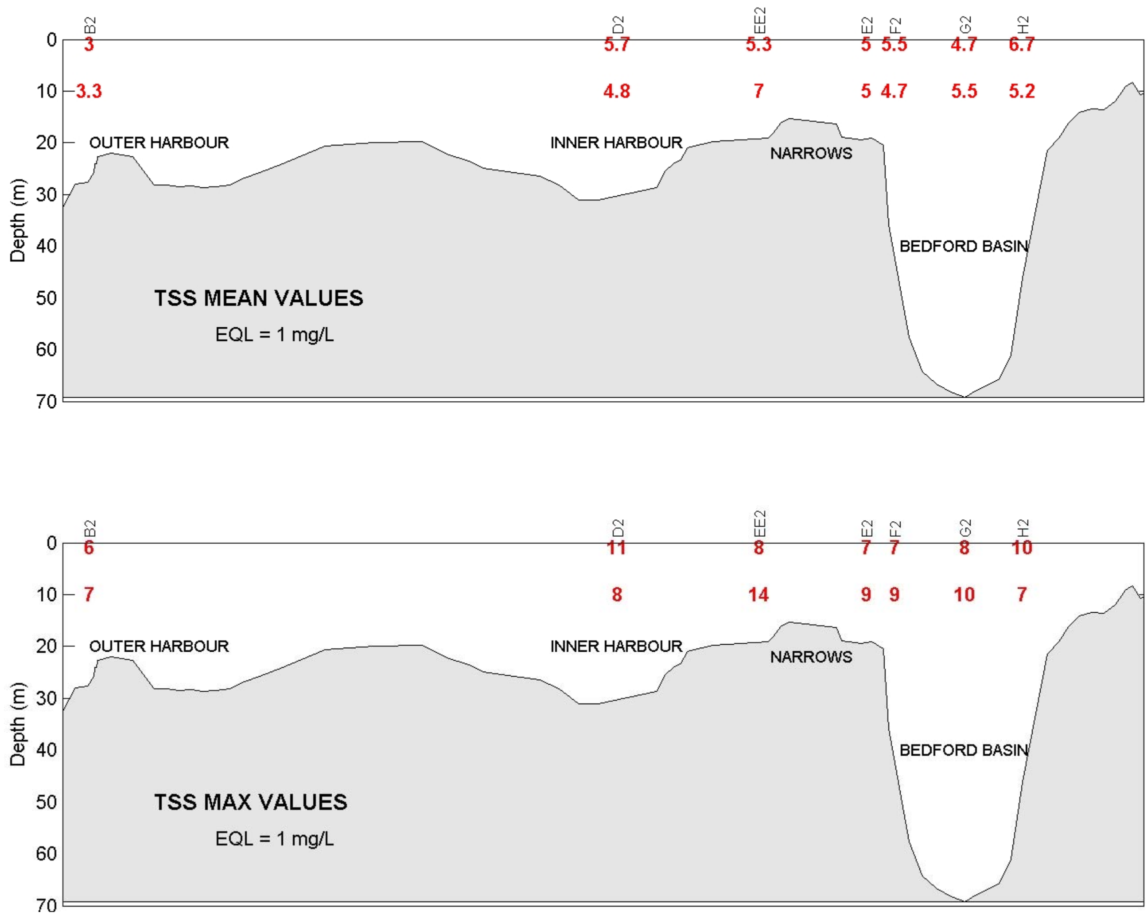


Figure 8. Mean and maximum values of total suspended solids (mg/L) over all eighth quarter samples.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report #5 regular sampling for Total Oil and Grease was discontinued on 23 November 2005, survey 73. The analysis is retained for supplemental samples.

4.6 Metals

The low level metals scan was discontinued on 23 November 2005 (survey 73). This was in response to recommendations made in Quarterly Report 4. The analysis was inadequately resolving metals concentrations in the harbour and an alternative procedure with higher resolution is being developed. Therefore, in this quarter there are no metals data.

4.7 Profile Data

The Bedford Basin Plankton Monitoring Program (BBPMP) is a long standing program of the Department of Fisheries and Oceans at the Bedford Institute of Oceanography. Starting in 1991, the program has collected a time series to record the weekly state of the plankton ecosystem in Bedford Basin. The purpose is to provide data to assess the environmental variability on weekly to decadal time scales. As part of the program, oceanographic profiles from the centre of Bedford Basin are collected on a weekly basis. The BBPMP data are available on their website: www.mar.dfo-mpo.gc.ca/science/ocean/BedfordBasin. The data consist of (among many other parameters) continuous profiles of temperature, salinity, fluorescence, and dissolved oxygen. The HHWQMP collects profiles of these variables at all sample stations to give a synoptic view of the oceanographic state of the harbour during the monitoring program. The spatial distribution of these parameters is discussed in the individual weekly survey reports.

The BBPMP sample site (44^{o} 41' 36.54" N, 63^{o} 38' 25.67") and the HHWQMP site G2 (44^{o} 41' 35.52" N, 63^{o} 38' 31.20" W) are located about 125 m apart near the deepest part of Bedford Basin. Both sites are sampled weekly, with similar, if not identical, Seabird CTDs (Conductivity Temperature and Depth profilers with additional sensors to measure dissolved oxygen and fluorescence). The HHWQMP samples on Tuesday, with contingency days on Wednesday or sometimes Thursday, while the BBPMP usually samples on Wednesday. The slight shifts in time and location are generally expected to create only minor variations in measured parameters. In the worst case, during an intrusive event where things change relatively rapidly, the two datasets might differ in the timing of the event by a week. The overlap of these two programs provides a good opportunity to inter-compare and further validate the collected data. This quarter the BBPMP discontinued the summary time series contour plots about 1 month (day 105) into the quarter. The data is still available in the form of individual profile plots and timeseries plots at selected depths. The following discussion is based on this first month of contoured data (day 75 to day 105), with reference to selected profiles where appropriate.

4.7.1 Temperature and Salinity

The HHWQMP and BBPMP temperature and salinity data from 1 January 2006 are presented in Figures 9 and 10. As would be expected the temperature data for each of the two programs show a nearly perfect correspondence. The salinity data for this period also shows high degree of correspondence. Some of the fine detail of these plots varies, but this variation can mostly be reconciled by differences in contouring routines and perhaps, in some cases where change is relatively rapid, the difference in sampling day. The biggest difference is the apparent intrusion of lower salinity at depth in the BBPMP at about day 75 at the end of the previous quarter. This is not seen in the HHWQMP data. With the addition of this quarter's data, it appears that this may be a problem with the BBPMP salinity data. The salinity drops by more than 1.5 PSU at a depth of 50 to 60 m.

There is no commensurate change in temperature so the water is significantly less dense than the overlying water, a statically unstable condition. Subsequently the data returns to the pattern consistent with earlier data and consistent with the HHWQMP data.

In this quarter, as expected, the water is generally warming and the surface water salinity decreases due to spring freshet and rainfall. A mid-water intrusion of slightly warmer, more saline water is noted in survey report 102 (30 May 2006, day 149). This is evident in the temperature, and to a lesser extent, the salinity data plots. It appears that the intrusion mixes with, more than replaces, the bottom water resulting in relatively uniform slightly warmer, more saline conditions in the bottom (below 15-20 m) waters. This also is seen in the dissolved oxygen data discussed below (Section 4.7.3).

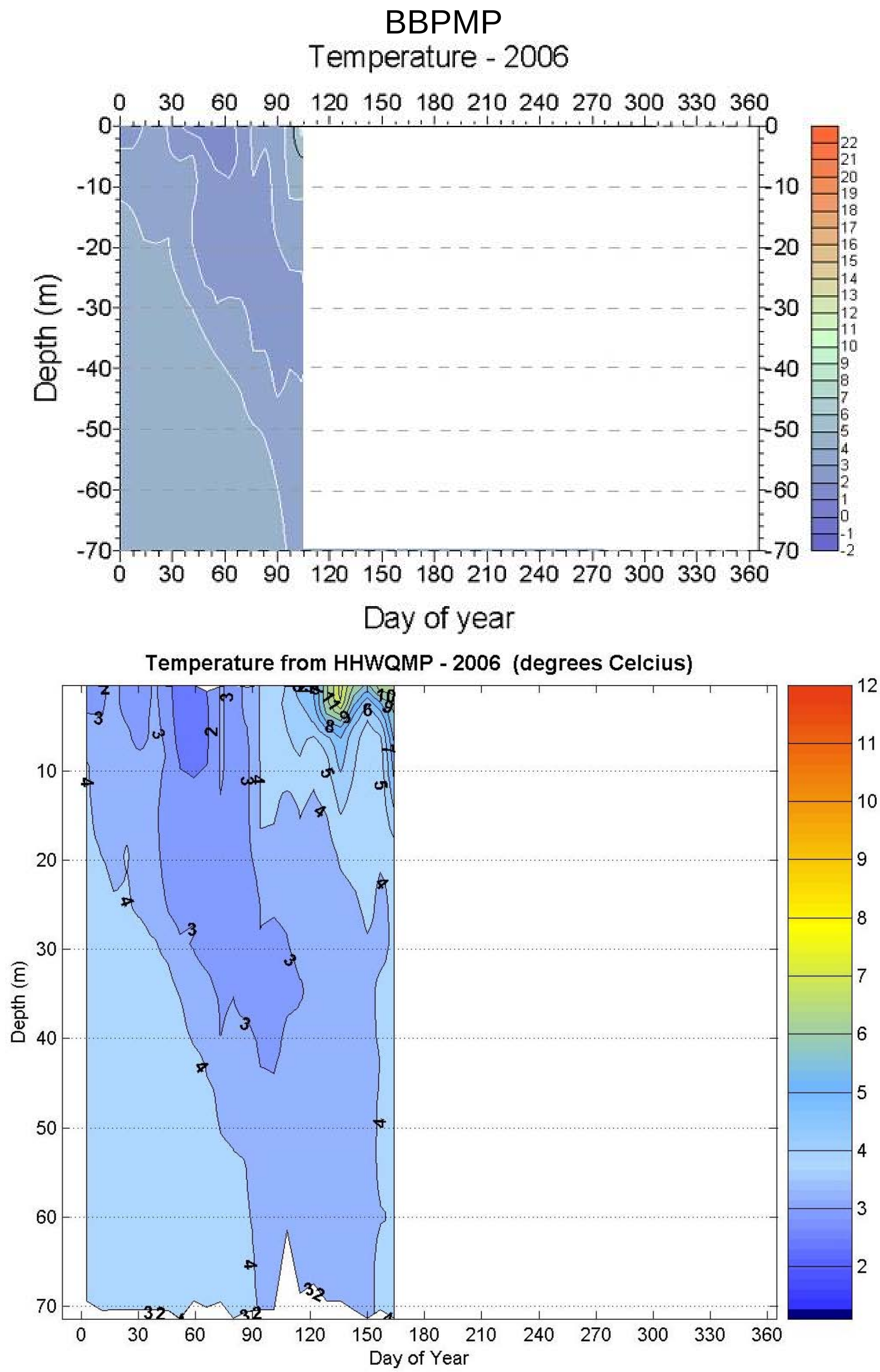


Figure 9. Comparison of BBPMP and HHWQMP temperature data from Station G2 (1 January 2006 to 13 June 2006).

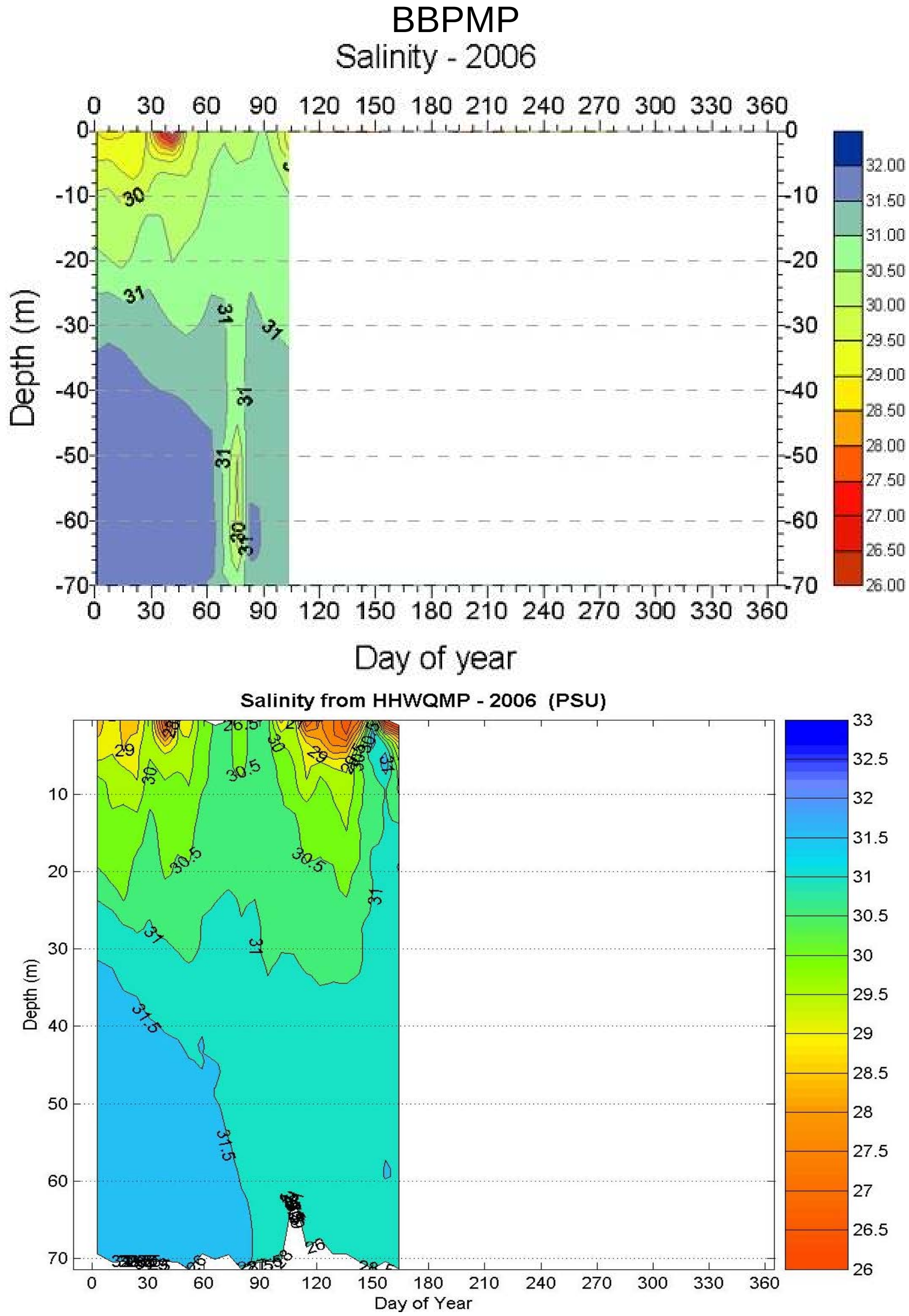


Figure 10. Comparison of BBPMP and HHWQMP salinity data from Station G2 (1 January 2006 to 13 June 2006).

4.7.2 Fluorescence

The HHWQMP reported values of Chlorophyll *a* are un-calibrated, generated using the default values provided with the Seabird instrument software. As such, though the units are mg/m^3, they are really more of a measure of fluorescence than of a true measure of the mass concentration of phytoplankton. The conversion to biomass is highly dependant on many factors, including species and condition of plankton present, and is approximate even when fully calibrated with water samples. The fluorescence values can be useful when considered on a relative basis. This comparison is probably more valid within a survey, where conditions are more likely to be consistent over the harbour, than between surveys which occur under different conditions. The more separated in time, the more uncertain the comparison. Nonetheless, due to the large variability in natural plankton concentrations, the data provides useful information on the relative spatial and temporal variability of phytoplankton activity.

A comparison of HHWQMP fluorescence data with that of the BBPMP is presented in Figure 11. Note that BBPMP data is relative fluorescence presented without dimensions. Also, the BBPMP is presented on a variable scale, while the HHWQMP data is presented on a linear scale. These two factors dictate that the units and figure colours are not directly comparable. The general trends in the two data sets, however, are very similar.

Again, there is only one month of BBPMP data for this quarter, roughly from day 75 to day 105. This data indicated a second peak to the spring bloom that is reflected in the HHWQMP data. The HHWQMP data generally indicates elevated fluorescence throughout the quarter, there are three peaks that occur higher in the water column as the quarter progresses, likely in response to the shallower pycnocline later in the quarter.

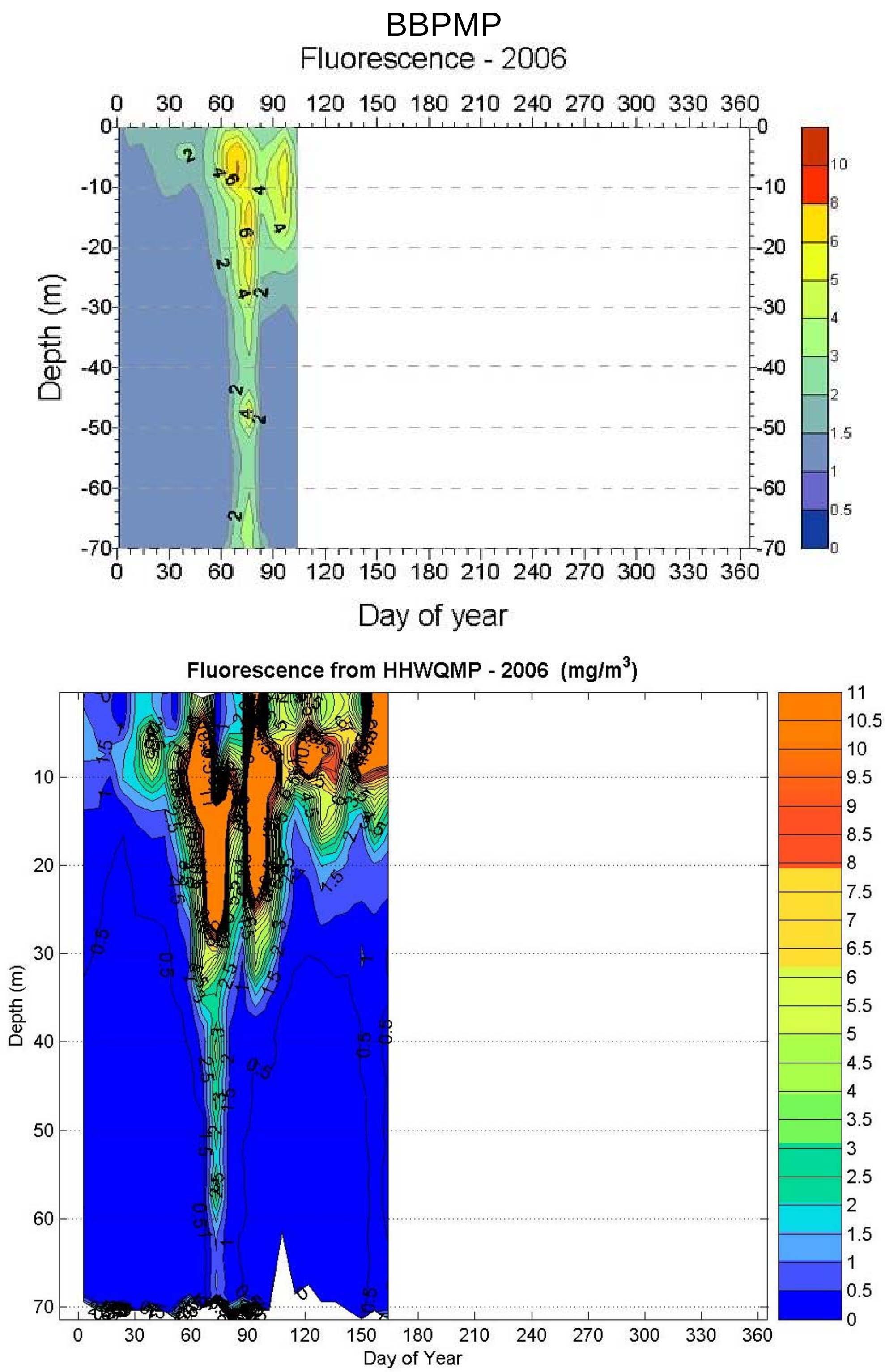


Figure 11. Comparison of BBPMP and HHWQMP fluorescence data from Station G2 (1 January 2006 to 13 June 2006).

4.7.3 Dissolved Oxygen

The dissolved oxygen data for this quarter are generally above the applicable use-specific (SA, SB and SC) guidelines. Overall, the DO levels have been quite uniform and remained uniform throughout the quarter between 8-9.6 mg/L. The usual exception is the Bedford Basin bottom water, which becomes oxygen deprived in its regular cycle of stagnation and renewal. Based on the weekly reports, the minimum DO at the bottom of the Basin at G2 varied from 2.1 mg/L (week 102, 30 May 2006) to 4.6/4.7 mg/L at the end of the quarter (week 103 and 104, 6 June and 13 June 2006) indicating an increase in the exchange of the bottom water. This is driven by an apparent mid-water intrusion into the Basin noted in survey report 102 (30 May 2006, day 149). This increase in DO at the end of the quarter can be seen in the contour plots in Figure 12.

Figure 12 is a comparison of HHWQMP oxygen data with the BBPMP oxygen data from the beginning of the year to the end of this quarter (13 June 2006). Note that the units for the HHWQMP plot are mL/L, rather than the mg/L, the units used in the weekly reports. These units correspond to the units of the published BBPMP data. The conversion factor from mg/L to mL/L is approximately 0.7. In this quarter, the two datasets show a high degree of correspondence. Aside from differences due to data presentation (i.e. contouring), the major difference is that the surface values in the HHWQMP data are lower (up to 0.5 mL/L) than those of the BBPMP. The maximum contour in the HHWQMP plot is 6.5 mL/L, while the corresponding contour in the BBPMP plot is 7.0 mL/L. The values correspond nearly exactly deeper in the water column.

Comparison between dissolved oxygen determinations by different methods/instruments has proven uncertain. Part of this uncertainty is due to the vagaries of the instruments themselves. Additionally, small variations in processing procedures, particularly with "alignment" procedures, that assign depths to the DO measurements obtained with the CTD, can add uncertainty. The CTD sensors are quite stable, however due to the nature of the CTD itself, they cannot be user calibrated. The BBPMP routinely collects water samples for ground truthing their DO measurements. The samples are analyzed with a well calibrated benchtop DO meter. This data can be used to adjust the profile data. For a period of time the water samples were collected and analyzed, but the presented BBPMP data did not appear to be corrected (up to QR #6). The uncorrected data has been removed from the website, but previous comparisons in quarterly reports are quarterly reports is questionable. These values had always been lower than the HHWQMP values. It appears, based on individual profiles, that the data presented in Figure12 has been corrected.

On survey 102 (30 May 2006) five samples were taken for Winkler titration. On average these samples were almost 2.0 mg/L (1.4 mL/L) higher than the Seabird values determined in situ. However, the BBPMP "corrected" 1 m value (31 May 2006) compares almost exactly with the HHWQMP value at G2 obtained the previous day (8.7 mg/L vs 8.6 mg/L). This demonstrates the difficulty in getting consistent values between different analyses. Note there were two other Winkler samples taken on survey 100 (16

May 2006), these resulted in values both significantly higher and lower than the seabird values and the sample handling technique has been questioned.

The importance of this data set has been discussed in previous reports. It is important that the data be appropriately quality controlled, and warrants continued attention.

4.8 Supplemental Samples

During this quarter, seven samples were obtained for Winkler titraton. These were taken over two surveys (survey 100, 16 May 2006 and survey 102, 30 May 2006). These were discussed in the previous section. Detailed results are reported in the survey reports.

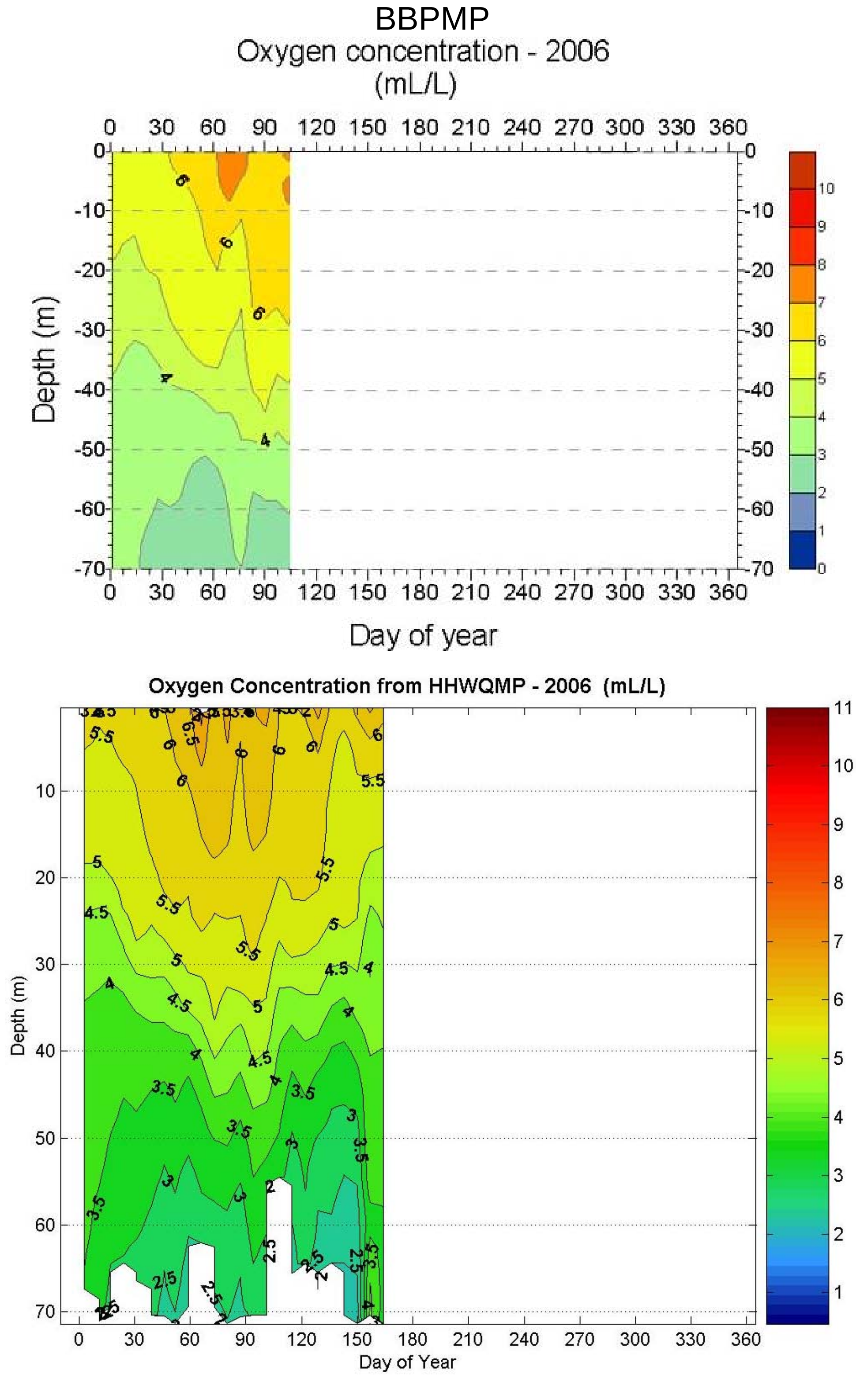


Figure 12. HHWQMP dissolved oxygen data from Station G2 (1 January 2006 to 13 June 2006).

5 Annual Summary

The following section is a summary of the previous year from 21 June 2005 through 13 June 2006 and includes information provided in Quarterly Reports 5 through 7 combined with information in the previous sections of this report. There is a very large amount of information in this data bearing on oceanographic and water quality processes in the Harbour. The detailed process-oriented analysis of this data is beyond the scope of a monitoring program, but some discussion of these processes is included.

5.1 Hydrographic Data

The temperature and salinity data reflect the dynamic state of the harbour and therefore represent a base from which to interpret the water quality data. To some extent the temperature and salinity, and resultant density stratification, in Halifax Harbour vary predictably on seasonal timescales. The surface water generally warms in spring and summer, reaching a maximum in late August or early September, and cools in fall and winter (minimum late February early March). The surface salinity is low with spring freshet in the Sackville River and other tributaries. On top of the seasonal signal is a large amount of variability, mostly on a meteorological timescale (days to weeks). Large rainfall events cause freshening of the harbour similar in magnitude to the freshet anytime throughout the year. Wind forcing directly on the harbour can push surface water either up or down harbour for days at a time resulting in local upwelling or downwelling and enhanced vertical mixing. On a larger scale, the passage of weather systems/storms on the continental shelf can cause larger scale upwelling or downwelling along the coast. Upwelling pushes colder saltier bottom water into the harbour forcing the warmer fresher harbour water out of the harbour in a surface layer. Downwelling is the reverse. These two layer events are very effective in exchanging harbour water and can result in rapid changes water properties.

Perhaps the most oceanographically interesting feature of the Halifax Harbour is Bedford Basin. The Basin is a fiord. The near surface water (<20-30 m) exchanges freely with the remainder of the harbour and to a large extent reflects conditions there. The deep water (up to 70m) is relatively isolated by a sill (20-25 m) in the Narrows and is only renewed periodically by the upwelling of dense continental shelf bottom water over the sill. This water displaces and/or mixes with the existing bottom water. As a result of this mechanism, the bottom water in the Basin is normally denser than any water in the remainder of the harbour, reflecting its origins in deeper continental shelf water. These renewals can be seen in the salinity and temperature data, but often the most telling signature of this phenomenon is the dissolved oxygen of the deep bottom water. Under normal conditions, the dissolved oxygen in this water drops as oxygen is consumed by decomposing organic matter, present in the sediments and “raining” down from the surface water. With time, the dissolved oxygen can become very low. The water in an intrusion is generally well oxygenated and dramatically increases the DO. The DO therefore tends to reflect the time since the previous renewal. Between intrusions

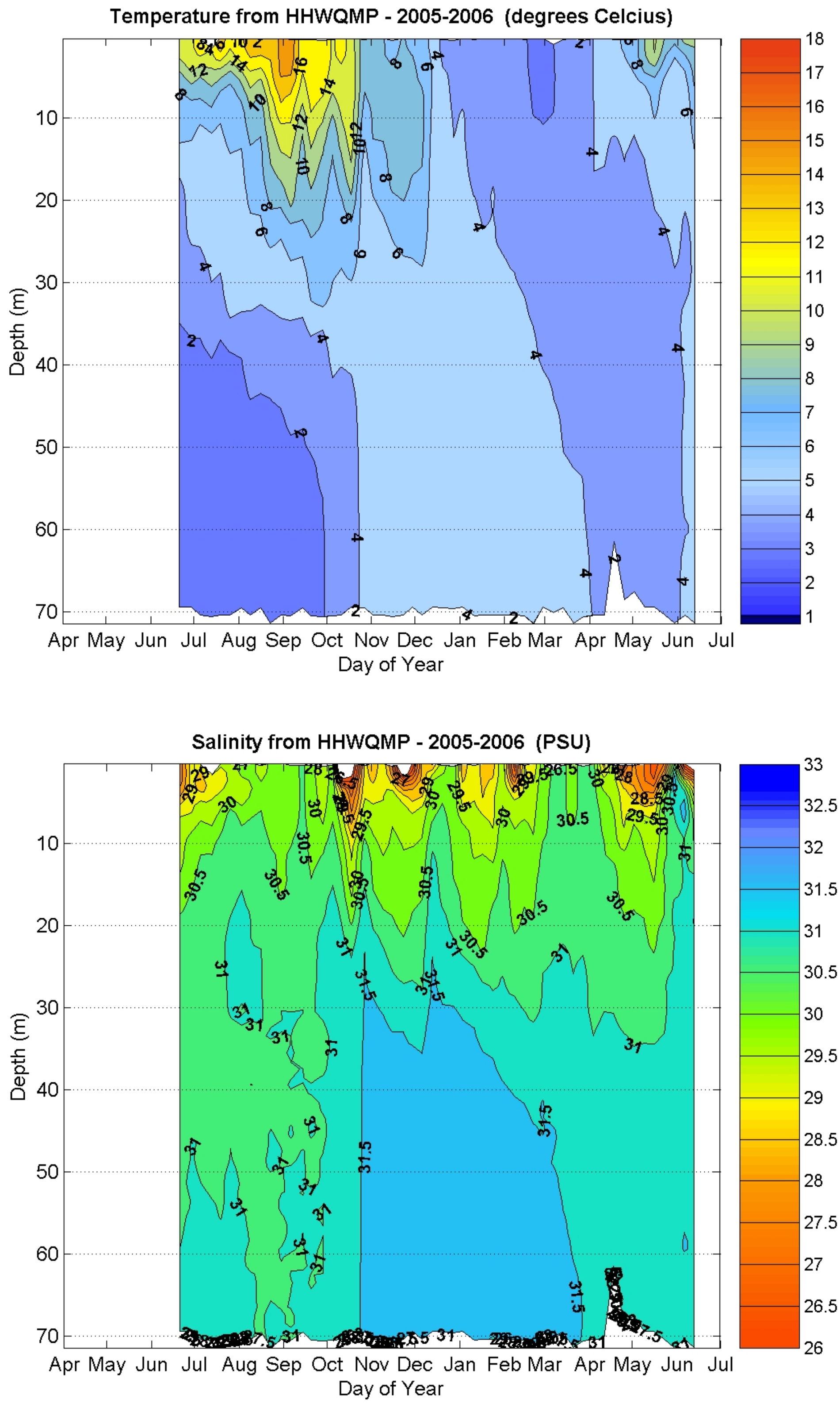


Figure 13. HHWQMP temperature and salinity data from Station G2 (21 June 2005 to 13 June 2006).

vertical diffusion slowly decreases the bottom water density by mixing with less dense overlying water. Historical information (i.e. The BBPMP) indicates that these events occur on average once or twice a year in Bedford Basin. Less intense upwelling can occur more often, resulting in intrusion at intermediate depth in the Basin. All intrusions can have surface signatures as the deeper, generally colder, more saline, water is displaced upward and flushed out in the surface layer.

The salinity and temperature data from station B2 in the centre of Bedford Basin, for the year including quarters 5, 6, 7 and 8 are shown in Figure 13. The features of this data is discussed in somewhat more detail in the quarterly reports. The temperature data shows the seasonal temperature trend in the surface water with a maximum temperature of about 18º C in the beginning of September and a minimum of less than 2º C in the beginning of March. There are six or seven upper water column "freshening" events, due to precipitation /snowmelt evident in the salinity data.

In both data sets the effects of intrusions, characterized by abrupt changes in water properties, is apparent. There appears to be at least two classic intrusions replacing the bottom water. The first, in late October (27 October 2005 survey) in response to the passage of Hurricane Wilma across the Scotian Shelf. The second about six weeks later, noted in the 13 December 2005 survey, "builds" on the distribution left by the first and the seasonal cooling to establish a nearly uniform (~4º C) vertical temperature distribution. These events leave a relatively warm >4º C salty water mass in the bottom of the Basin that persists throughout the winter. It appears that there are several incomplete or mid-water intrusions that don't displace the whole water column e.g. those noted on surveys 57 (19 July 2005) and 102 (30 May 2006).

5.2 Fluorescence

The fluorescence data collected by the CTD is a proxy for chlorophyll and can be used to get a relative sense of primary productivity (See Section 4.8). The units of the values discussed here are mg/m^3 as generated by the CTD data processing software, but should not be interpreted strictly as biomass measurements.

Phytoplankton blooms tend to start in the Basin and migrate outward to the rest of the harbour. The profile maximum values generally decrease in magnitude and occur lower in the water column further out of the harbour. The data in the Basin generally represents the maximum concentrations observed and is representative of the timing of phytoplankton activity in the remainder of the harbour. Figure 14 shows the timeseries of fluorescence profiles in the centre of the Basin (site G2). This shows relatively continuous low level activity in the beginning of the summer (quarter 5) increasing to relatively high levels at the end of the summer. This subsides in the fall, with relatively continuous lower level activity. There was only a brief period in January where activity dropped to "background levels" (about $< 2\ mg/m^3$). By the end of January some activity returns. It appears that the spring bloom began in earnest at about the beginning of March, with significant activity occurring episodically until the end of the record in June.

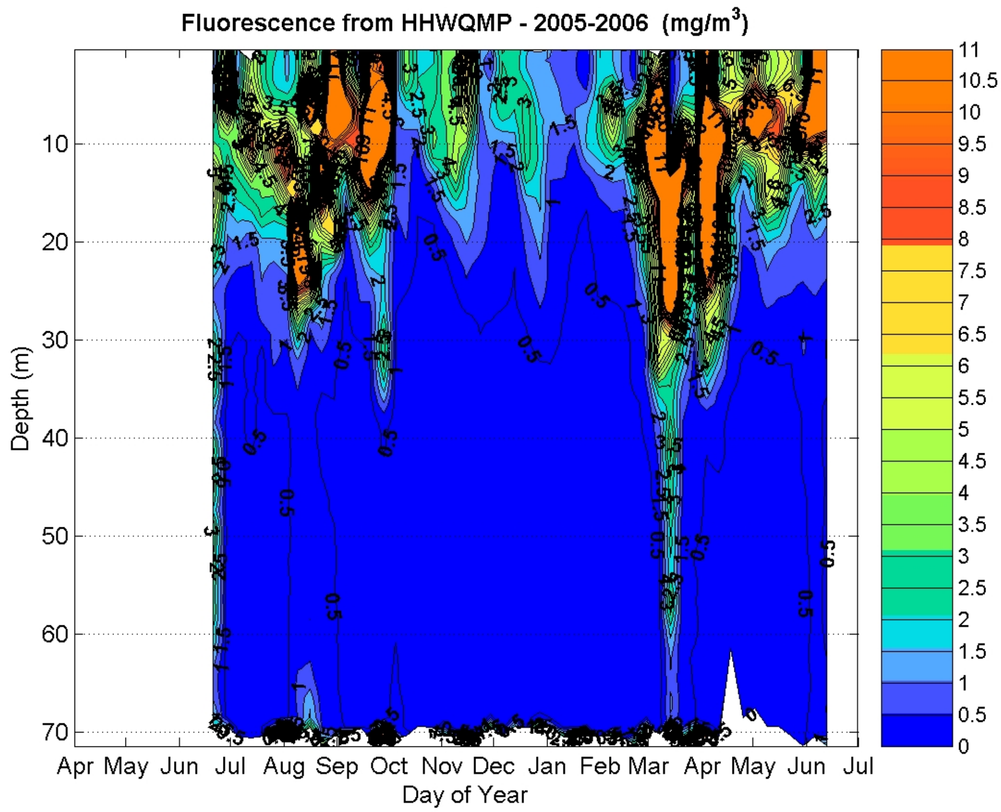


Figure 14. HHWQMP dissolved oxygen and florescence data from Station G2 (21 June 2005 to 13 June 2006).

During the bloom, maximum concentrations of 20-40 mg/ m^3 occur in Bedford Basin. In the Inner Harbour, the typical profile maximum values are about half those in the Basin. In the Outer Harbour the profile maximum values are lower still, usually 3-4 mg/ m^3, but a value of 32 mg/ m^{3,} the highest value in the survey, was observed near bottom at B2 on 28 March 2006. Consistent with the previous year it appears that, while there is a definite spring bloom, phytoplankton activity continues sporadically throughout the spring, summer and fall, until activity ceases due to lack of light in the late fall and winter.

5.3 Dissolved Oxygen

During this period there was additional data collected to verify the Dissolved Oxygen data acquired with the Seabird profiler. For most of quarter 5 a Hydrolab oxygen probe was used to make surface measurements simultaneously with the Seabird deployment (discussed in Quarterly Report 5). In quarter 8 samples were taken for Winkler titration on two occasions (discussed in Section 4.7.3). Throughout the program the DO data at station G2 is compared to that at the nearby BBPMP site (discussed in all quarterly reports). The results are mixed, but, with corrections to the BBPMP data, it appears that the Seabird values were always equal to or lower than the other methods. This difference could be as much as 20%. This uncertainty must be considered in the following discussion. An increase of 10-20% in measured DO would eliminate most of the criteria exceedences discussed below.

5.3.1 Harbour and Basin Surface Water

There are spatial variations in dissolved oxygen in any survey. These patterns vary from survey to survey depending on the dynamic state of the Harbour. Sometimes these patterns are significant, but most of the time the spatial variations are small compared to the large-scale temporal variations. The following discussion is based on the values throughout the harbour, however the general trends can be seen in the upper portion (top 20-25 m) of the Basin timeseries contours in Figure 15.

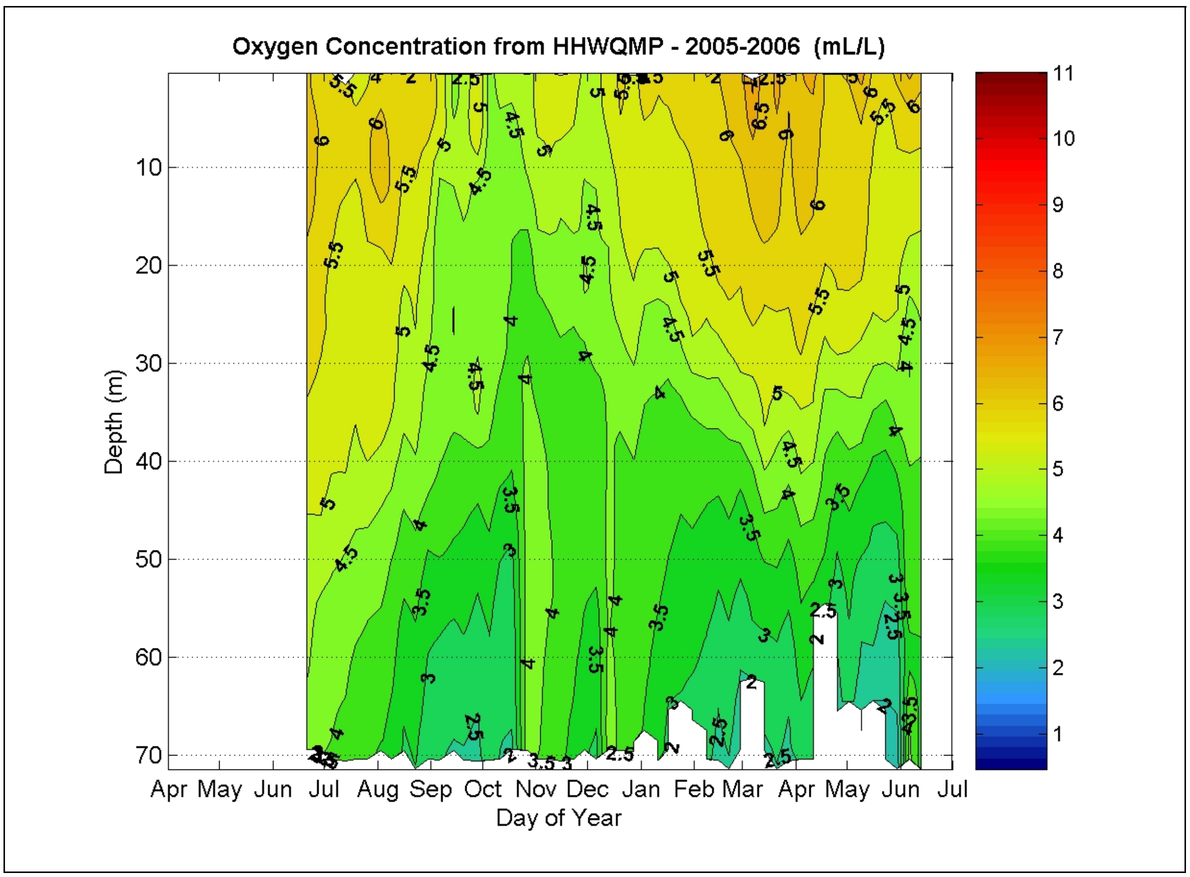


Figure 15. HHWQMP dissolved oxygen data from Station G2 (June 21, 2005 to June 13, 2006)

The dissolved oxygen data for the beginning of this period (summer) are generally above the applicable use-specific (SA, SB and SC) guidelines. Near the end of the summer, starting at survey 61 (16 August 2005), the DO in the surface water began to drop below guideline levels. On that week, the measured DO in the surface water at site B2, dropped below the Class SA level of 8.0 mg/L (5.6 mL/L). Subsequently, the DO levels continued to drop. By 30 August there were values measured throughout the harbour that were below 7 mg/L (4.9 mL/L). This implies guideline exceedences in all class SB waters (Bedford Basin, NW Arm, Eastern Passage and section C in Outer Harbour) as well as the class SA exceedence at Site B2 in the Outer Harbour. The only area where guidelines are met is the Inner Harbour, which is classified SC and has a DO requirement of 6.0 mg/L (4.2 mL/L). This general condition continues into the fall, with values throughout the harbour in the 6-8 mg/L (4.2 to 5.6 mL/L) range, resulting in frequent values below the applicable guidelines in the class SA and SB regions of the harbour. The lowest values occur on surveys on 11 October 2005 thru 27 October 2005, a period of time of very wet weather and of elevated concentrations of other water quality parameters, particularly coliform and metals. The data during this period indicate DO levels from just below 6 to 7 mg/L (4.2 to 4.9 mL/L). These are below the use specific criteria for all class SA (> 8 mg/L) and SB (>7 mg/L) areas and are borderline for the Inner Harbour, class SC (>6 mg/L). After this, the measured values generally increase though periodic criteria exceedences occur until mid-December. In quarter 7, from January on, values remain quite uniform throughout the harbour with values generally increasing from >7.0 mg/L at the start, to 9-10 mg/L by the end in mid-March. The dissolved oxygen data for this quarter are generally above the applicable use- specific (SA, SB and SC) guidelines. Throughout the spring (quarter 8) the DO levels fluctuate somewhat, between approximately 8.0 and 9.6 mg/L (5.6 - 6.7 mL/L), but are generally above the applicable use-specific guidelines.

5.3.2 Bedford Basin Bottom Water

The Dissolved Oxygen in the Bedford Basin bottom water (Figure 15) generally responds to different processes than the surface water (Section 5.1). On occasion, but not always, the signature of an intrusion can be seen in the near-surface water as the oxygen depleted bottom water is displaced upward and flushed out of the harbour. The reason this is not always seen is likely due to mixing with the larger volume of surface water.

This water only rarely has dissolved oxygen above the Class SB guideline (7.0 mg/L). At the start of the year, the minimum DO at the bottom was 6.5 mg/L (4.5 mL/L), due to a bottom water renewal in the previous quarter. This was the highest value of the year. This dropped to a minimum of less than 3 mg/L (2mL/L) by October, when the water was replaced by the intrusion associated with hurricane Wilma that shows up in survey 71 (27 October 2005). This intrusion had a large effect on the hydrographic properties (section 5.1) but not as large an effect on the DO as many intrusions. The water deeper than 30 m, was raised uniformly to about 6.1 mg/L (4.3 mL/L). Until mid-December the bottom DO drops slowly. At this time the second intrusion raises it to about 6.0 mg/L (4.2 mL/L). After this, the DO generally drops with some oscillation (e.g. what appears to be a mid water intrusion in April) to a minimum of just under 3 mg/L (2.0 mg/L) at the end of May. An event right at the end of the record, at the beginning of June, brings the DO up again to nearly 6 mg/L (4.2 mL/L).

5.4 Fecal Coliform

Maps showing the annual geometric mean fecal coliform concentrations at 1 and 10 m are presented in Figure 16. The key characteristics of the distribution are that the highest concentrations are in the Inner Harbour, specifically the EE section, in both the 1 and 10 m samples. This is consistent with the distribution of outfalls in the harbour. Additionally, south of the Narrows (E section) the concentrations are higher in the 1 m samples, while north of the Narrows the concentrations in the 10 m samples are higher than in the 1 m samples. In the Narrows the mean concentrations are similar in the 1 and 10 m samples. The water density (salinity and temperature) data indicates that in the Basin, the higher coliform values are usually associated with a deeper layer consisting of water with density similar to that of the near surface water in the Inner Harbour, while the 1 m sample generally occurs in a less dense layer normally resulting from freshwater runoff into the Basin. Therefore, the Inner Harbour is likely to be the major source of bacteria over much of the Basin, rather than a local source, such as the Mill Cove sewage treatment plant or Sackville River.

Within the basic annual pattern there is quite a bit of variability in both the magnitude and distribution of the bacteria concentrations in the harbour. These variations are due to interactions of meteorological and oceanographic factors affecting source strength, effluent trajectory and mixing, and bacteria die-off on seasonal, weekly and daily timescales. Maps representing the geometric mean values over all samples for each of the four quarters are reproduced from the quarterly reports in Figures 17 through 20. In these figures, values in red exceed swimming guidelines (200 cfu/100 mL); values in blue exceed shellfishing guidelines (14 cfu/100 mL); and values in green indicate suitability for either activity. In each figure, separate maps are presented for the 1 and 10 m samples. These maps show that on average the concentrations are lowest in the summer (Figure 17) and spring (Figure 20) and higher in fall (Figure 18) and winter (Figure 19). This is consistent with previous results, though the seasonal differences are not quite as dramatic as in the first year. The seasonal variation is due to differences in bacteria decay and circulation. Cooler water and reduced sunlight both increase bacterial survival times, resulting in higher concentrations in the cold water and short days of fall and winter. Increased harbour flushing, due to high freshwater input (e.g. spring freshet or storms) or upwelling/downwelling along the coast can also result in lower concentrations.

The data from each quarter generally exhibits the vertical distribution observed in the annual mean concentration. The 1 m values were higher than the 10 m values in the southern part of the Inner Harbour (section EE and south) and the Outer Harbour, while the reverse was true in Bedford Basin. However, the transition point between these two regimes varies with season (quarters). Similarly, the relative displacement (north or south) of the center of 1 m and 10 m distributions varies with season. In summer the 1 m and 10 m distributions were relatively aligned and the transition was displaced its furthest North into the Basin. These observations are likely, at least partially, in response to the strength of estuarine circulation (freshwater input), though seasonal variation in winds (local and non-local) will also play a role.

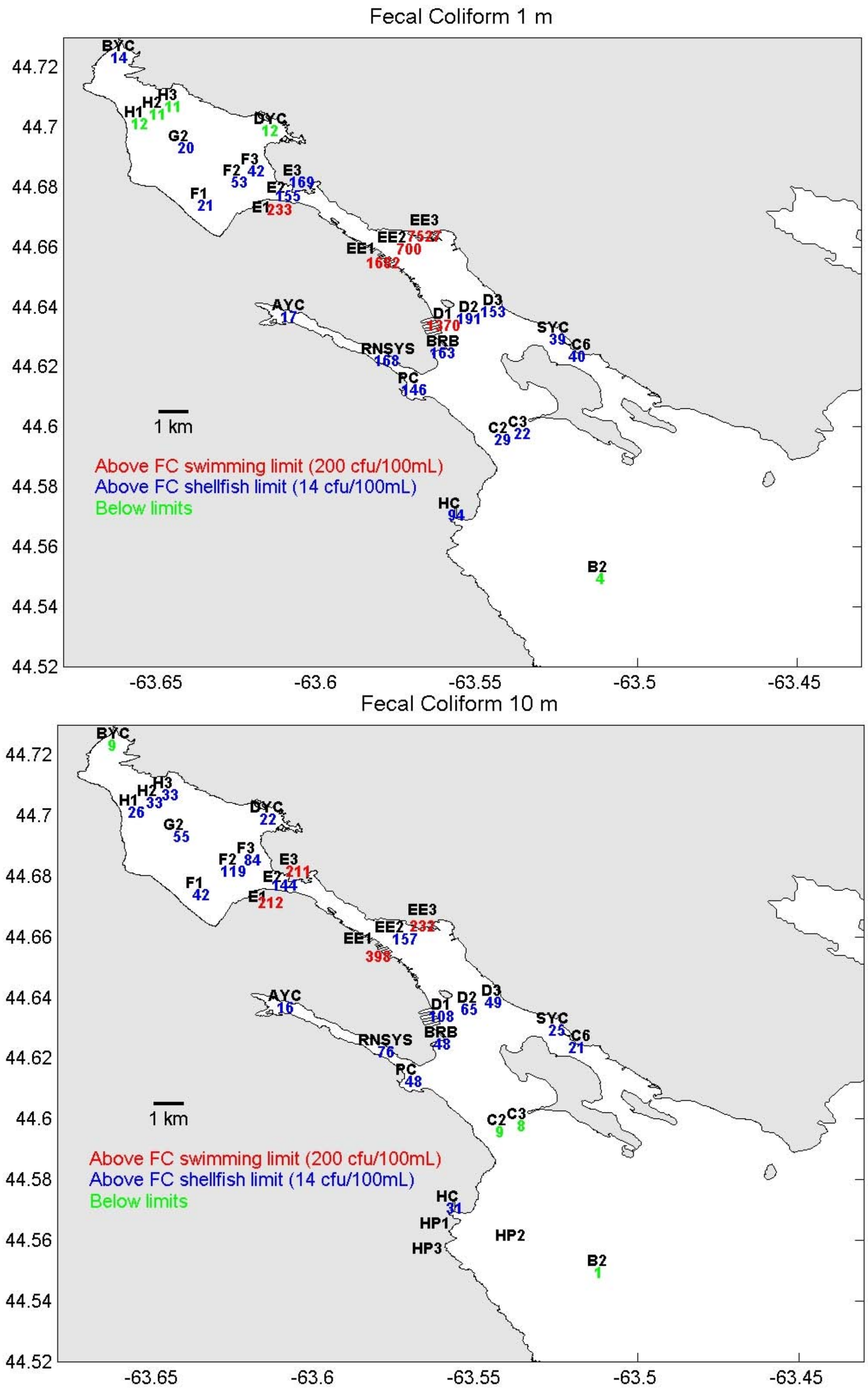


Figure 16. Fecal coliform geometric means (cfu/100mL), 21 June 2005 to 13 June 2006.

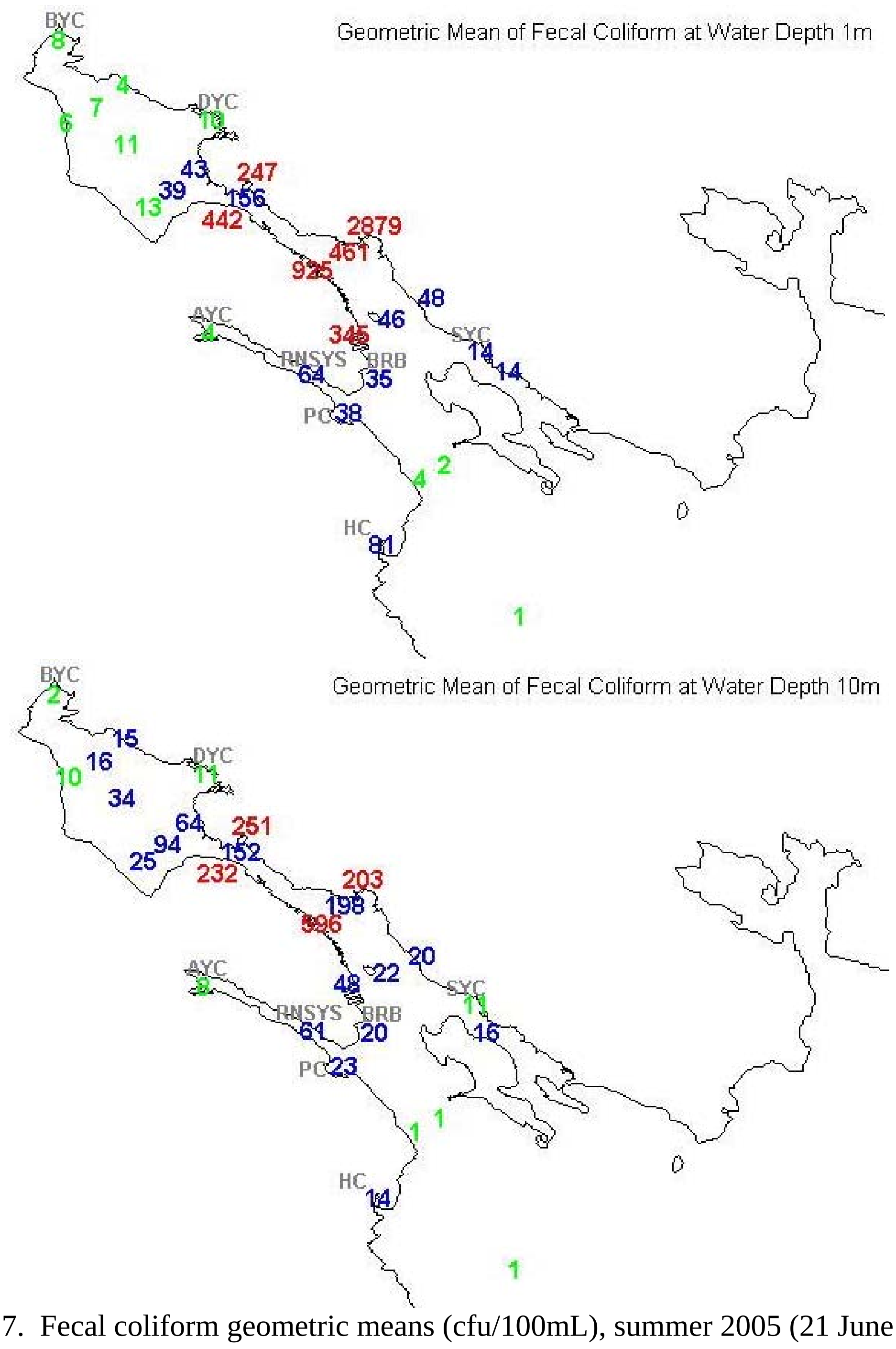


Figure 17. Fecal coliform geometric means (cfu/100mL), summer 2005 (21 June 2005 to 14 September 2005)

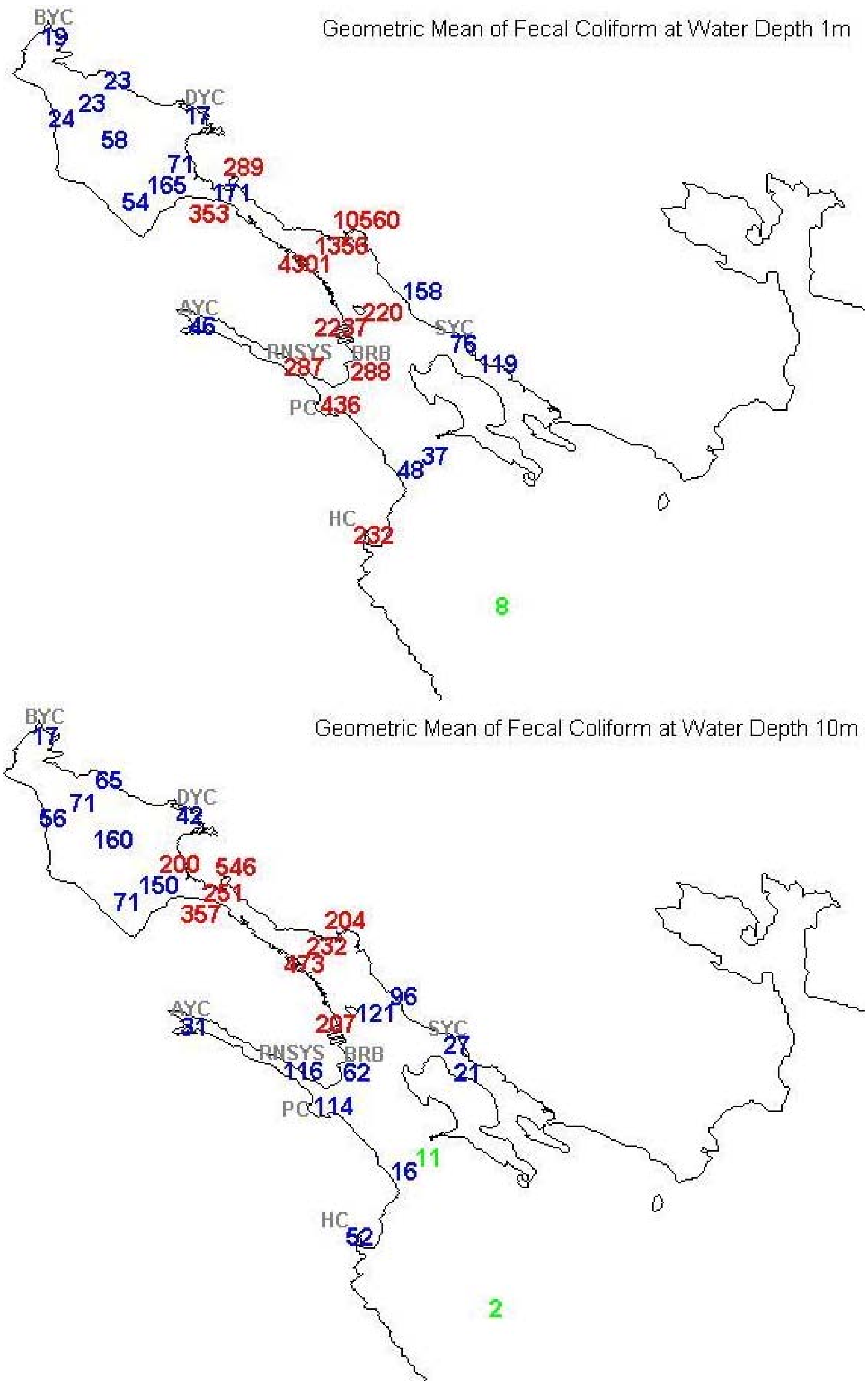


Figure 18. Fecal coliform geometric means (cfu/100mL), fall 2005 (20 September 2005 to 13 December 2005).

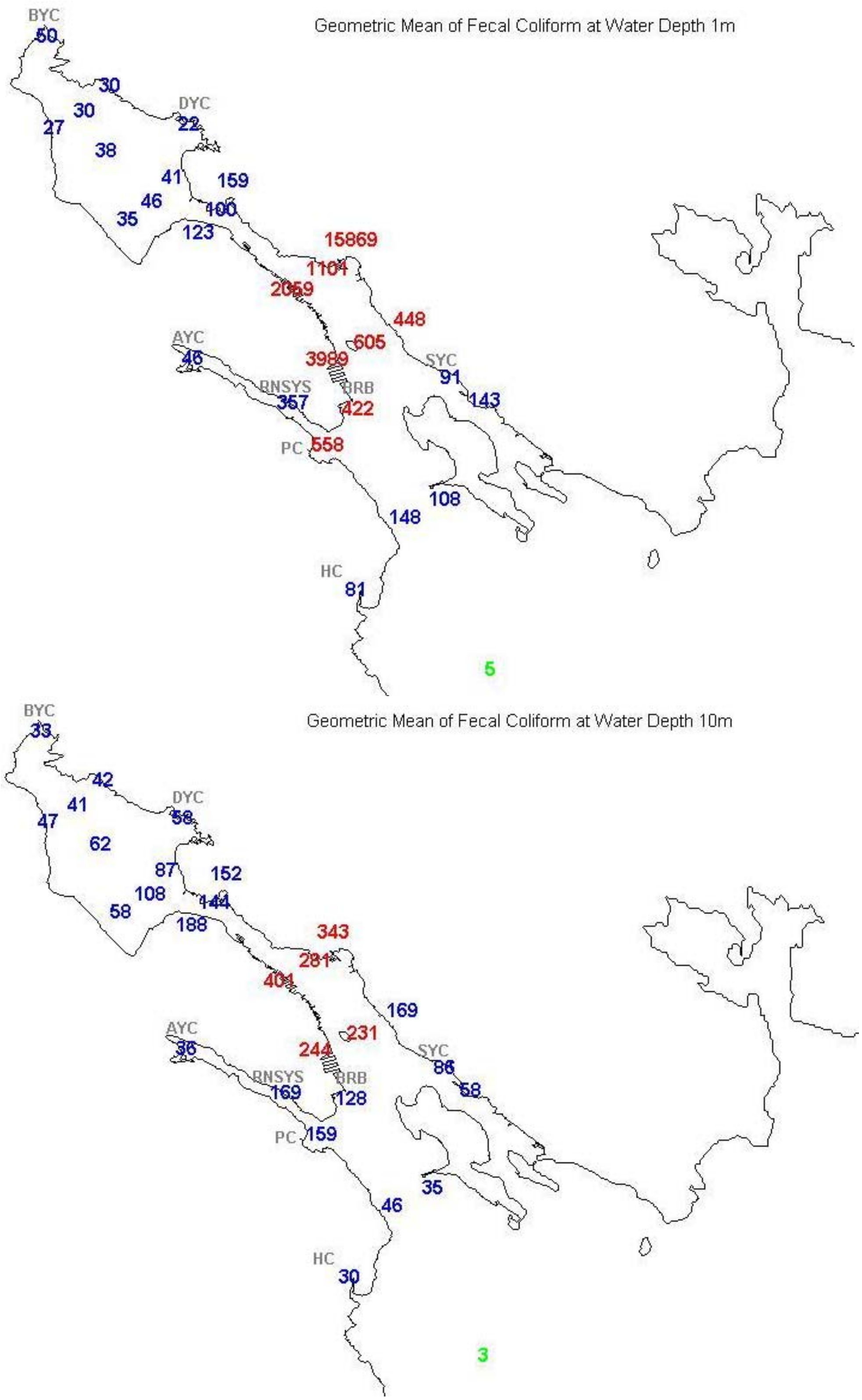


Figure 19. Fecal coliform geometric means (cfu/100mL), winter 2006 (20 December 2005 to 14 March 2006).

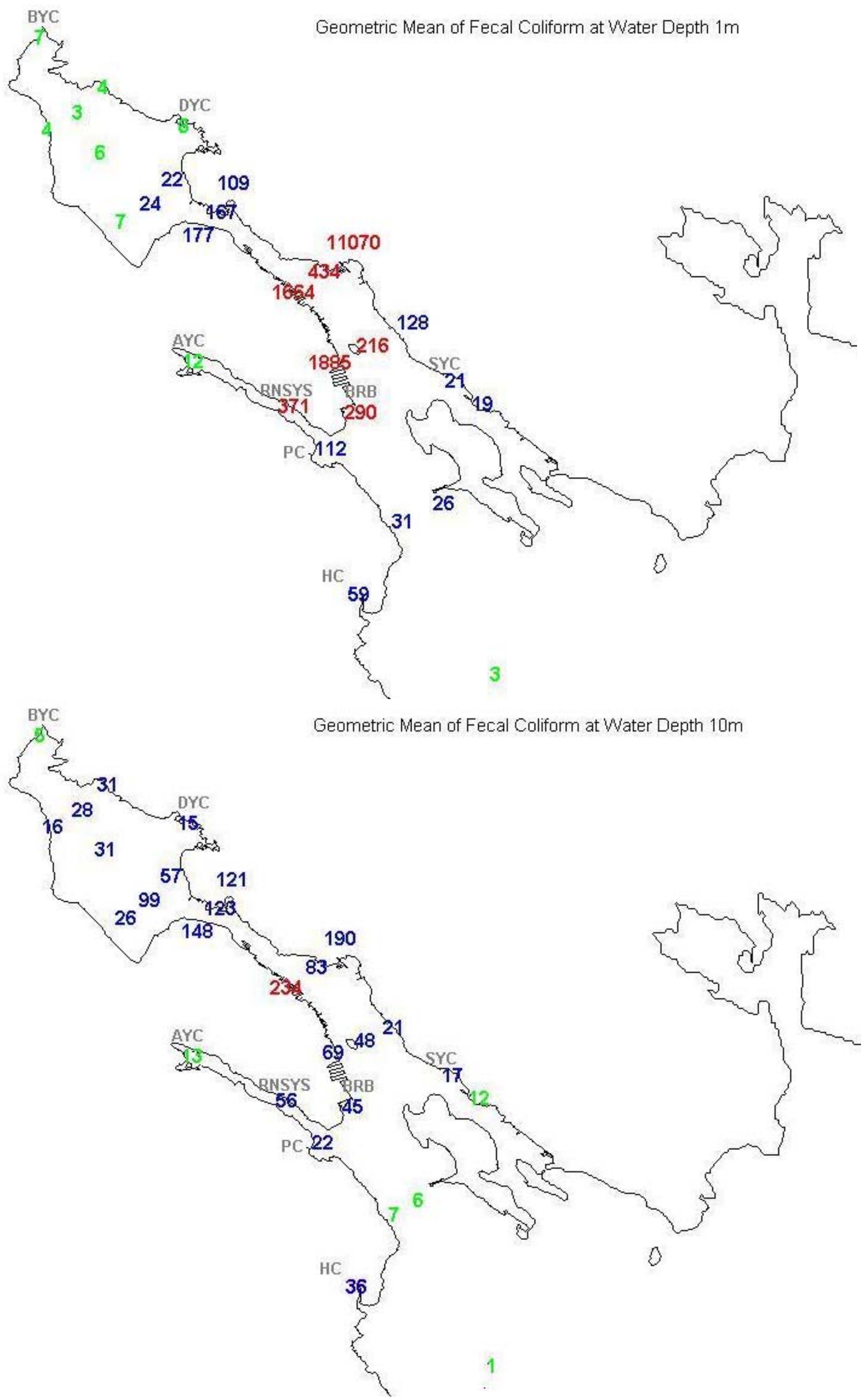


Figure 20. Fecal coliform geometric means (cfu/100mL), spring 2006 (21 March 2006 to 13 June 2006). Duplicate of Figure 6.

These seasonal trends are also evident in the floating thirty-day geometric mean, compiled for the entire year here in Tables 7 and 8. Particularly notable is the increase in bacteria concentration in the fall (surveys 66 -78) and winter (surveys 79 - 91).

There is also significant survey to survey variability in the bacteria concentrations. This is likely mostly due to the higher frequency variability in harbour flushing in the meteorological timescale (3-5 days). Figures 21 through 24 show timeseries of the fecal coliform concentrations at representative sites in the Outer Harbour, NW Arm, Inner Harbour and Bedford Basin. The mean patterns discussed above can be seen as trends in the timeseries data, namely:

- values are highest in the Inner Harbour
- values are highest in the Fall and Winter
- in the Inner Harbour the highest values are in the 1 m samples
- in the Basin the highest values are in the 10 m samples

As discussed in quarterly and various weekly reports, the significant week to week variations in FC levels and distribution appear to correlate, at least qualitatively, with observed meteorological and oceanographic phenomena. Variations in circulation can displace high bacteria counts either up or down harbour as well as increase or decrease vertical differences and increase or decrease overall concentrations (periods of low or high flushing). The easiest place to see this is in the Outer Harbour at site B2 (Figure 24). The concentrations here are generally <10 cfu/100 mL, but wind/intrusion events that move the surface water out of the harbour are occasionally strong enough to result in quite high concentrations here. In addition to advection and dispersion, cloud cover can reduce bacteria decay rate causing increased concentrations.

Table 7. 30 day geometric mean (number of samples) of 1 m fecal coliform concentrations (MPN/100 ml).

	Outer Harbour				Eastern Pass.		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey53	4	92	12	10	16	17	50	338	73	114	1359	425	909	251	109	124
Survey54	3	106	7	7	3	8	25	245	36	51	857	602	816	208	83	124
Survey55	2	67	5	2	1	2	8	177	18	19	484	359	407	97	75	98
Survey56	1	50	2	1	1	2	9	228	16	9	395	319	224	268	153	135
Survey57	1	50	4	2	3	6	20	835	29	26	549	613	467	243	207	119
Survey58	1	76	4	2	7	30	34	472	42	37	600	828	1484	797	573	588
Survey59	1	72	4	2	7	30	27	748	74	37	345	387	4116	435	385	441
Survey60	1	69	2	2	8	30	27	597	70	62	278	551	7494	826	364	394
Survey61	1	76	2	2	8	17	15	269	56	154	394	638	20062	521	222	346
Survey62	1	114	1	1	16	10	13	156	37	47	183	289	13263	440	110	242
Survey63	1	119	1	1	21	9	14	216	17	22	540	347	10956	365	75	224
Survey64	1	69	1	1	39	15	21	146	18	37	1460	447	6069	1160	63	243
Survey65	1	86	2	1	71	17	69	288	31	35	2606	374	5700	782	84	405
Survey66	2	97	2	1	62	19	56	264	21	8	2049	310	7185	768	133	485
Survey67	5	93	5	5	27	26	81	536	37	20	3377	235	7792	186	53	178
Survey68	5	123	8	10	13	8	102	723	123	25	1684	239	9953	212	124	124
Survey69	7	474	34	26	27	20	213	1427	145	50	1918	547	9234	94	200	118
Survey70	19	645	84	97	55	76	133	2217	156	86	1968	623	9907	130	137	69
Survey71	25	865	202	147	137	155	277	5240	362	273	5152	1155	6286	137	93	56
Survey72	12	608	112	46	119	110	311	5513	387	423	7629	3334	8593	791	582	310
Survey73	41	371	111	29	215	162	266	8933	296	838	8167	3792	6845	621	557	337
Survey74	35	136	109	33	178	149	258	29240	471	857	11488	4724	19390	544	439	294
Survey75	11	95	78	16	92	85	496	9721	549	777	13881	6024	51962	751	756	676
Survey76	10	141	87	32	110	87	621	11478	614	962	9010	6741	77460	545	557	732
Survey77	26	243	201	136	208	207	967	11356	1245	1190	8227	4968	47622	297	160	613
Survey78	26	354	477	578	263	245	1667	9599	3336	1541	6989	4523	47622	219	95	438
Survey79	12	199	330	390	184	164	851	3312	2522	889	4338	2174	8780	149	73	339
Survey80	12	199	288	283	264	160	473	4693	1531	718	3144	1930	10919	69	102	117
Survey81	14	124	414	315	239	183	568	4502	1524	899	2651	1527	13373	106	141	168
Survey82	5	60	298	231	154	160	459	4203	1767	819	2422	1956	15194	138	239	144
Survey83	5	60	230	203	197	270	333	5775	1121	799	2554	1789	12781	112	193	139
Survey84	12	93	175	186	229	276	503	8980	1237	1200	2062	1955	15417	231	150	174
Survey85	12	69	213	102	543	213	759	5463	1180	1224	1645	1489	16772	324	120	261
Survey86	16	86	158	136	818	265	410	4970	686	827	1479	946	12981	203	108	175
Survey87	6	54	117	93	525	127	437	3359	506	630	1135	703	10621	139	67	128
Survey88	4	75	109	63	274	72	417	2216	350	381	945	454	16023	84	63	152
Survey89	3	63	99	48	214	70	251	2274	187	218	790	323	20777	36	65	110
Survey90	3	56	90	66	72	45	178	3482	230	178	854	177	10239	48	73	84
Survey91	1	43	62	28	24	13	201	1215	155	101	833	226	16096	57	74	82
Survey92	1	34	53	29	15	19	98	925	153	88	927	189	18654	92	130	92
Survey93	1	29	28	21	14	23	71	1539	175	93	683	183	14461	78	107	59
Survey94	1	15	26	14	14	15	139	1873	180	66	740	136	3564	112	229	104
Survey95	1	17	25	15	10	15	155	1047	122	49	837	125	6648	70	163	62
Survey96	1	12	36	26	21	39	191	3045	230	78	786	96	5402	47	112	56
Survey97	2	26	29	15	19	19	196	2958	147	90	892	95	5875	45	73	60
Survey98	2	21	22	14	17	10	273	1898	129	81	1213	203	5875	214	86	92
Survey99	2	61	12	12	8	6	246	1565	89	80	1476	276	10443	275	131	154
Survey100	2	96	13	8	14	12	451	2258	123	89	1943	682	13577	609	282	436
Survey101	8	129	17	11	16	14	377	747	110	104	2228	783	19194	457	122	292
Survey102	5	114	17	21	26	17	652	1210	184	87	2315	1118	11412	457	153	302
Survey103	8	161	35	45	31	40	645	1159	261	190	2225	996	15317	201	178	230
Survey104	12	187	62	79	59	87	542	1265	722	394	2772	1642	17013	343	164	61

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey53	51	59	66	23	71	51	40	18	30	44	103	6
Survey54	28	53	64	10	55	16	11	5	15	14	25	3
Survey55	12	28	41	5	25	7	4	3	8	12	13	2
Survey56	6	18	16	4	9	3	1	1	4	14	10	1
Survey57	3	17	12	9	4	2	1	2	7	23	16	3
Survey58	4	32	14	15	3	2	2	2	7	20	45	3
Survey59	4	18	9	15	2	2	2	2	6	20	33	4
Survey60	4	26	9	15	2	2	2	2	6	15	70	4
Survey61	11	26	40	25	3	4	4	3	11	8	45	3
Survey62	8	14	23	4	5	2	4	1	2	17	28	2
Survey63	13	37	45	4	15	5	7	2	2	19	17	4
Survey64	9	20	91	5	11	5	8	3	3	60	102	4
Survey65	12	51	161	8	13	5	7	3	3	192	131	5
Survey66	11	126	81	8	22	4	7	4	3	434	610	8
Survey67	9	58	48	8	13	4	7	4	3	264	373	12
Survey68	7	46	39	6	7	2	3	2	3	430	386	6
Survey69	9	169	18	8	33	11	9	8	8	759	505	26
Survey70	26	130	20	11	83	26	19	22	18	563	287	38
Survey71	43	125	31	11	74	32	27	37	23	313	189	65
Survey72	194	566	110	20	177	61	48	72	34	324	187	63
Survey73	336	643	137	29	297	114	84	141	56	260	92	93
Survey74	282	438	147	44	112	56	47	66	20	208	46	45
Survey75	385	622	199	60	156	101	79	103	44	243	114	106
Survey76	242	402	141	46	112	63	50	67	44	498	142	126
Survey77	152	185	115	51	102	64	61	72	51	804	237	145
Survey78	144	108	87	66	107	99	81	68	115	1321	818	287
Survey79	102	102	59	40	89	53	66	61	136	929	1098	185
Survey80	63	72	59	27	59	31	36	33	66	651	586	75
Survey81	70	93	81	40	80	57	59	55	111	724	357	45
Survey82	88	123	109	43	97	88	72	69	177	570	338	46
Survey83	77	139	150	45	106	81	83	99	129	514	174	40
Survey84	88	95	120	24	121	86	70	79	75	516	170	90
Survey85	58	70	97	24	90	68	53	61	41	683	276	177
Survey86	46	65	85	16	62	55	37	38	32	325	204	114
Survey87	30	37	43	8	37	29	24	21	16	513	164	98
Survey88	12	15	28	5	18	13	12	12	9	691	231	42
Survey89	11	19	33	9	16	15	15	17	14	681	91	14
Survey90	7	9	13	5	8	8	8	9	14	372	108	4
Survey91	7	9	7	3	5	3	6	6	13	577	347	5
Survey92	7	10	7	7	5	3	5	5	12	93	241	4
Survey93	11	17	8	4	6	4	3	5	11	55	112	5
Survey94	7	27	12	4	5	2	2	4	5	69	313	6
Survey95	11	27	19	3	7	3	2	4	5	62	228	6
Survey96	13	21	30	3	12	6	3	6	4	62	62	5
Survey97	13	23	51	4	12	5	4	6	7	277	187	13
Survey98	13	43	81	5	17	4	4	4	7	200	489	23
Survey99	11	42	86	7	10	4	4	2	7	217	431	53
Survey100	8	79	130	6	7	3	4	2	6	258	677	61
Survey101	4	55	62	6	3	2	2	2	3	185	482	41
Survey102	3	38	24	5	2	1	1	2	2	76	310	12
Survey103	4	30	17	6	3	4	3	4	4	99	178	9
Survey104	6	18	11	8	4	7	5	7	8	58	295	7

Note: Red indicates exceedance of swimming criteria (mean >200), yellow denotes "questionable" water quality, (mean < 200, but one or more samples >400), green indicates compliance with criteria.

Table 8. 30 day geometric mean (number of samples) of 10 m fecal coliform concentrations (MPN/100 mL).

	Outer Harbour				Eastern Pass.		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey53	1	9	3	1	18	13	21	69	22	34	231	98	191	123	113	275
Survey54	1	9	2	1	5	7	10	52	16	17	258	66	139	101	81	207
Survey55	1	10	1	1	2	3	6	39	12	10	427	47	156	72	61	179
Survey56	1	5	1	1	3	5	7	31	7	10	434	28	98	84	93	143
Survey57	1	5	1	1	5	4	10	37	9	19	971	44	127	98	65	120
Survey58	1	8	1	2	10	6	16	49	20	23	2188	200	301	366	121	223
Survey59	1	9	1	2	16	7	17	42	17	27	2229	201	404	199	119	231
Survey60	1	9	1	2	40	9	22	27	13	31	1587	244	387	444	181	239
Survey61	1	22	1	2	29	6	20	23	16	16	1420	388	471	477	123	251
Survey62	1	42	1	2	26	8	26	27	27	10	984	403	478	641	198	247
Survey63	1	34	1	1	20	8	19	27	19	9	807	370	337	216	167	179
Survey64	1	29	1	2	25	17	19	22	26	12	398	303	148	579	264	275
Survey65	1	27	1	2	18	26	36	80	46	14	467	523	125	349	305	497
Survey66	1	21	2	2	15	26	48	131	57	18	395	456	84	395	443	673
Survey67	1	21	3	4	10	19	51	149	47	19	276	226	46	176	213	531
Survey68	1	39	5	4	6	15	64	111	40	22	191	112	33	315	225	455
Survey69	1	97	8	6	9	13	99	185	50	23	368	155	68	215	195	543
Survey70	2	154	11	12	10	13	60	166	36	45	294	96	60	230	156	419
Survey71	3	276	18	16	19	21	71	183	49	95	335	107	198	235	148	362
Survey72	2	127	12	10	21	29	43	214	60	145	583	158	343	357	255	573
Survey73	3	55	12	8	30	43	26	320	83	246	937	216	529	307	238	683
Survey74	7	38	27	12	31	50	44	478	125	451	868	261	707	368	238	566
Survey75	5	26	49	10	22	43	88	487	299	546	1259	355	1276	671	328	765
Survey76	5	40	63	16	16	26	68	343	382	528	1019	304	658	436	205	607
Survey77	6	42	74	33	27	27	80	320	530	310	537	254	401	473	198	656
Survey78	6	62	123	69	54	38	178	347	768	293	505	278	355	526	243	496
Survey79	4	41	55	52	38	36	92	167	476	114	285	201	184	290	133	318
Survey80	4	41	41	57	84	68	60	163	353	94	250	165	148	214	157	262
Survey81	6	54	45	94	151	138	93	273	383	125	334	183	162	325	220	307
Survey82	4	73	61	92	168	283	187	423	469	240	564	327	332	305	264	275
Survey83	4	73	67	113	215	341	194	509	511	326	429	393	319	282	235	228
Survey84	9	118	107	126	270	347	274	793	582	579	820	542	456	480	275	244
Survey85	9	62	104	83	206	272	356	826	631	529	677	542	489	429	229	275
Survey86	2	20	73	46	112	167	168	414	253	259	344	344	391	249	132	143
Survey87	1	14	59	36	85	97	141	214	123	163	229	195	383	159	85	87
Survey88	1	18	32	18	38	53	107	130	82	78	224	102	306	92	69	94
Survey89	1	16	20	15	37	63	73	106	74	105	204	92	326	44	52	76
Survey90	2	17	25	12	36	63	75	112	75	103	200	73	308	48	73	56
Survey91	2	20	23	10	26	56	108	120	69	93	426	123	481	62	123	77
Survey92	2	16	17	10	20	58	67	152	106	86	559	142	336	78	192	105
Survey93	1	23	16	13	22	92	73	276	124	96	681	224	410	60	164	85
Survey94	1	17	13	10	15	54	106	285	97	54	547	190	263	109	286	106
Survey95	1	18	9	12	7	35	64	156	66	31	342	188	188	75	97	117
Survey96	1	16	13	22	16	55	92	234	124	50	371	134	76	61	78	115
Survey97	1	33	8	12	15	31	79	195	95	44	391	139	83	79	66	95
Survey98	1	12	6	7	13	18	61	123	89	43	342	135	88	231	116	137
Survey99	1	24	6	6	11	12	52	136	109	24	302	152	122	171	102	135
Survey100	1	32	4	4	15	11	51	123	89	24	338	127	146	253	211	174
Survey101	1	36	3	2	7	6	21	42	46	8	147	85	306	369	148	130
Survey102	1	60	5	3	9	8	19	36	35	7	131	67	212	382	144	166
Survey103	1	81	5	4	7	6	24	13	18	5	118	39	231	210	76	119
Survey104	1	110	4	4	10	8	17	8	9	7	81	24	247	255	65	114

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey53	62	98	53	23	53	23	28	36	4	20	36	12
Survey54	40	59	33	15	46	15	13	17	2	9	29	5
Survey55	46	80	22	10	30	7	7	10	1	8	30	7
Survey56	33	64	20	5	26	3	4	6	1	8	22	6
Survey57	30	55	16	4	19	3	3	7	2	12	23	5
Survey58	26	187	31	6	18	5	4	5	2	9	45	5
Survey59	11	194	33	4	9	4	4	3	1	10	36	5
Survey60	4	144	41	3	9	4	6	4	1	14	49	3
Survey61	4	199	38	4	10	8	10	6	1	18	67	3
Survey62	7	159	47	7	23	16	30	14	1	23	78	5
Survey63	9	78	93	9	30	8	36	25	1	36	110	6
Survey64	20	33	204	11	39	13	64	57	2	66	156	10
Survey65	31	54	244	20	93	16	53	40	2	108	152	19
Survey66	52	79	336	34	182	28	70	52	4	98	159	24
Survey67	32	39	248	17	75	18	32	17	3	112	126	22
Survey68	29	47	146	22	75	32	33	19	4	133	105	16
Survey69	39	149	142	32	118	51	46	27	11	130	97	23
Survey70	55	117	183	39	111	95	74	47	14	110	62	21
Survey71	60	115	214	61	121	96	79	53	21	110	63	28
Survey72	95	286	295	51	284	127	144	115	41	82	62	19
Survey73	129	367	275	29	314	114	140	100	71	46	44	21
Survey74	136	340	193	30	308	100	128	102	47	91	45	23
Survey75	170	427	297	51	402	150	183	195	85	96	118	55
Survey76	87	359	157	28	233	82	88	109	46	84	106	40
Survey77	90	221	123	41	152	77	77	97	41	141	124	55
Survey78	112	205	137	101	135	72	62	114	45	276	255	107
Survey79	84	168	104	82	101	60	45	78	26	213	162	58
Survey80	70	154	71	56	76	39	33	48	17	233	93	29
Survey81	134	195	136	81	118	73	69	85	30	371	127	32
Survey82	161	279	243	124	166	89	96	132	55	333	149	36
Survey83	138	224	254	112	176	144	147	159	83	242	111	34
Survey84	130	197	211	105	152	102	103	87	128	187	267	64
Survey85	122	195	222	88	142	95	83	65	84	246	380	75
Survey86	85	119	117	55	84	61	48	39	57	129	196	59
Survey87	59	82	69	34	55	43	27	21	29	138	219	58
Survey88	44	48	40	23	35	26	17	13	14	121	149	36
Survey89	41	47	37	25	34	32	21	20	12	94	79	18
Survey90	23	31	25	19	17	29	20	19	18	70	54	11
Survey91	18	39	32	11	17	18	17	14	13	90	140	12
Survey92	19	47	24	6	21	20	21	18	14	43	106	8
Survey93	16	71	38	9	15	21	21	21	10	48	122	7
Survey94	15	123	49	10	13	14	14	17	8	76	115	10
Survey95	18	136	57	13	21	11	14	19	4	54	103	13
Survey96	25	102	59	18	25	19	19	32	5	54	52	12
Survey97	33	117	127	28	40	20	36	56	4	59	44	18
Survey98	38	170	116	23	54	18	34	49	4	42	49	13
Survey99	45	111	106	29	80	25	58	69	4	27	52	14
Survey100	61	152	100	32	98	40	68	87	7	18	34	12
Survey101	45	150	66	21	80	21	42	49	4	10	26	13
Survey102	33	136	53	13	30	16	16	16	3	7	32	12
Survey103	35	92	41	13	36	10	22	25	5	5	22	17
Survey104	29	111	46	11	29	10	27	27	4	6	31	16

Note: Red indicates exceedence of swimming criteria (mean >200), yellow denotes "questionable" water quality, (mean < 200, but one or more samples >400), green indicates compliance with criteria.

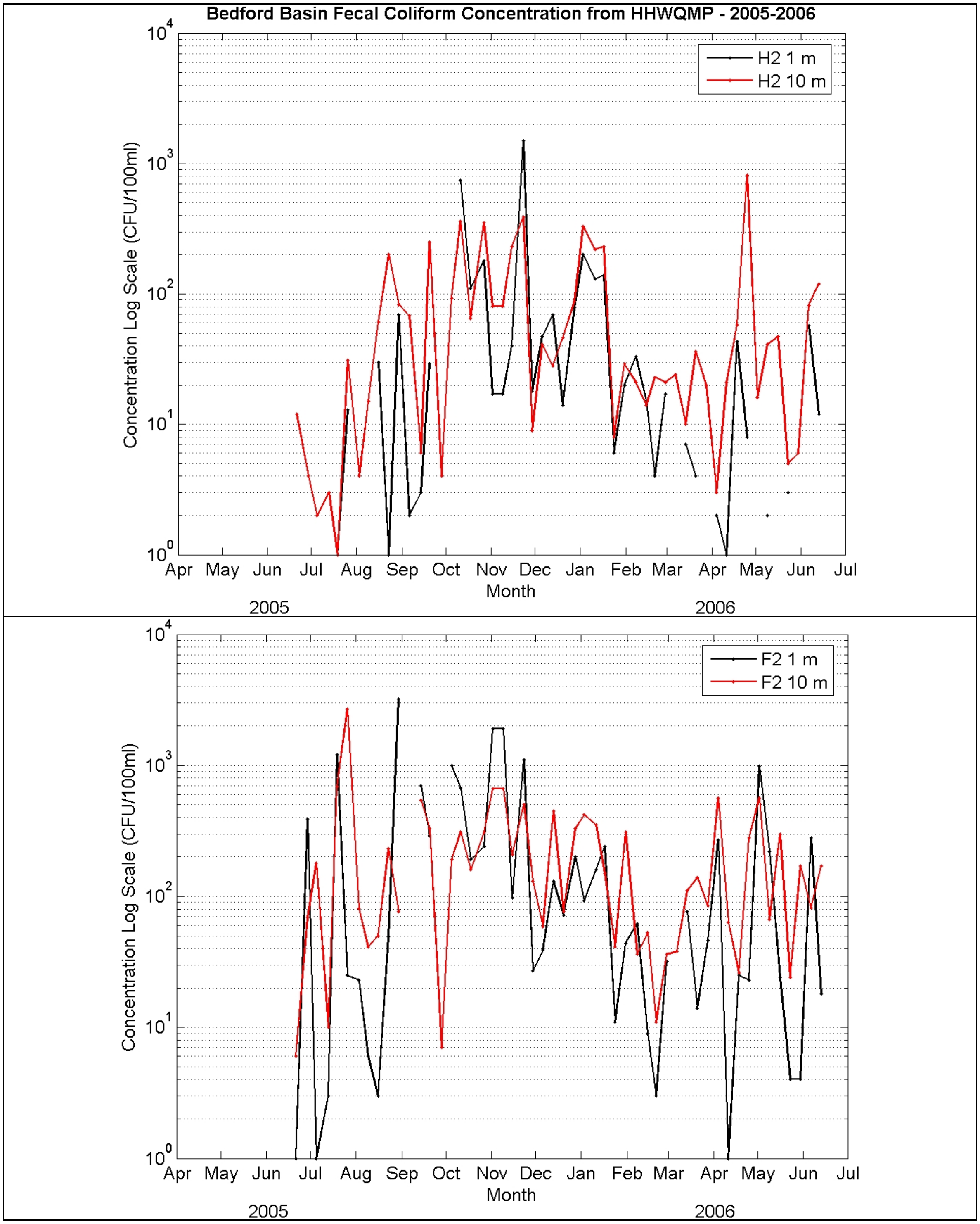


Figure 21. HHWQMP Bedford Basin Fecal Coliform Concentration (21 June 2005 to 13 June 2006).

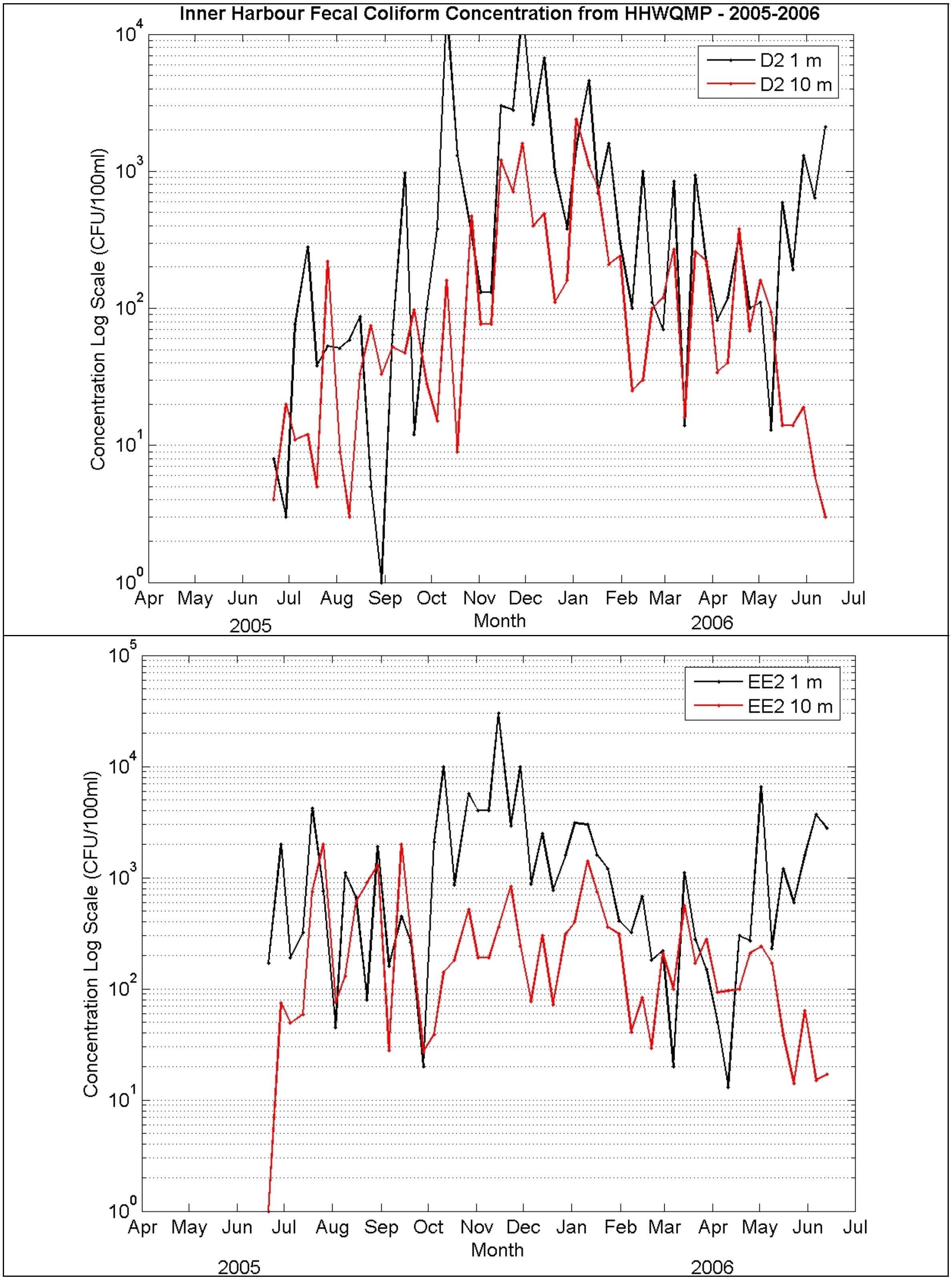


Figure 22. HHWQMP Inner Harbour Fecal Coliform Concentration (21 June 2005 to 13 June 2006).

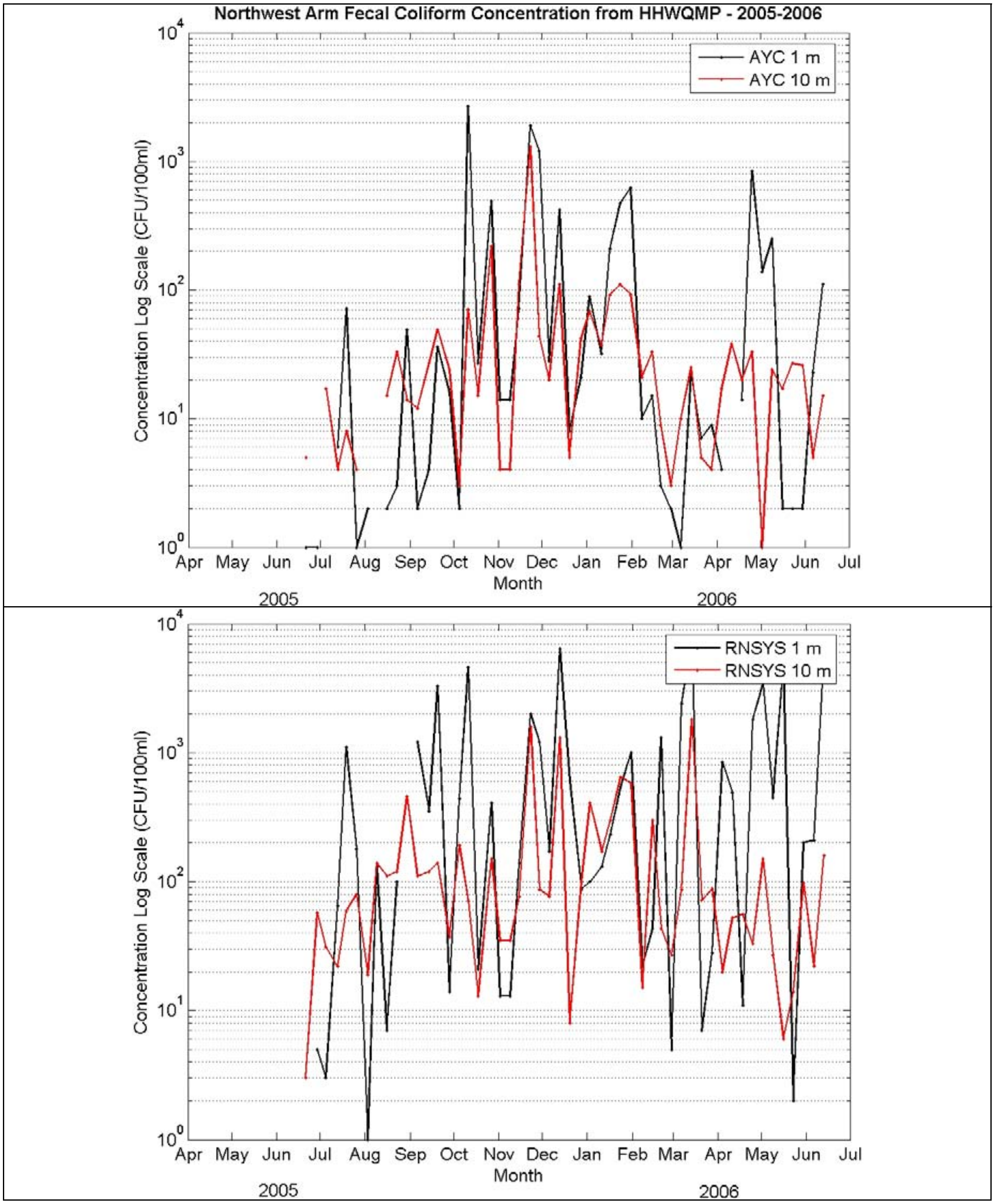


Figure 23. HHWQMP Northwest Arm Fecal Coliform Concentration (21 June 2005 to 13 June 2006).

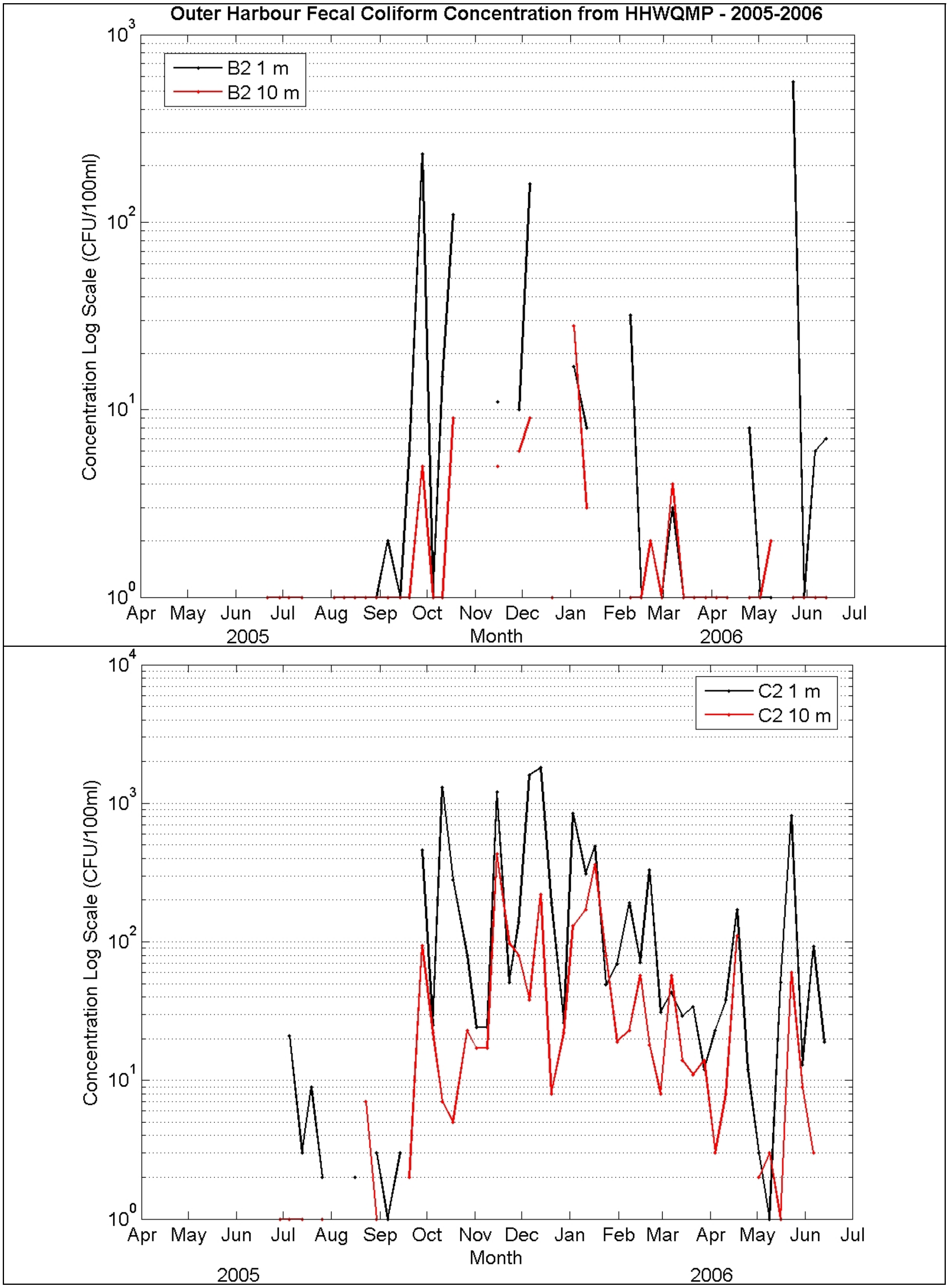


Figure 24. HHWQMP Outer Harbour Fecal Coliform Concentration (21 June 2005 to 13 June 2006).

5.5 Ammonia Nitrogen

The measured values of ammonia nitrogen over the entire second year are presented in Tables 9 and 10. Samples that were below the EQL of 0.05 mg/L have been assigned values of 0.025 (EQL/2) for statistical purposes, and are shaded green. Overall there were 358 samples analyzed of which 209 (58%) had detectable values of ammonia nitrogen. The values cover a relatively limited range around the detection limit, with most values less than 0.10 mg/L and only 5 above 0.20 mg/L. There was essentially no difference in the number of detectable values between the 1 and 10 m samples, nor is there a significant difference in the magnitude of the average concentrations. While there are spatial (site to site) variations, there is not a readily discernable pattern, except that the concentrations at B2 (Outer Harbour) are lowest of any site.

There is temporal variability, which appears to be inversely related to phytoplankton activity (fluorescence). The lowest values occur around a period of apparently low flushing and extended phytoplankton activity (August 2005) and spring bloom (March 2006). There appears to be a similar pattern in the TSS data, discussed below. This behaviour seems to be nearly opposite the pattern observed in the first year. Overall the values this year are 30% higher, on average, than last year.

Table 9. Annual Summary of 1 m Ammonia Nitrogen

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
21-Jun-05	0.025	0.025	0.09	0.025	0.05	0.08	0.08	0.075	0.09
5-Jul-05	0.08	0.19	0.1	0.13	0.025	0.025	0.06	0.112	0.19
19-Jul-05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
3-Aug-05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
16-Aug-05	0.025	0.025	0.025	0.025	0.025	0.025	0.09	0.090	0.09
30-Aug-05	0.025	0.025	0.025	0.11	0.05	0.09	0.025	0.083	0.11
14-Sep-05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
28-Sep-05	0.025	0.08	0.025	0.025	0.025	0.025	0.025	0.03	0.08
11-Oct-05	0.025	0.09	0.12	0.07	0.14	0.13	0.12	0.10	0.14
27-Oct-05	0.025	0.06	0.08	0.12	0.11	0.13	0.13	0.09	0.13
9-Nov-05	0.025	0.09	0.09	0.11	0.10	0.09	0.10	0.09	0.11
23-Nov-05	missed	0.08	0.08	0.17	0.08	0.20	0.18	0.13	0.20
6-Dec-05	0.06	0.1	0.08	0.12	0.12	0.12	0.12	0.10	0.12
20-Dec-05	0.025	0.08	0.09	0.07	0.08	0.05	0.09	0.07	0.09
3-Jan-06	0.06	0.05	0.14	0.09	0.09	0.08	0.06	0.08	0.14
17-Jan-06	missed	0.07	0.09	0.15	0.11	0.09	0.13	0.11	0.15
31-Jan-06	missed	0.025	0.12	0.025	0.08	0.07	0.09	0.07	0.12
15-Feb-06	0.07	0.07	0.08	0.07	0.07	0.08	0.08	0.07	0.08
28-Feb-06	0.025	0.025	0.025	0.06	0.025	0.05	0.05	0.04	0.06
14-Mar-06	0.06	0.025	0.05	0.025	0.025	0.025	0.025	0.03	0.06
28-Mar-06	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
11-Apr-06	0.025	0.025	0.08	0.025	0.025	0.025	0.025	0.03	0.08
25-Apr-06	0.08	0.08	0.12	0.14	0.11	0.14	0.11	0.11	0.14
9-May-06	0.06	0.09	0.06	0.11	0.05	0.06	0.05	0.07	0.11
23-May-06	0.09	0.07	0.06	0.14	0.12	0.11	0.18	0.11	0.18
6-Jun-06	0.025	0.025	0.025	0.025	0.06	0.08	0.025	0.04	0.08
mean	0.02	0.06	0.07	0.07	0.06	0.07	0.07	0.07	
max	0.09	0.19	0.14	0.17	0.14	0.20	0.18		0.20

Table 10. Annual Summary of 10 m Ammonia Nitrogen

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
21-Jun-05	0.05	0.06	0.05	0.025	0.19	0.025	0.025	0.06	0.19
5-Jul-05	0.11	0.05	0.18	0.12	0.025	0.025	0.06	0.08	0.18
19-Jul-05	0.025	0.025	0.025	0.025	0.11	0.025	0.025	0.04	0.11
3-Aug-05	0.025	0.025	0.025	0.025	0.025	0.025	0.09	0.03	0.09
16-Aug-05	0.05	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.05
30-Aug-05	0.025	0.025	0.025	0.025	0.025	0.025	0.12	0.04	0.12
14-Sep-05	0.025	0.025	0.14	0.025	0.14	0.11	0.14	0.09	0.14
28-Sep-05	0.06	0.025	0.025	0.025	0.07	0.025	0.05	0.04	0.07
11-Oct-05	0.025	0.06	0.08	0.1	0.09	0.12	0.1	0.08	0.12
27-Oct-05	0.025	0.025	0.06	0.11	0.11	0.13	0.13	0.08	0.13
9-Nov-05	0.025	0.10	0.08	0.09	0.13	0.10	0.10	0.09	0.13
23-Nov-05	missed	0.07	0.07	0.13	0.09	0.14	0.12	0.10	0.14
6-Dec-05	0.94	0.06	0.06	0.11	0.14	0.13	0.12	0.22	0.94
20-Dec-05	0.05	0.05	0.07	0.09	0.025	0.025	0.06	0.05	0.09
3-Jan-06	0.07	0.08	0.05	0.025	0.07	0.025	0.08	0.06	0.08
17-Jan-06	missed	0.10	0.08	0.09	0.09	0.12	0.07	0.09	0.12
31-Jan-06	missed	0.025	0.06	0.025	0.07	0.06	0.18	0.07	0.18
15-Feb-06	0.025	0.025	0.09	0.12	0.15	0.08	0.08	0.08	0.15
28-Feb-06	0.025	0.025	0.07	0.025	0.025	0.025	0.025	0.03	0.07
14-Mar-06	0.06	0.07	0.49	0.025	0.025	0.025	0.07	0.11	0.49
28-Mar-06	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
11-Apr-06	0.025	0.025	0.025	0.025	0.05	0.025	0.025	0.03	0.05
25-Apr-06	0.08	0.11	0.10	0.21	0.13	0.18	0.23	0.15	0.23
9-May-06	0.06	0.07	0.08	0.11	0.06	0.08	0.025	0.07	0.11
23-May-06	0.025	0.18	0.08	0.09	0.11	0.11	0.11	0.10	0.18
6-Jun-06	0.025	0.07	0.07	0.08	0.025	0.05	0.06	0.05	0.08
mean	0.06	0.07	0.10	0.09	0.07	0.08	0.10	0.08	
max	0.94	0.18	0.49	0.21	0.19	0.18	0.23		0.94

5.6 Total Suspended Solids

The measured values of TSS over the entire year are presented in Tables 11 and 12. The EQL for the analysis is 1 mg/L (or sometimes 2 mg/L if the sample is split in the lab for duplicate analysis). Samples which were below the EQL have been assigned values of (EQL/2), either 0.5 or 1.0 as appropriate) for statistical purposes, and are shaded green. Throughout the year there were 5 of 358 samples that were below EQL. These were all at station B2 in the Outer Harbour.

Overall, the TSS values decreases from quarter to quarter. This is exactly the opposite trend seen in the first year of the study. The mean over all samples in the fifth quarter (summer) was approximately 11.1 mg/L, which compares to approximately 9.5 mg/L in the sixth quarter (fall), 7.4 mg/L in the seventh quarter (winter), and 5.1 mg/L in the eighth (summer) quarter. There were some elevated values associated with the spring bloom in March but the values were not as high as those experienced in August. The August high values appear to be associated with a period of relatively low flushing (dry weather with relatively light wind), and increased productivity as seen in the fluorescence data.

There appears to be some evidence of coherent spatial variability. On average, the lowest values tend to occur in the Outer Harbour at B2 and the highest values in the Narrows and southern Basin. For this year the site mean values indicate that the highest values were at F2 (9.8 mg/L) with the second highest at EE2 (9.1 mg/L). This compares with the first year where max values were at E2 and H2. However there is quite a bit of variability. The survey maximum values have occurred at every site. On average, the concentrations are lower at B2 (6.1 mg/L), but there are weeks where the B2 values are amongst the highest in the survey. A preliminary look suggests that high values at B2 may be associated with wind events.

Table 11. Annual summary of 1 m TSS values

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
21-Jun-05	8.7	3.8	8.8	6.8	12.0	17.0	12.0	9.9	17.0
5-Jul-05	7.2	4.4	15.0	3.2	13.0	9.3	12.0	9.2	15.0
19-Jul-05	1.0	9.5	14.0	8.8	9.0	7.7	15.0	10.7	15.0
3-Aug-05	10.0	8.4	13.0	11	22.0	12.0	13.0	12.8	22.0
16-Aug-05	8.4	17.0	13.0	14	17.0	16.0	4.2	12.8	17.0
30-Aug-05	4.4	11.0	14.0	10	13.0	13.0	14.0	11.3	14.0
14-Sep-05	6.6	14.0	11.0	13	8.3	9.1	11.0	10.4	14.0
28-Sep-05	13.0	12.0	11.0	13.0	6.0	5.0	7.0	9.6	13.0
11-Oct-05	10.0	10.0	6.0	7.0	10.0	13.0	11.0	9.6	13.0
27-Oct-05	1.0	6.0	18.0	9.0	16.0	10.0	8.0	9.7	18.0
9-Nov-05	14.0	9.0	11.0	14.0	35.0	1.0	7.0	13.0	35.0
23-Nov-05	missed	9.0	10.0	5.0	6.0	6.0	12.0	8.0	12.0
6-Dec-05	2.0	8.0	4.0	8.0	5.0	4.0	5.0	5.1	8.0
20-Dec-05	9.0	6.0	5.0	7.0	6.0	8.0	5.0	6.6	9.0
3-Jan-06	4.0	7.0	8.0	5.0	6.0	9.0	8.0	6.7	9.0
17-Jan-06	missed	3.0	6.0	7.0	7.0	8.0	8.0	6.5	8.0
31-Jan-06	missed	3.0	4.0	7.0	11.0	9.0	7.0	6.8	11.0
15-Feb-06	4.0	3.0	6.0	6.0	5.0	7.0	6.0	5.3	7.0
28-Feb-06	5.0	6.0	9.0	5.0	8.0	9.0	7.0	7.0	9.0
14-Mar-06	8.0	12.0	13.0	4.0	14.0	14.0	13.0	11.1	14.0
28 Mar 06	3.0	5.0	8.0	6.0	7.0	8.0	10.0	6.7	10.0
11 Apr 06	5.0	4.0	7.0	7.0	7.0	6.0	8.0	6.3	8.0
25 Apr 06	0.5	9.0	7.0	4.0	7.0	1.0	5.0	4.8	9.0
9 May 06	0.5	1.0	2.0	4.0	5.0	6.0	4.0	3.2	6.0
23 May 06	3.0	4.0	1.0	4.0	1.0	2.0	3.0	2.6	4.0
6 Jun 06	6.0	11.0	7.0	5.0	6.0	5.0	10.0	7.1	11.0
mean	5.8	7.5	8.9	7.5	10.1	8.3	8.7	8.1	
max	14.0	17.0	18.0	14.0	35.0	17.0	15.0		35.0

Table 12. Annual summary of 10 m TSS values

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
21-Jun-05	4.9	8.1	9.3	9.2	7.8	9.3	5.3	7.7	9.3
05-Jul-05	5.4	6.4	9.7	14.0	5.4	7.1	8.9	8.1	14.0
19-Jul-05	1.0	26.0	13.0	5.4	8.2	18.0	16.0	14.4	26.0
03-Aug-05	9.6	12.0	14.0	25.0	20.0	12.0	8.6	14.5	25.0
16-Aug-05	9.8	6.3	18.0	9.4	10.0	17.0	16.0	12.4	18.0
30-Aug-05	6.8	11.0	8.4	12.0	12.0	14.0	16.0	11.5	16.0
14-Sep-05	9.7	11.0	9.0	8.8	7.5	16.0	7.3	9.9	16.0
28-Sep-05	14.0	14.0	4.0	1.0	5.0	9.0	8.0	7.9	14.0
11-Oct-05	7.0	4.0	14.0	10.0	11.0	9.0	10.0	9.3	14.0
27-Oct-05	1.0	10.0	19.0	5.0	17.0	8.0	8.0	9.7	19.0
09-Nov-05	18.0	10.0	9.0	33.0	37.0	11.0	10.0	18.3	37.0
23-Nov-05	missed	9.0	10.0	8.0	5.0	8.0	6.0	7.7	10.0
06-Dec-05	5.0	7.0	5.0	4.0	8.0	6.0	8.0	6.1	8.0
20-Dec-05	5.0	4.0	6.0	7.0	8.0	7.0	6.0	6.1	8.0
03-Jan-06	8.0	4.0	10.0	6.0	10.0	6.0	10.0	7.7	10.0
17-Jan-06	missed	4.0	6.0	6.0	9.0	8.0	7.0	6.7	9.0
31-Jan-06	missed	7.0	6.0	6.0	14.0	8.0	9.0	8.3	14.0
15-Feb-06	4.0	4.0	5.0	7.0	6.0	8.0	7.0	5.9	8.0
28-Feb-06	7.0	7.0	9.0	7.0	11.0	9.0	7.0	8.1	11.0
14-Mar-06	10.0	10.0	16.0	13.0	9.0	11.0	10.0	11.3	16.0
28-Mar-06	4.0	7.0	10.0	9.0	9.0	8.0	6.0	7.6	10.0
11-Apr-06	7.0	8.0	10.0	7.0	4.0	10.0	7.0	7.6	10.0
25-Apr-06	4.0	5.0	2.0	5.0	6.0	6.0	7.0	5.0	7.0
09-May-06	0.5	4.0	4.0	3.0	5.0	4.0	4.0	3.5	5.0
23-May-06	1.0	2.0	2.0	2.0	1.0	2.0	4.0	2.0	4.0
06-Jun-06	3.0	3.0	14.0	4.0	3.0	3.0	3.0	4.7	14.0
mean	6.3	7.8	9.3	8.7	9.6	9.0	8.3	8.5	
max	18.0	26.0	19.0	33.0	37.0	18.0	16.0		37.0

5.7 Metals

In the sixth quarter (survey 73, 23 November) the low level metals scan was discontinued. This was in response to recommendations made in Quarterly Report 4. The analysis was inadequately resolving metals concentrations in the harbour and an alternative procedure with higher resolution is being developed. Therefore, in this year, metals data exist for only the fifth quarter and the first four of the six detailed ("chem") surveys in the sixth quarter. The metal scan analysis includes a suite of 25 metals (Table 1). There are eight of these with guidelines established by the Halifax Harbour Task Force, these are: cadmium, chromium, copper, lead, manganese, mercury, nickel and zinc. While mercury has a HHTF guideline it is not measured in the metal scan, so there are seven metals discussed here. In addition, two of the seven metals, copper (EQL 20μg/L, guideline 2.9 μg/L) and nickel (EQL 20 μg/L, guideline 8.3 μg/L) have EQL values greater than the guidelines so concentrations in excess of the guidelines could go undetected.

In the period sampled there have been a total of 1043 independent determinations of metals concentrations of interest. Of these 78 have resulted in detectable concentrations for an overall data return of approximately 7.5%. This rate is significantly higher than in the first year of sampling. All seven metals have been detected in at least one sample in year two. A summary of the metal scan results is presented in Tables 13 through 17. Any value that exceeds the guideline in the tables is highlighted in red. Overall there are 6 values in excess of the applicable guidelines, three for zinc and one each for copper, lead and nickel. Note that the detection limits for copper and nickel are much higher than the applicable water quality guideline, so any detectable value exceeds the guideline.

There were three "events" of note during the sampling period. These are discussed in quarterly reports 4 and 5. Two were individual surveys with relatively elevated metals concentration. The first (16 August 2005) had some elevated metals, including two guideline exceedences, with a hint of a potential point source. The second (11 October 2005) had high metals primarily located in the Narrows, generally associated with a freshwater lens, the result of an extremely large rainfall event. In addition to these individual surveys, almost all samples in the four surveys from 14 September thru 27 October 2005 had uniformly high zinc values. Over the whole observation period (149 zinc samples) there were 54 detectable levels or 36% (Table 13). Over the four surveys with elevated zinc 87.5% of samples had detectable levels. For comparison, in the first year 3% of samples had detectable zinc levels. The values are generally just above the detection limit of 50 ug/L and there were only three exceedences of the 86 ug/L guideline. There is nothing obvious in the spatial distribution of zinc to indicate a hotspot. This would be expected if there were a point source. There is also nothing in the other data sets, including the analysis for other metal constituents, to indicate anything particularly unusual oceanographically or with overall sewage loads. There is no known reason for this large scale extended increase in zinc levels but it seems that there must have been some, heretofore undefined, extraordinary source of zinc. Large scale addition of cathodic protection (addition of zinc anodes) on some harbour structures might be investigated.

Table 13. Zinc levels in quarters five and six (until 23 November 2006).

Zinc EQL = 50 µg/L: Guideline=86 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
16-Aug-05	68	B2	10
	180	D2	1
14-Sep-05	53	B2	1
	55	B2	10
	54	D2	1
	51	D2	10
	53	EE2	1
	56	EE2	10
	62	E2	1
	54	E2	10
	51	F2	1
	61	G2	1
	57	H2	1
28-Sep-05	56	B2	1
	53	B2	10
	50	D2	1
	60	D2	10
	51	E2	1
	54	E2	10
	54	EE2	1
	57	EE2	10
	58	F2	1
	63	F2	10
	57	G2	1
	56	G2	10
	70	H2	1
	53	H2	10
	53	DC	1
	53	DC (DUP)	1
	57	F2(QA/QC)	1
11-Oct-05	57	B2	1
	53	B2	10
	57	D2	1
	50	D2	10
	68	E2	1
	55	E2	10
	62	EE2	1
	52	F2	1
	54	F2	10
	51	G2	1
	53	H2	1
	51	H2	10
	51	H2 (QA/QC)	1
27-Oct-05	72	D2	10
	99	D2	1
	86	E2	10
	58	E2	1
	68	EE2	10
	57	EE2	1
	71	F2	10
	62	F2	1
	60	G2	10
	72	G2	1

Zinc EQL = 50 µg/L: Guideline=86 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
	68	H2	1
	64	H2 (dup)	1
	51	E2 (QA/QC)	1
9-Nov-05	67	D2	1
	51	EE2	10
	56	H2	1

Aside from zinc, the most frequently detected metal is manganese (Table 14), which has an EQL of 20 µg/L. There was manganese detected in 14 out of 149 independent samples, or in 9.4% of samples. The values generally range from 20-40 µg/L, except for two higher values on the 11 October 2005 survey. All observations are below the guideline of 100 µg/L.

Table 14. Manganese levels in quarters five and six (until 23 November 2006).

Manganese EQL = 20 µg/L: Guideline=100 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
5-Jul-05	32	F2	1
3-Aug-05	21	D2	10
	32	F2	1
16-Aug-05	33	E2	10
	21	EE2	1
	30	G2	10
	44	E2 (QA/QC)	1
11-Oct-05	60	E2	1
	34	EE2	1
	43	F2	1
	22	G2	1
	29	H2	1
27-Oct-05	32	EE2	10
	32	E2 (QA/QC)	1
9-Nov-05	25	D2	1
	24	EE2	10

Overall there were six samples with detectable levels of chromium (>20 µg/L), five of which occurred on the unusual 16 August and 11 October surveys. The values were generally between 20-30 µg/L with no values above the guideline level of 50 µg/L.

Table 15. Chromium levels in quarters five and six (until 23 November 2006).

Chromium EQL = 20 µg/L: Guideline=50 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
19-Jul-05	21	D2	1
16-Aug-05	31	D2	1
	30	D2	10
	32	E2	1
11-Oct-05	23	E2	1
	22	E2	10

Cadmium, copper, lead and nickel all had detectable levels in single samples. The values of copper, lead and nickel all exceeded guidelines.

Table 16. Cadmium levels in quarters five and six (until 23 November 2006).

Cadmium EQL 3 µg/L: Guideline=9.3 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
11-Oct-05	4	E2	1

Table 17. Copper levels in quarters five and six (until 23 November 2006).

Copper EQL = 20 µg/L: Guideline=2.9 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
16 Aug 05	22	D2	1

Table 18. Lead levels in quarters five and six (until 23 November 2006).

Lead EQL =5 µg/L: Guideline=5.6 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
11-Oct-05	6	E2	1

Table 19. Nickel levels in quarters five and six (until 23 November 2006).

Nickel EQL = 20 µg/L: Guideline=8.3 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
14-Sep-05	20	G2	10

Copper has been identified as a "key" contaminant (i.e. the concentration in the sewage effluent is the highest compared to the environmental guideline, so it is most likely to be violated by sewage contamination) and is under-resolved by the current analysis. This, and the general under-resolution of metals concentrations, has lead to ongoing discussion. As input to this discussion, three test samples were taken at a depth of 1 m on 30 August. These were analyzed with a more detailed scan having an EQL of 1 µg/L. These results are shown in Table 20. Of the three samples only one had a detectable level of copper (1.3 µg/L) at G2. This is relatively consistent with previous observations in the Harbour (Dalziel et al., 1989), though the maximum observed in that survey is 0.9 µg/L.

Table 20. High resolution Copper analysis (30 August 2005)

HR Copper EQL = 1 µg/L : Guideline=2.9 µg/L

Survey Date	Concentration (µg/L)	Site	Depth(m)
30-Aug-05	1.3	G2	1
	<1	B2	1
	<1	EE2	1

The remaining metals for which no guidelines exist include boron, lithium, strontium, titanium and uranium. These metals are regularly detected, and have quite consistent concentrations across all samples and all surveys. Typical concentrations are: boron (4000 µg/L), lithium (180 µg/L), strontium (6300 µg/L), titanium (70 µg/L), and uranium (3.2 µg/L). Other metals show up sporadically, these are documented in the weekly reports/data files.

The resolution of metals concentrations in the harbour has been recognized as an issue and options for modifying the program to obtain higher resolution are bring developed.

6 Summary and Action Items

For each item, a brief statement of summary is provided along with any changes that occurred during the quarter, and action items resulting from discussions of the issues with the Harbour Solution Project Team. These items reflect issues arising in this quarter as well as issues carried forward from previous quarterly reports. Issues from previous reports are identified as "ongoing", and are listed with the number of the quarterly report in which they first occurred. These issues may include issues deferred until a later date, items in progress but not completed, or longer term items requiring continuing consideration.

6.1 Reporting

Weekly Reports

Summary Statement – The weekly report analysis/presentation has been refined and is essentially in final form. There may be periodic changes required to accommodate any changes in data collection.

Changes None

Action
Continued review/adjustment of reports to reflect program changes.

Quarterly Reports

Summary Statement – The quarterly report discussion is limited to the data of that quarter. Every fourth quarterly report includes a section reviewing the data over the last year. There remains a future reporting issue of comparison of data between years. The documentation of sampling/sample handling/lab procedures/ data analysis remains incomplete.

Changes – None

Action
1. Continued development of quarterly report content and format, with respect to project requirements.
2. Consideration of reporting implication of inter-annual data comparison.
3. Outstanding item (QR#1): Complete documentation of sampling and analysis methods along with QA/QC procedures for inclusion in the project binder.

6.2 Sampling Program

Summary Statement – Sampling continues as per the end of the seventh quarter. There is a potential bias being introduced in the NW Arm based on selection of sampling routes.

Changes –none

Action

1. Continued analysis of sampling scheme with respect to sample bias versus boat travel time with adjustment of scheduling to improve efficiency as dictated. Particularly with respect to sample scheduling in the NW Arm.
2. Continued consideration of modification to the analysis suite to include/improve/remove some parameters (see sections on measured parameters below).
3. Outstanding item (QR#3): Consider additional/or substituted sampling sites to address Herring Cove (Hospital Point) STP and Tribune Head outfall and/or recreational area issues. Additional sampling around Hospital Point will begin next quarter, closer to the commissioning of the STP (last of the three plants to be commissioned).

6.3 Water Quality Parameters

Fecal Coliform

Summary Statement – The existing variable sample resolution scheme resulted one out-of-range value in week 98 (2 May) at E2 at 1 m for this quarter. The seasonally adjusted variable resolution scheme discussed last quarter has been rejected based on the potential loss of resolution on the lower detection limit.

The current CCME guidelines recommend enterococci over fecal coliform as a tracer of human waste contamination in salt water. There are several practical reasons for continuing to monitor fecal coliform including historical continuity, and consistency with WWTP monitoring procedures. The trend toward enterococci will likely continue and the monitoring program should recognize that at some level.

Changes - None.

Action

Ongoing (QR#1): Consider inclusion of enterococci as an alternate and/or additional tracer.

Ammonia Nitrogen

Summary Statement – There was 100% data return for this quarter. Ammonia Nitrogen has consistently been present at levels that are is at or slightly above the detection limit of

0.05 mg/L. There are periodic higher measurements that are up to about 10 times the detection limit. Overall, in this quarter, 59 % of samples had detectable levels of ammonium. Ammonia Nitrogen is an attractive tracer as it is routinely monitored in sewage treatment facilities and, therefore, has quantifiable source strength in sewage. Recognizing nitrogen as the key nutrient in marine systems, and the potential importance that nutrients have in the Harbour oxygen dynamics, additional species of nitrogen continue to be considered for monitoring.

The BBPMP monitors nutrients at their site in Bedford Basin, including nitrate, silicate and phosphate. There were discussions about collecting samples throughout the harbour for additional nutrients, however, BBPMP did not have the resources for this analysis.

Changes – None.

Action

1. Ongoing (QR#1): Consider monitoring more nitrogen species.

$CBOD_5$

Summary Statement – Based on recommendations in QR#2, $CBOD_5$ was dropped from regular analysis on 25 May 2005. Until that time there was an insignificant number of regular samples with detectable $CBOD_5$ at the 5 mg/L level. $CBOD_5$ has been retained as a tracer for the supplemental sampling program.

Changes – None

Action - None

Total Suspended Solids

Summary Statement – The survey averaged TSS concentrations ranged from 2.3-7.1 mg/L over the quarter. In total there were three values below the current detection limit of 1 mg/L at site B2, in the Outer Harbour.

Changes – None

Action – None

Total Oils and Grease

Summary Statement — Based on recommendations in QR #5, Total Oils and Grease was dropped from regular analysis on 23 November 2005, survey #75, due to lack of detection. It is retained in supplemental sample analysis.

Changes - None

Action – None

Metals

Summary Statement – Based on recommendations in QR #2, the low resolution metals scan was dropped from regular analysis on 23 November 2006, survey #75, due to lack of detection.

Changes – None

Action – Develop a modified sampling protocol for metals based on previously discussed modifications (QR#2, Section 4.6). This aim is to resolve the existing metals concentrations in the Harbour (Dalziel et al. 1989) at a resolution in time and space compatible with the scope of the project. As of this writing, a modified metals analysis has been instituted starting on survey 111 (29 August 2006).

Fluorescence

Summary Statement - Uncalibrated fluorescence provides a relative measure of chlorophyll and hence phytoplankton activity throughout the Harbour, but the absolute quantification of phytoplankton mass requires lab analysis of water samples. Phytoplankton dynamics is an important piece of the overall oxygen budget in the Harbour. The BBPMP collects water samples at their site in Bedford Basin and performs the required lab analyses to extend the utility of the fluorescence data. Discussions to investigate cooperation with the BBPMP to have chlorophyll analysis performed at selected HHWQMP sites throughout the Harbour, were not productive, due to lack of resources for the BBPMP. The HHWQMP data allows for the gross identification of phytoplankton activity and is particularly useful in the interpretation of the DO data. The fluorescence data remains a very useful supplement to the BBPMP phytoplankton/chlorophyll data, as it gives an idea of spatial distribution of identified phytoplankton blooms.

Changes – None

Action – None

Dissolved Oxygen

Summary Statement – To date, including this quarter, oxygen levels as measured in the program, are relatively high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which depressed oxygen in bottom water is typical. The DO levels, except for the deep Basin water, with relatively rare exceptions, meet the guidelines set by the Harbour Task Force (Halifax Harbour Task Force. 1990).

In situ oxygen measurements are particularly sensitive to a variety of factors and there is some discrepancy between the HHWQMP profile data and data collected from other sources (i.e. other instruments deployed by HHWQMP, periodic water samples analyzed by Winkler titration, and the monitoring data of BBPMP in Bedford Basin). In general, the measured DO profiles have been somewhat lower than data obtained with other instruments and by Winkler titration; however there are significant uncertainties associated with those values as well. In previously analyses the HHWQMP data was reported as being somewhat higher than the BBPMP data. However in this quarter, the HHWQMP data corresponds reasonably well with, but is slightly lower than, the BBPMP data. This likely reflects the fact that the BBPMP data is now corrected to reflect its ground truth samples, raising questions about the previous comparisons with seemingly uncorrected data. Given this uncertainty and the fact that dissolved oxygen is perhaps the most important indicator of the health of a water body, it is important to insure the quality of the collected data. If sewage load is contributing significantly to oxygen depression in the Harbour it will be a critical parameter in future waste management decisions.

Changes – none

Action

1. Ongoing (QR#3) Continue dialogue with BIO (BBPMP) to coordinate sampling and maximize cross comparison of data for ground truth purposes.
2. Ongoing (QR#1) Consider alternate ground-truthing procedures, including Winkler titration or laboratory instruments.
3. Institute discussions with other parties (e.g. Dalhousie Oceanography) regarding potential calibration/verification procedures.

7 References

CCME, 1999. Canadian water quality guidelines for the protection of aquatic life: In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Dalziel, J.A., P.A. Yeats and D.H. Loring (1989). Dissolved and particulate trace metal distributions in Halifax Harbour, In: H.B. Nicholls (ed.), Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693.

Halifax Harbour Task Force. (1990). Halifax Harbour Task Force Final Report. Prepared for Nova Scotia Department of Environment, R. Fournier ed.

Health and Welfare Canada (1992). Guidelines for Canadian Recreational Water Quality.

Hurlbut, S., A. Isenor, J.M. MacNeil and B. Taylor (1990). Residual Circulation in Halifax Inlet and its Impact on Water Quality, report prepared by ASA Consulting Ltd. for Nova Scotia Department of the Environment.

Jordan, F. (1972), Oceanographic Data of Halifax Inlet", BIO data series, B1-D-72-8.

JWL and COA (2004 – 2005). Halifax Harbour Waster Quality Monitoring Program, Weekly and Quarterly Reports 2004 to 2008, report to the Halifax Regional Municipality, Harbour Solutions Project. http://www.halifax.ca/harboursol/waterqualitydata.html

USEPA (1985). Rates Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). EPA 600385040.